# PROCEEDINGS
## WESTERN SOCIETY OF WEED SCIENCE

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# 1989

# PROCEEDINGS

# OF

# THE WESTERN SOCIETY OF WEED SCIENCE

VOLUME 42

PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 13, 19, 15, 16, 1989

ALA MOANA HOTEL

HONOLULU, HAWAII

## PROGRAM AND TABLE OF CONTENTS

# PRESIDENTIAL ADDRESS

Donald C. Thill[1]

Members of the Western Society of Weed Science, honored guests, Fellows, visitors, ladies and gentlemen--Aloha. This 42nd meeting of the Western Society of Weed Science is only the second time in our 53-year history for us to meet in Hawaii. The 27th meeting of the WSWS was held on the island of Maui 15 years ago during March, 1974. Donald L. Burgoyne presided and Gary A. Lee served as program chairman. William Anliker was our Secretary, J. LaMar Anderson was serving his ninth year as Treasurer-Business Manager, Ed Schweizer was Chairman of the Research Section, and A.H. Lange was Chairman of the Extension and Regulatory Section. In 1974, members presented 46 research papers. Over 115 research papers will be presented at this meeting.

President Burgoyne's address was entitled, "It's Time to Make our Move." In his address, President Burgoyne discussed the negative attitude that some members of the media and the public had for those of us associated with the use of agricultural chemicals. He told WSWS members present at the 27th meeting that we need to communicate better with the media and the public. That was true 15 years ago, and it is still true today. To achieve this goal, President Burgoyne supported the formation of a WSWS Public Relations Committee, he suggested that we should recruit magazine editors, members of the press, radio, and television as members of the WSWS, and he challenged each WSWS member to work hard to improve our public image.

Fifteen years later, how have we done? First of all, we have a standing committee in the WSWS that handles items dealing with public relations. Also, we do have a few representatives of the media as members of the Society, but we really should have more. Finally, as individual members, have we met President Burgoyne's challenge to communicate better to the public what we do and who we are? I am sure the answer to this question is "yes" for some members, but for others the answer is probably "no." Each of us should be an ambassador of weed science, technology and control. For example, we should recruit media representatives as members and volunteer to talk at public meetings on issues pertaining to weed control.

Ken Dunster and Allen Teshima have done an excellent job as co-chairmen of the local arrangements committee. Through their efforts, many of us enjoyed an interesting and educational tour of sugarcane and pineapple production yesterday. All of us will be able to enjoy the next two and one-half days of meetings, because Ken, Allen and the rest of their committee have worked very hard on local arrangements during the past year.

Sheldon Blank, your program chairman, along with Paul Ogg and Steve Radosevich, members of the program committee, have prepared an action-packed program for you. In fact, this meeting will have more papers presented than at any other WSWS meeting. You had the opportunity this morning to view 20 poster presentations which will be displayed for the rest of the day. There will be about 100 research papers presented of which seven will be presented by graduate students competing in the graduate student paper contest. The Education and Regulatory Section will feature a videotaped lecture on carcinogens, anticarcinogens, and risk assessment by Dr. Bruce Ames. Chairmen for each of the six scheduled research project meetings have prepared interesting programs

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that should lead to lots of discussion. Also don't forget to attend the WSWS Business Meeting on Thursday morning. We will be voting on a number of constitutional changes and resolutions. Later in my presentation, I will return to the program agenda and make a few comments regarding topics that will be covered by our general session speakers.

A milestone will be reached for the WSWS in 1989. After 24 years of service, J. LaMar Anderson will step down--or probably more appropriately termed--he will retire from his position as Treasurer-Business Manager of the WSWS. If my check of the records is correct, LaMar began his duties as Treasurer-Business Manager following the 1965 meeting in Albuquerque. We are all greatly indebted to LaMar for his tireless service to the Society. Thank you LaMar. The duties of the Treasurer-Business Manger will, for the first time in the history of the WSWS, pass to someone outside the Society. Your Executive Board is finalizing these arrangements, and I will announce the name of our new Treasurer-Business Manager at the Business Meeting.

LaMar also saw to the timely publication of the WSWS Proceedings. This involved collecting the abstracts and papers, editing, retyping all of them, indexing the publication, having it printed, and finally, distributing it to the members. This job now will be assigned most likely to an editor. Rod Lym has been appointed chairman of an ad hoc Editorial Committee whose responsibilities will include drafting editorial rules for the Proceedings. Please contact Rod if you are interested in working with him on this committee.

Other important items of business include three new standing committees. You will have the opportunity to discuss and vote on the new committees at our Thursday morning Business Meeting. The new committees that you will be considering are Poster, Student Paper Judging, and Necrology. Information on these new committees will be distributed to you before the Business Meeting.

I am sure that most of you noticed the increased registration cost for this meeting. During the past two fiscal years, the Society has spent about $1,000 per year more than our income. To balance income with expenses, your Executive Board approved the $15 increase at the 1988 Summer Business Meeting. The price of our two publications also was increased to meet current publication and mailing costs. The Research Progress Report and the Proceedings each increased $3 from $12 to $15.

In February, 1989 all of you should have received a letter from Lowell Jordan, our representative to CAST. In that letter, Lowell encouraged each of you to join CAST as individual members. I am sure, as you are all aware, CAST provides a major educational service to lawmakers and government officials in Washington, D.C., the news media, and the public. The WSWS has been a member of CAST since 1978. If you are not currently a member of CAST, I also encourage you to join. Your tax-deductible membership includes a quarterly newsletter and a free copy of any new CAST publication. Dr. William Marion, Executive Vice President of CAST, is attending our meeting. Please take this opportunity to visit with Dr. Marion. If you are interested in a more active involvement in CAST, I am sure Dr. Marion will put you to work.

The Weed Science Society of America has a project underway to provide copies of our journals to weed scientists in foreign countries that do not have ready access to these publications. In keeping with this endeavor, the WSWS will donate copies of past Proceedings to the newly formed Egyptian Weed Science Society. Dr. Mamdouh Abdallah is here at our meeting representing the Egyptian Weed Science Society. Welcome Dr. Abdallah. I also would like to extend a special welcome to members of the Asian-Pacific Weed Science Society and individuals representing weed science societies from other parts of the world.

A highlight for me this past year was a trip to Washington, D.C., where I represented the WSWS on a team comprised of senior officers of the WSSA and presidents of the regional weed science societies. We met with several key Congressmen and Senators to discuss eight legislative issues important to weed science. Position papers on suspension/cancellation of pesticides, formation of a WSSA advisory committee on endangered species for cooperation with the EPA, the importance of the Federal Noxious Weed Act of 1974, the need for alternative herbicides for each minor crop, providing critical support for the IR-4 program, liability for minor acreage crop damage from pesticides, groundwater quality and herbicides, and pesticides and food safety were presented during these meetings. I encourage the WSWS to continue providing funds to assist the President of the WSWS on his trip to Washington, D.C. Please let members of your Executive Board know about legislative issues that you think are important to weed science--especially in the west.

In a few minutes, you will have the opportunity to hear from three distinguished gentlemen. Each speaker will be discussing different but timely topics. Dr. Patrick Madden will discuss the role of weed scientists in Low-Input/Sustainable Agriculture or as many of us know it as LISA. Dr. Homar LaBaron will discuss management of herbicides as it relates to herbicide resistant weeds. Dr. John Goss will discuss crop herbicide resistance. The diversity of these topics reminds me of the slogan used this year at the University of Idaho during its centennial celebration--"Where Tradition Meets the Future." In this case, perhaps tradition is the way we control weeds in our crops today, and the future is new technologies, whether they be methods involving less inputs, weed resistance management, herbicide resistant crops or an integration of all three. I think the important point is that we need to train weed scientists in each of these areas, as well as in areas of traditional weed science. However, it is very easy to get caught up in the new technologies and place less emphasis on still important areas of training in traditional weed science. Not all weed problems will be solved, at least in the near future, with less inputs or advances in biotechnology. The problem as I see it, is that less funding is available for research in many traditional weed science areas. This may mean it will be harder to fund graduate student research in traditional areas. Also it may be more difficult to attract quality undergraduate students into departments with traditional agronomy programs.

This topic was discussed recently in an article in the October 1988 issue of Agrichemical Age. According to the article, many scientists are having trouble getting money for their production-oriented research. The article also points out the continuing need for people trained in production agriculture even in the future world of high-tech agriculture.

As weed scientists and technologists concerned about the future of agriculture, we should always be recruiting or encouraging young people to pursue careers in agriculture. Likewise we should be willing to incorporate new technologies and techniques that are developed in areas such as plant molecular biology into weed science. Ultimately, we should integrate tradition with the future.

In closing I have been encouraged by many of my good friends to make the following Presidential Proclamation. Thus, as President of the Western Society of Weed Science, I proclaim that ties are out and brightly colored Hawaiian shirts are in for this 42nd meeting of the WSWS.

# THE ROLE OF WEED SCIENTISTS IN LOW-INPUT/SUSTAINABLE AGRICULTURE

J. Patrick Madden[1]

Weed scientists historically have made major advances in providing an abundance of food and fiber by developing effective measures for controlling weeds. Increasing concerns over problems such as groundwater contamination and health risks to farm workers have stimulated more aggressive regulation of herbicides. An alternative to pesticide regulation is being promoted by the USDA grants program, Low-Input/Sustainable Agriculture (LISA). Weed scientists and other scientists and educators in public and private organizations are encouraged to develop multi-disciplinary teams to design and implement research studies to improve the productivity and profitability of alternative weed control strategies that require substantially less herbicide than conventional methods. The teams also conduct educational programs, including on-farm tests and demonstrations, to promote the adoption of these alternative methods as their effectiveness becomes established.

In the first year of operation of the LISA program, Fiscal Year 1988, the federal government appropriated $3.9 million. A total of 49 projects were funded, with grants ranging in size from $2,000 to $220,000. Nine projects deal explicitly with weed control. Five project teams include weed scientists: Jane Mt. Pleasant of Cornell; Rhonda Janke of Rodale Research Center; John Teasdale of the ARS Weed Science Laboratory; Michael Owen of Iowa State; Ford Baldwin and John Boyd of Arkansas; and Leon Wrage of South Dakota State University. In the western region, no projects explicitly focused on weed control were fully funded, but two received planning grants to prepare more fully developed proposals for 1989; Taro production in Micronesia (including Hawaii, Somoa, the Marianas, and Guam; and rice production in northern California).

The following two project descriptions, taken from the proposals of LISA projects funded in 1988, illustrate some of the non-herbicide approaches taken. First, weed scientists Rhonda Janke of Rodale Institute and John Teasdale of the ARS Weed Science Laboratory are cooperating with plant ecologists at Cornell University and farmers ins three states (Illinois, Missouri and Nebraska) in conducting a study to test the ability of mulch crops and relay crops to control weeds in no-till and reduced tillage corn-soybean rotations. In 1987 a long-term (20-year) experiment was begun at the Rodale Research Center to address problems that farmers face when adopting low-input (no pesticides, minimal purchased fertilizer use) reduced tillage cropping systems. Four different tillage regimes will be evaluated in the context of three different cropping systems. Two rotations will use no pesticides and minimal fertilizer, and one will use standard rates of pesticides and fertilizers. In the low-input rotations, weed control in soybeans will be achieved by relay cropping the beans into a small grain crop. To control weeds in corn, a rye grain and hairy vetch mixture will be broadcast into soybeans in the fall and flail chopped the following spring. Corn will be planted into this mulch. Preliminary trials at Rodale and a large body of ecological theory indicate that these techniques have potential for effective weed control. Weed control in these systems will be evaluated by seedling counts four times during the growing season and by clipping and measuring the biomass of each weed species at two times in the season. Perennial weed invasion, of particular concern in no-till systems, will be

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monitored by annual mapping of perennial weed clumps. Perennial seeds were mapped prior to treatment initiation.

Since perennial weeds are a major concern, a satellite trial is being conducted at Cornell University to look at the emergence and survival patterns of perennial weeds which will be planted at known densities in the experimental plots as well as emergence and survival of naturally occurring annual weeds. In this trial, one of the low-input rotations used at Rodale will be compared with a conventional rotation using herbicides, all at three tillage levels. A second satellite trial at the Beltsville Agricultural Research Center will examine emergence and survival of weeds in several of the treatments used at Rodale and Cornell, and in addition will examine the effects on weeds of double cropping soybeans with winter grains. In addition to learning more about mechanisms of weed establishment and survival under reduced tillage conditions, these satellite trials will also allow us to evaluate the crop rotations over a large range of climates and soils.

In addition to these research trials, four reduced tillage experiments are being conducted in 1988 by farmers in collaboration with Rodale's On-Farm Research Network in Illinois, Missouri, and Nebraska. These farmers will be planting corn and soybeans into mulches of rye and hairy vetch, and comparing this planting method to their previous convention tillage method. All plots will be herbicide-free. The experiments are randomized and replicated at least six times to allow for statistical analysis of crop yield and weed abundance. This on-farm research effort adds a valuable demonstration and outreach component to this work in addition to providing feedback to researchers.

In another study, Ken McNamara, Rodale Institute, and Jerry Doll, University of Wisconsin, are working with farmers in eight midwestern states to test the allelopathic capability of winter rye in controlling weeds in soybeans. Along with the on-farm research sites, greenhouse and small plot work will focus on questions of the effectiveness of rye versus oats, some detailed work on herbicidal action of rye, and closer study of the growth stages of rye as related to nonchemical means of killing it.

In LISA's second year (FY 1989), the federal appropriation was increased to 14 percent, to $4.45 million. The western region is using a two-stage procedure for selection of LISA projects in 1989. Pre-proposals have been evaluated by teams of farmers and scientists. Authors of the pre-proposals judged to be most promising will be asked to develop full proposals, which will be evaluated and funded by early June of 1989. The future of the program's funding is highly secure, in view of its strong support in Congress and across the nation.

It is a matter of great urgency that we intensify efforts to develop and promote adoption of weed control methods that are environmentally harmless, safe to humans, effective, and profitable. This goal includes simultaneously developing safer herbicides and modes of application, while improving the efficacy of low-input methods that require little or no herbicide. Promising low-input approaches include crop rotations, allelopathic cover crops, biological control of weeds, reduced dosage methods such as banded application of herbicides, innovative tillage methods, and improved management.

What is needed to bring these efforts to fruition? An essential ingredient is the sustained, long-term effort of many dedicated weed scientists, working in cooperation with farmers, educators, ecologists, scientists of other disciplines, and private industry. If the Western Society of Weed Science is anything like most other professional scientific associations, a major challenge lies within the editorial policies of your refereed journal. Your challenge is to support and reward the active involvement of weed scientists in long-term, interdisciplinary team efforts. It is essential that the editorial board respect the potential scientific contribution of interdisciplinary, on-farm field studies. Even though such studies normally lack the rigorous controls attainable in greenhouse or experiment station plots, they include the management input which is absolutely essential to the success of low-input farming methods and systems. The prestige and professional stature of carefully executed and clearly stated reports and articles emanating from such projects must be elevated to a position of parity with the equally important sole- or senior-authored disciplinary research articles. Both a philosophical and methodological paradigm shift will be required in most agricultural sciences and peer review committees at many institutions before this can happen. The difficulties are many and stubborn, but the potential rewards to mankind are inestimable.

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## MANAGEMENT OF HERBICIDES TO AVOID, DELAY AND CONTROL RESISTANT WEEDS: A CONCEPT WHOSE TIME HAS COME

H.M. LeBaron[1]

The discovery of triazine-resistant common groundsel (*Senecio vulgaris*) in western Washington in the late 1960's, and the subsequent widespread and frequent occurrence of other triazine-resistant weeds over the past 20 years, have made triazine herbicide resistance the best known and most studied case of herbicide resistance. Triazine resistance has also been of greatest interest because of the importance and extensive use of this group of herbicides. It is likely that if other single target site residual herbicides (e.g., diuron (*N*'-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea)) were used as extensively and continuously as the triazines, they would have almost certainly led to resistant biotypes.

Although weeds have taken longer to evolve herbicide resistance compared to insect pests and pathogens, according to my recent survey, biotypes of 40 broadleaves and 15 grass weed species are known to have developed resistance to triazine herbicides somewhere in the world (See Tables 1A and 1B). A total of 45 weed biotypes (29 broadleaves and 16 grasses) have evolved resistance to 14 other types of classes of herbicides, making a grand total of 100 herbicide-resistant weed biotypes to date (see Table 1). Only 21 of the triazine-resistant biotypes and 16 biotypes resistant to other herbicides have been found in the U.S., but one or more of these resistant biotypes have invaded 38 states, 6 provinces of Canada and 26 other countries.

Within the west, ten weed species have evolved resistant biotypes to one or more of four classes of herbicides and in one or more of nine states (see Tables 3 and 4). At least one herbicide-resistant biotype has been found in all of the western states except Arizona and Hawaii.*

*While in Hawaii to attend this meeting, I was informed there are at least two triazine-resistant annual grass weeds which have evolved during the past few years in some sugar cane fields. I observed and obtained samples of seed from these weeds in a plantation on Maui. They are plush grass or radiate fingergrass (*Chloris radiato*) and swollen fingergrass (*Chloris barbata*).

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Past experience has shown that weeds resistant to triazines can be managed or restrained within a reasonable limit. In the U.S., the total area of land or crops infested with triazine-resistant weeds is still relatively small (estimated to be about 250,000 acres) and does not seem to be expanding rapidly. In most areas of the U.S. where triazine-resistant weeds have evolved, it has not even been necessary or desirable to cease using the triazine herbicide of choice, due to the many susceptible weeds that are still usually prevalent. In a few cases, the resistant biotypes have even disappeared.

Over the 45 years that modern herbicides have been developed and used extensively, there have been many cases of differential tolerance within various weed species, such as intraspecific resistance to 2,4-D {(2,4-dichlorophenoxy)-acetic acid}, dalapon {2,2-dichloropropanoic acid}, and other herbicides. We have also seen many examples of evolution toward interspecific herbicide tolerance. We, who have been researching and trying to control weeds for some time, have learned in many ways that nature is neither an exact nor fixed science. Nothing remains constant, and weeds have been around a lot longer than we have. They have learned to adapt and evolve to survive.

Some of our modern chemical tools have been so spectacular compared to the cultivator and hoe, and we have gotten so accustomed to seeing clean weed-free fields, that we have gotten a bit complacent. Some of us thought we have finally solved some of the major problems and could go on to work on the minor ones.

Occasional observations that more tolerant phenotypes or species were moving in to spoil the fine recommendations we worked out for our farmers did not bother us too much. Even when triazine resistance evolved, while it was striking how a weed that looked the same could be so different and grow so well where it should be dead, we found some easy way to circumvent these interlopers.

Then came the new generation of spectacular herbicides (e.g., sulfonylureas, imidazilinones) which are effective at grams per acre instead of pounds per acre. They were just what was needed to help solve environmental concerns and other problems while adding a great dimension and flexibility to our weed control technology. We again marveled at the success and potential of our inventions, but we did not look back to see what nature was doing. As you know, within the past few years, an increasing number of weeds have evolved resistance to these and several other types of herbicides.

Our knowledge about herbicide sites and modes of action has been essential in our research and understanding of herbicide resistance mechanisms. Herbicide-resistant weeds have also been valuable scientific tools, contributing greatly to our understanding of herbicide modes of action, plant biochemical and physiological processes, molecular genetics, physical structure, and anatomy. However, it is interesting and, I believe, significant that the mechanisms of resistance developed by weeds are often different from the mechanisms of selectivity to those herbicides in most crops. This is certainly true with the most prevalent and thoroughly studied cases of herbicide resistance, including the triazines, dinitroanilines, and AHAS inhibitors.

For example, in the goosegrass (*Eleusine indica*) weed biotype resistant to trifluralin {2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine}, the tubulin in the roots is apparently altered so dinitroaniline herbicides are not effective in preventing tubulin polymerization into microtubules, which is assumed to be the mechanism of action of these herbicides. However, selectivity in most crops to these herbicides is believed to be due to the ability of their tap roots to rapidly grow through the treated soil layer or differential lipid content in seeds, thereby avoiding significant herbicide exposure.

Resistance mechanisms in weed biotypes to AHAS inhibitors are apparently due to an alteration in the gene coding for acetolactate synthase, resulting in variable forms of insensitive AHAS enzymes, which is the main target site of these herbicides. Crop tolerance, however, seems to be mostly dependent on differential metabolism.

Research to date indicates that most of the triazine-resistant biotypes lack the normal triazine binding sites in their chloroplasts, whereas crop selectivity is due mainly to metabolism or translocation differences. Triazine-resistant velvetleaf (*Abutilon theophrastis*) in Maryland is an exception in that resistance is due to enhanced glutathione transferase activity.

While most crops and weeds are susceptible to paraquat {1,1'-dimethyl-4,4'-bipyridinium ion}, paraquat-resistant horseweed (*Conyza*) biotypes may be insensitive to the herbicide due to elevated levels of superoxide dismutase and other enzymes, or to differential binding or distribution of the herbicide in the weed. Data on the mechanisms of most other types of herbicide resistance in weeds are still not complete.

Of special concern is the occurrence of serious cross-resistance to many herbicides within the same species. The few cases to date are still a long distance away. The most noted examples are *Lolium rigidum* (annual ryegrass) in Australia and *Alopecurus* (blackgrass) in the U.K. However, it is very worrisome that multiple cross-resistance to herbicides can occur in plants, apparently by similar mechanisms (metabolic detoxification, e.g., mixed function oxidases) to some insects which rapidly evolve resistance to insecticides. Such efficient oxidation of foreign organic chemicals may prevent almost any herbicide from reaching the target site entact.

My first view of this phenomenon was when I went to Australia about 3 1/2 years ago to speak at a conference on herbicide resistance. They had several areas where paraquat-resistant weeds (e.g., *Hordeum*) were causing problems. One location had reported failures in controlling annual ryegrass (*Lolium rigidum*) with diclofop methyl{(±)-2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid}. While there, I learned this was the most serious and widespread weed in their major crops (wheat and barley); there were not many herbicides that could give good selective control; the most promising herbicides that could replace diclofop methyl for this purpose were sulfonylureas; preliminary tests indicated that diclofop methyl resistant ryegrass was also resistant to chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide}; and two new but widely scattered cases of similar resistance came to my attention while I was there. I changed the text of my paper to strongly recommend they begin a major research effort on this weed promptly, and instead of what to do if resistance occurs, warned them that they were potentially facing the worst case of herbicide resistance I knew of in the entire world.

This has proven to be the case, as this multiple-resistant weed has become generally widespread throughout most of the cereal producing areas of Australia. The solutions to this problem will not be easy, and they will have to include cultural and agronomic methods as well as, or possibly in place of chemical methods. Because of the striking ability this weed has for developing resistance to many herbicides, not only in Australia but in other parts of the world, I refer to *Lolium* as the housefly or Colorado potato beetle of the plant kingdom. A diclofop methyl resistant *Lolium multiflorum* (Italian ryegrass) was recently discovered in Oregon. It was found to have some degree of cross-resistance. We need to respect this genus, and avoid in any way possible plants with multiple resistant potential.

Resistance to the AHAS inhibitors and other newer herbicides have already become a very serious issue. Because of their much lower rates, with less human, animal, and environmental exposure and risks, and coming at a time when some of the earlier herbicides are being discontinued or are in trouble because of economics, reregistration requirements, toxicology, and environmental concerns, a very strong perception exists among government agencies and policymakers that the new herbicides will replace many in current use. I maintain there will be a great need for older herbicides and other tools of agricultural technology that can be preserved in the future. Chemical herbicides must be a major part of the agricultural technology in the decades ahead, to provide the constantly greater demand for food, fiber, and shelter, with greater cost effectiveness. But we must not become complacent, discard other means of pest control, or depend too much on chemicals alone. Herbicide resistance is acting as a self-imposed limiting system of nature. Nature sets the rules. We have to be just as flexible or we lose.

There is no way that biological and other nonchemical methods of pest control will totally replace chemicals in our lifetime. If we have learned anything in the past 40 years, it is that we will need all the help we can get to keep ahead of our pests, and to depend on only one tool or method against major pests is a sure road to failure and scientific heresy. Chemicals will continue to be essential and the main line of defense against pests, and will help to produce the crops and pay for the research on biological controls, biotechnology, and sustainable agriculture while these tools are being developed.

With the first invasion of resistant weeds, prompt action is essential in order to avoid serious and more permanent problems. Preventive action to avoid herbicide resistant weeds from developing in the first place is definitely the best strategy. It is virtually essential in all cases of herbicide resistance to have other classes or types of herbicides, with alternate sites and mode of action, available. In some countries and situations, failure to respond promptly, the lack of suitable alternatives, or for other reasons, control of triazine-resistant weeds have not been successful, resulting in rapid invasion and almost total loss of these herbicides in the area.

I have great concerns and doubts whether we can be as successful in avoiding or managing some of the more recent resistant biotypes as we have been with triazine-resistant weeds in the past. Not only are herbicide-resistant weeds appearing after fewer repeat annual applications of some of the newer herbicides, but there seems to be more species that have potential for resistance. It is likely that many, if not all, weeds possess some ability to evolve resistance to these herbicides. Enzyme induction mechanisms involved in herbicide metabolism by plants may evolve faster than a change in other target sites. In addition, the resistant biotypes are apparently equally fit and competitive once they evolve, unlike most biotypes resistant to triazine herbicides.

The lack of fitness in most triazine-resistant weeds is a very important reason why they have been fairly easily controlled, and why more problems of cross-resistance or multiple resistance have not occurred where both a triazine and other type of herbicide have been used repeatedly together. Actually, some cases of such cross-resistance are now beginning to appear.

It is obvious that we must apply all the wisdom and understanding we have developed on pest resistance to pesticides, as well as exercise a greater degree of marketing control and self-restraint than has ever been demonstrated in U.S. agriculture in order to protect, preserve, or prolong the use of sulfonylurea and other herbicides with a single site of action and high risk for resistance.

The following are some of the changes or strategy rules I believe will be required:

1. These herbicides should be marketed only in combinations, especially in major crops, if other types of herbicides are available as suitable partners.

2. Crop and herbicide rotations should be used whenever possible. In rotations, avoid those with the same weed spectra.

3. Use of long residual AHAS herbicides should be avoided or minimized.

4. Use of the lowest rates possible.

5. Minimize the number of applications per season, and use only every two or three years.

6. Education and cooperation of industry management, marketing, sales, extension, farmers, and others are essential.

7. Government agencies and policymakers must realize that all possible herbicides must be retained as potential mixing partners.

8. Industry should not develop and market AHAS resistant crops or crops resistant to only one herbicide with a high risk for resistance for the purpose of greatly expanding their use. This approach should be used to enhance tolerance in crop varieties, to avoid carryover injury, for specific and limited special problems, and for minor acreage and high value crops. A major objective of developing herbicide resistant crops should be to provide more flexibility in control of resistant weeds.

9. These herbicides should be used in crops only where several other good mixing partners, cultivation, and other weed control options are available.

10. Cultivators or other mechanical weed control options should remain available. Conservation tillage systems may not be a long-term or continuing option.

11. If possible, industry should continue to develop chemicals in this class that will inhibit all types of AHAS enzymes and overcome this resistance.

12. Develop other herbicides that do not have a single site of action and are not as likely to induce resistance.

13. Lastly, do not yet throw away the hoe, but rogue out the weeds that escape if resistance occurs or is suspected, or use systems that preferentially control resistant weeds.

I can agree with proponents of sustainable agriculture that we have at times depended on herbicides too much, or I should say we have expected too much from them. However, I will never agree that we should ask our farmers to get by without them, and no one who likes to eat should try to compel them to do so. Rather, we must learn to better manage herbicides and preserve them by learning to use them as essential tools while avoiding and managing resistant weeds. These new low-rate herbicides must continue to be an important part of our future defense against weeds, but they will require greater wisdom, restraint, scientific knowledge, and attention than we have applied to our weed research and control methods in the past. Our main problem in agriculture today is not with the technology, but with public perceptions. There is no significant exposure or risk to human health or the environment from herbicides in food or groundwater, but we are in serious risk of solving the wrong problem. Ignorance, *fear, and emotions must be replaced by education, reason, and rational thought* and action. California or other states have the option of deciding to drop pesticide use, but they cannot choose to remain competitive in agriculture or to purchase only food produced without them. We will depend more and more on imported foods, our surpluses will disappear, we will have less control on the quality of our food, and the greatest agricultural technology in the world that is responsible for providing by far, the highest quality and variety of food at the lowest price that this country or any other has ever known, will be weakened or in jeopardy.

We should not forget or ignore that God put us all on notice in the beginning when he said to Adam: "Cursed is the ground for thy sake; --thorns also and thistles shall it bring forth to thee;--in the sweat of thy face shalt thou eat bread;" (Genesis 3:17-19). Resistant weeds are another reminder that we will need to continue to sweat and must never become lazy or complacent. But remember that he did it for "our sake."

Table IA

Distribution of Triazine-Resistant Dicot Weeds
(as of March, 1989)

| Genera | No. of species | Location[a] |
|---|---|---|
| Abutilon | 1 | U.S. (1)<br>Europe (1) |
| Amaranthus | 8 | U.S. (21)<br>Canada (3)<br>Europe (10)<br>Other (1) |
| Ambrosia | 1 | U.S. (1)<br>Canada (1) |
| Arenaria | 1 | Europe (1) |
| Atriplex | 1 | Europe (2) |
| Bidens | 1 | Europe (2) |
| Brassica | 1 | Canada (1)<br>Europe (1) |
| Capsella | 1 | Europe (1) |
| Chenopodium | 6 | U.S. (19)<br>Canada (3)<br>Europe (9)<br>Other (1) |
| Conyza | 2 | Europe (7) |
| Epilobium | 2 | Europe (6) |
| Galinsoga | 1 | Europe (2) |
| Kochia | 1 | U.S. (12) |
| Matricaria | 1 | Europe (1) |
| Myosoton | 1 | Europe (2) |
| Physalia | 1 | U.S. (1) |
| Polygonum | 5 | U.S. (2)<br>Europe (4) |
| Senecio | 1 | U.S. (3)<br>Canada (2)<br>Europe (9) |
| Sicyos | 1 | U.S. (1) |
| Sinapis | 1 | Canada (1) |
| Solanum | 1 | U.S. (1)<br>Europe (7) |
| Sonchus | 1 | Europe (1) |
| Stellaria | 1 | Europe (2) |

[a] These numbers indicate the number of states, provinces, or countries where the species or genera have been found.

Table IB

Distribution of Triazine-Resistant Monocot Weeds (as of March, 1989)

| Genera | No. of species | Location[a] |
|---|---|---|
| Alopecurus | 1 | Other (1) |
| Brachypodium | 1 | Other (1) |
| Bromus | 1 | U.S. (5)<br>Europe (1) |
| Digitaria | 1 | Europe (3) |
| Echinochloa | 1 | U.S. (2)<br>Canada (1)<br>Europe (4) |
| Lolium | 1 | Other (2) |
| Lophochloa | 1 | Other (1) |
| Panicum | 1 | U.S. (1)<br>Canada (1) |
| Phalaris | 1 | Other (1) |
| Poa | 1 | U.S. (1)<br>Europe (7)<br>Other (1) |
| Polypogon | 1 | Other (1) |
| Setaria | 4 | U.S. (2)<br>Canada (1)<br>Europe (1) |

Totals: 35 genera
55 species
63 broadleafs
27 grasses

| | |
|---|---|
| U.S. | 31 states |
| Canada | 4 provinces |
| Europe | 15 countries |
| Other | 4 countries |

Table 2

Distribution of Weeds Resistant
To Other Herbicides (non-triazines)
(as of March, 1989)

| Herbicide | Genera | No. of Species | Location |
|---|---|---|---|
| Aminotriazole | Lolium | 1 | Other (1) |
| | Poa | 1 | Europe (1) |
| Bromoxynil | Chenopodium | 1 | Europe (1) |
| Carbamates | Amaranthus | 2 | Europe (1) |
| Chlortoluron, etc. | Alopecurus | 1 | Europe (2) |
| | Amaranthus | 2 | Europe (1) |
| | Chenopodium | 1 | Europe (1) |
| | Conyza | 1 | Europe (1) |
| 2,4-D | Cirsium | 1 | Europe (1) |
| | Daucus | 1 | Canada (1) |
| | Sphenoclea | 1 | Other (1) |
| Diclofop | Alopecurus | 1 | Europe (1) |
| | Avena | 1 | Other (2) |
| | Lolium | 2 | U.S. (1)<br>Other (1) |
| Diuron | Amaranthus | 1 | Europe (1) |
| Mecoprop | Stellaria | 1 | Europe (1) |
| MSMA & DSMA | Xanthium | 1 | U.S. (2) |
| Paraquat | Arctotheca | 1 | Other (1) |
| | Conyza | 2 | Europe (1)<br>Other (2) |
| | Epilobium | 1 | Europe (2) |
| | Erigeron | 2 | Other (1) |
| | Hordeum | 2 | Other (1) |
| | Lolium | 1 | Europe (1) |
| | Poa | 1 | Europe (1) |
| | Younquia | 1 | Other (1) |
| Picloram | Centaurea | 1 | U.S. (1) |
| Propanil | Echinochloa | 2 | Europe (1)<br>Other (1) |
| Pyrazon | Chenopodium | 1 | Europe (3) |
| Sulfonylureas & Imidazolinones | Ixophorus | 1 | Other (1) |
| | Kochia | 1 | U.S. (8) |
| | Lactuca | 1 | U.S. (1) |
| | Lolium | 1 | Other (1) |
| | Salsola | 1 | U.S. (2) |
| | Stellaria | 1 | Canada (1) |
| Trifluralin | Eleusine | 1 | U.S. (4) |
| | Setaria | 1 | Canada (1) |
| Uracils | Amaranthus | 2 | Europe (1) |

**Totals:** 14 different classes of herbicides
25 genera
33 species
U.S. 14 states
Canada 3 provinces
Europe 7 countries
Other 7 countries

Table 3

Distribution of Herbicide Resistant Weeds In Western U.S. By Species (as of March, 1989)

| Genera Species | Common Name | Year Found | Location |
|---|---|---|---|
| *Amaranthus arenicola* | sandhills amaranth | 1977(t)[a] | Colorado |
| *Amaranthus hybridus* | smooth pigweed | 1985(t) | Colorado |
| *Amaranthus powellii* | green pigweed | 1968(t) | Washington |
| | | 1970(t) | Oregon |
| *Bromus tectorum* | downy brome | 1977(t) | Montana |
| | | 1978(t) | Oregon |
| | | 1978(t) | Washington |
| *Centaurea solstitialis* | yellow star-thistle | 1988(p) | Idaho |
| *Chenopodium album* | common lambs-quarters | 1973(t) | Washington |
| *Kochia scoparia* | kochia | 1976(t) | Idaho |
| | | 1987(s) | |
| | | 1976(t) | Utah |
| | | 1977(t) | Colorado |
| | | 1988(s) | |
| | | 1977(t) | Oregon |
| | | 1978(t) | Wyoming |
| | | 1979(t) | Montana |
| | | 1988(s) | |
| | | 1980(t) | Washington |
| | | 1988(s) | |
| | | 1984(t) | California |
| | | 1988(s) | New Mexico |
| *Lolium multiflorum*[b] | Italian ryegrass | 1987(d) | Oregon |
| *Poa annua* | annual bluegrass | 1976(t) | California |
| *Senecio vulgaris* | common groundsel | 1968(t) | Washington |
| | | 1973(t) | Oregon |
| | | 1977(t) | California |

a(t) = triazine resistance
(s) = sulfonylurea resistance
(d) = diclofop-methyl resistance
(p) = picloram resistance (confirmed in laboratory only).

[b]This biotype is cross-resistant to other polycyclic alkanoic acid herbicides.

Table 4

Distribution of Herbicide Resistant Weeds Within Western U.S. By State (as of March, 1989)

| States | Species | Year |
|---|---|---|
| California | Kochia scoparia | 1984(t)[a] |
| | Poa annua | 1976(t) |
| | Senecio vulgaris | 1977(t) |
| Colorado | Amaranthus arenicola | 1977(t) |
| | Amaranthus hybridus | 1985(t) |
| | Kochia scoparia | 1977(t) 1988(s) |
| Idaho | Centaurea solstitialis | 1988(p) |
| | Kochia scoparia | 1976(t) 1987(s) |
| Montana | Bromus tectorum | 1977(t) |
| | Kochia scoparia | 1979(t) 1988(s) |
| New Mexico | Kochia scoparia | 1988(s) |
| Oregon | Amaranthus powellii | 1970(t) |
| | Bromus tectorum | 1978(t) |
| | Kochia scoparia | 1977(t) |
| | Senecio vulgaris | 1973(t) |
| | Lolium multiflorum[b] | 1987(d) |
| Utah | Kochia scoparia | 1976(t) |
| Washington | Amaranthus powellii | 1968(t) |
| | Bromus tectorum | 1978(t) |
| | Chenopodium album | 1973(t) |
| | Kochia scoparia | 1980(t) 1988(s) |
| | Senecio vulgaris | 1968(t) |
| Wyoming | Kochia scoparia | 1978(t) |

[a](t) = triazine resistance
(s) = sulfonylurea resistance
(d) = diclofop-methyl resistance
(p) = picloram resistance (confirmed in laboratory only).

[b]This biotype is cross-resistant to other polycyclic alkanoic acid herbicides.

# A KALEIDOSCOPIC VIEW OF CROP HERBICIDE RESISTANCE

John R. Goss and Barbara J. Mazur[1]

## INTRODUCTION

We are very pleased to represent DuPont and other biotechnology research organizations this morning, and thank Sheldon Blank and Donn Thill for asking our participation in the annual meeting of the Western Society of Weed Science. I am honored to be addressing the society about opportunities and challenges for commercializing herbicide-resistance crops.

Now just for a moment, please close your eyes and when you open them, imagine you are looking into a kaleidoscope that is focused on the future of biotechnology and crop protection in the 1990's. You will immediately be struck by the possibilities for new, intriguing patterns and by their multi-component nature. You will also notice the interrelatedness among segments of the patterns, and how some of them are bright and colorful, stimulating your scientific curiosity, while others are complicated, composed of dark and somber colors, and creating feelings of uncertainty. Now, as you are redirecting your attention to the present and the imminent development of herbicide-resistant crops, I think you will find several appropriate analogies with these kaleidoscopic patterns.

The invention and development of herbicide-resistant crops requires inputs from multiple disciplines and specific knowledge about plant regeneration, transformation, gene structure, biochemistry, genetics, and herbicide mode of action, to produce a plant having a resistant phenotype. This is analogous to the many components of a kaleidoscopic pattern. The successful commercialization of crop herbicide-resistance will be directly related to its compatibility with current weed control practices, to future needs, and to the principles of crop science and plant breeding. Just as the kaleidoscope triggers our curiosity, it's exciting to think that biorational approaches can now be used for optimizing both herbicide activity and crop selectivity spectra. In contrast, it is sobering to consider the uncertainty of public policy issues surrounding environmental release and the use of food products derived from herbicide-resistant transgenic crops. And similar to every new turn of the kaleidoscope, it is certain that herbicide-resistant crops will create new, and in some cases, novel patterns of cultural uses in agriculture.

Many of you will have the opportunity to become involved, if you aren't already, in the research and development of herbicide-resistant crops. I hope you will gain some perspective from my comments about how biotechnology will impact weed science in the future, and that its potential for change will stimulate your scientific curiosity.

During the 1990's the first products of agricultural biotechnology research will be introduced into the marketplace. It is expected that herbicide-resistant crop varieties will be one of the significant new developments from this technology, with estimated revenues of greater than $500 million annually by the year 2000. This morning I will give a brief orientation to the methods and approaches for developing herbicide-resistant crops. An overview of marketplace perspectives will focus on the questions of customer needs, on what crops and

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compounds have been targeted for commercial development, on timelines for introduction, and on questions about the agronomic performance of herbicide-resistant crops. Opportunities for herbicide-resistant crops will be discussed to stimulate your thinking on how this technology could be extended to new uses. Challenges and key issues will be presented to re-enforce the findings that some aspects of commercializing herbicide-resistance crops are complicated and that public policy issues surrounding transgenic plants remain unresolved.

At this time I would like to acknowledge the following colleagues and collaborators whose contributions have been essential to the development of crop herbicide-resistance within DuPont: Barbara Mazur, Carl Falco, Jeff Mauvais, Gary Fader, Susan Knowlton, Tom Ray, Bob Giaquinta, Raymond Forney, Scott Sebastian and Roy Chaleff.

## TECHNOLOGY

Approaches to Crop Herbicide-Resistance. Two approaches have been successfully used by several biotechnology research organizations for developing herbicide-resistance crops.

1) If the herbicide site of action is known, it can potentially be altered making it insensitive to inhibition. A variation to this approach is to overexpress the gene(s) encoding the site of action, so that the number of sensitive inhibition sites is always greater than the number of herbicide molecules present within the plant at any one point in time.

2) If the site of action is not known, or if it cannot be altered without deleterious secondary effects, then the introduction of herbicide detoxification enzymes is another approach that has proven successful. Detoxification can result from the conjugation or degradation of the herbicide. The genes used can either be the native genes that normally produce the enzymes capable of metabolically detoxifying herbicides, or they can come from a different species, such as a bacterial source.

Both approaches assume that adverse secondary effects on plant growth and development will not occur when these novel traits are incorporated into the plant genome. However, results from the development of herbicide-resistant Canola and other Brassica crops teaches us this assumption is not valid in all cases. The atrazine {6-chloro-*N*-ethyl-*N*'-(1-methylethyl)-1,3,5-triazine-2,4-diamine}-resistant Canola cultivar "Triton" has a grain yield penalty of approximately 20% and reduced oil content from 2 to 3% as compared to herbicide sensitive varieties. Since the site of action of triazine herbicides is in the chloroplast, it is possible that the observed secondary effects may result from other chloroplast genes. In contrast, communications with researchers at Pioneer Hi-bred International, indicate that no yield penalty has been associated with a mutant herbicide-resistant acetolactate synthase (ALS) enzyme in corn, when compared to the performance of isogenic herbicide sensitive hybrids. So the potential "biological cost" to agronomic performance from herbicide-resistance genes needs to be evaluated on a case-by-case basis for each approach.

An alternative approach for creating herbicide-resistant plants would be to manipulate proteins so as to limit the penetration of herbicides into plants, or to sequester toxic molecules within cellular compartments. Both approaches would protect the site of action from inhibitory concentrations of the herbicide. While research indicates that some crop selectivity to herbicides results in part from this type of mechanism, genes controlling these processes of plant development have not yet been cloned. Thus this approach has limited usefulness at this time.

# METHODS FOR DEVELOPING HERBICIDE-RESISTANT CROPS

Gene modification by random or by specific mutations, or by gene transfer, are required to achieve herbicide-resistant crops using either of the above approaches. The following methods have been used successfully to select, modify and/or to transfer genes conveying herbicide-resistant traits:

1) Cell and tissue culture selection
2) Seed mutagenesis
3) Gene isolation and transfer

<u>Cell and Tissue Culture Selection</u>. Cell and tissue culture selection is a random process whereby single cells or callus tissues are selected in mass for their capabilities to overcome the inhibitory effects of a lethal dose of herbicide that is present in the nutrient media. An increased frequency of somatic cell mutation is observed when most plant species are placed into cell culture. Some of these mutations lead to herbicide tolerance or resistance that is stably inherited, allowing selected cells to survive a lethal dose. Mutant cells or tissue must be able to regenerate from cells into whole plants before the herbicide-resistant trait can become useful to the plant breeder. Unfortunately, not all crops or even varieties within a crop can be easily regenerated from cell or tissue culture, thus limiting the application of this method.

<u>Seed Mutagenesis</u>. Seed mutagenesis is a process whereby seeds of a crop are exposed to a chemical mutagen like ethylmethane sulfonate (EMS), whose alkylating effects convert cytosine nucleotide bases to guanine, thus randomly altering DNA sequences. Again, millions of seed collected from plants produced from mutagenized seed are selected in mass for their capabilities to overcome the inhibitory effects of a lethal concentration of herbicide. This approach is only successful when small and subtle changes can be made in existing genes which result in herbicide resistance without associated deleterious effects. This method has the advantages of not requiring transformation or regeneration phenomena in order to obtain a whole plant expressing the resistance trait.

<u>Genetic Transformation</u>. Genetic transformation is the process whereby a construct encoding a resistant gene is stably incorporated into the genome of a single plant cell. The transformed cell must be regenerated into a whole plant before the herbicide-resistant trait is useful to the plant breeder. The most successful and widely used method for transformation has been the bacterium *Agrobacterium tumefacians*. This bacterium causes crown gall disease because of its ability to incorporate tumor-inducing genes into cells of the host plant, resulting in the proliferation of undifferentiated gall-like tissues. Molecular biologists have devised methods to exploit this unique attribute for gene transfer by eliminating the virulence genes that cause disease symptoms, while still using the bacterium to transfer specific genes into plants. It is important to remember that this process does not change any of the genes that are already present in the plant, and therefore, a high level of expression of the new gene must be obtained before the resistance phenotype can be observed. Unfortunately, this transfer method has not yet worked effectively for many important crop species like corn, soybeans, or cereal grains.

Alternative methods have been developed, and recent reports indicate that soybeans may now be routinely transformable using the particle gun accelerator. With this technique, immature embryos or meristems are bombarded with tungsten or gold particles coated with DNA containing the genes of interest, so the DNA penetrates the cells and is incorporated into the chromosomes.

## ADVANTAGES OF GENETIC TRANSFORMATION

Genetic transformation has two distinct advantages for developing herbicide-resistant crops as compared to traditional plant breeding methods:

1) Genetic transformation can significantly reduce the amount of time necessary to develop herbicide-resistant crops, even if other approaches are possible. Workers at DuPont have recently demonstrated that transformation of canola with sulfonylurea-resistant acetolactate synthase (ALS) gene saves approximately three to four years as compared to a conventional backcross conversion plant breeding program. This time advantage results because only the herbicide resistance gene is transferred into the new variety. In contrast, the backcross conversion method results in all genes from the plant carrying the mutant ALS gene being recombined with the recipient variety. It then requires several cycles of backcrossing with the recurrent parent to recover a plant type similar to the initial variety.

2) If cell or tissue culture selection, or seed mutagensis approaches are not successful, the genetic transformation can be used to transfer herbicide resistance genes from one species to another. An example is the transfer of herbicide detoxifying genes from bacteria into crop plants.

Many aspects of genetic transformation and regeneration are empirical, in spite of the impression created by the popular press. Whether using *Agrobacterium* or particle gun technology, single or multiple copies of genes are randomly inserted into chromosomes, and the resulting recombinant DNA-carrying plants must be further evaluated for gene copy number, stability of expression, level of expression, and unintended pleiotropic effects.

## HERBICIDE-RESISTANCE SELECTION MARKERS

A recently recognized utility for herbicide resistance genes is in their use as selection markers. It is not obvious how one would detect the successful transformation of genes coding for increased levels of essential amino acids like lysine and methionine or decreased levels of saturated fatty acids unless they were linked to an easily detected chemical resistance gene. A potential consequence of this utility is that herbicide-resistance genes will be routinely incorporated into crops as part of the transformation process for transferring genes conveying other value added traits. Thus it is reasonable to expect crops that are genetically engineered for traits such as improved feed and food quality will also contain herbicide-resistance genes.

Antibiotic resistance genes have been widely used in the past as selection markers and have similar utility; however, regulatory agencies in Europe and Canada have not looked favorably upon the presence of these genes in transgenic food or feed crops.

## OVERVIEW OF MARKETPLACE PERSPECTIVES

The grower wants and needs cost-effective, reliable and safe weed control. In the near term, products addressing these needs will continue to be selective herbicides, integrated with other pest management strategies. However, perhaps as soon as 1992, the availability of herbicide-resistant crops will increase growers' options for the use of selective and non-selective herbicides. The performance attributes of a herbicide in terms of weed control spectra, cost/acre, rotational flexibility, environmental safety, and reliability will be the primary factors in designing a weed control program. Similarly, a grower's decision to purchase a particular variety or hybrid will be determined by its yield performance and other agronomic factors, in addition to the herbicide-resistance traits. So, in summary, the marketplace success of herbicide-resistant technology will be determined by the value added in weed control, by the herbicide reliability and environmental safety, and by the agronomic performance of the herbicide-resistant germplasms.

## NEW WEED CONTROL OPTIONS FROM CROP HERBICIDE-RESISTANCE

Several new options for weed control strategies should result from the use of herbicide-resistant varieties. Few herbicides have wide margins of crop selectivity, and when used at higher than labelled rates, temporary phytotoxicity or crop injury typically results. Herbicide-resistant crops should eliminate injuries from unintended overdose applications, and should also help to minimize phytotoxicity resulting from interactions between environmental stresses and temporary biochemical alterations caused by herbicides. In addition, herbicide-resistant varieties can tolerate increased herbicide rates resulting in a greater number of weed species being more reliably controlled.

Results from 1988 DuPont field research trials evaluating sulfonylurea-resistant soybeans have demonstrated the above benefits from herbicide-resistant varieties. Pinnacle Herbicide, when applied at the labelled use rate of 4 g/ha, provided excellent weed control (greater than 95% control) of velvetleaf (*Abutilon theorasti*) and pigweeds (*Amaranthus* spp.). However, on the average a slight, transient crop phytotoxicity (less than 5%) was also observed at this application rate. In side-by-side comparisons, the sulfonylurea-resistant soybeans variety W20 exhibited no such symptoms of phytotoxicity. When Pinnacle was applied at the higher rate of 18 g/ha, a wider spectrum of broadleaf weed control including cocklebur (*Xanthium strumarium*) and lambsquarters (*Chenopodium album*) was observed; however, herbicide-sensitive varieties exhibited significant phytotoxicity symptoms. Even at this higher rate, the herbicide-resistant soybean variety showed no symptoms of phytotoxicity.

In some crop production systems, closely related crop and weed species cause troublesome, unsolved problems. These weeds are difficult to control because of the similarity between the metabolic detoxification systems of both the crop and the weed. Examples of such problems are nightshades in tomato and potato production, red rice in rice production and weed beet in sugarbeet production. With the advent of resistant crop varieties, previously non-selective herbicides could be used to control these weeds. Additional benefits should also result when perennial weed species can be more easily controlled by broadcast applications of previously non-selective herbicides.

Resistant varieties should also permit the use of new herbicide mixtures for broader spectrum weed control and for improved weed resistance management strategies. Crops exhibiting resistance to two herbicides with different sites of action will become a research target because of continuing concerns about the development of weed resistance, and because of the desirability of increasing flexibility in weed control options.

Herbicide resistance also may be a timely solution to the ongoing problems of label abandonment and product withdrawal from minor crop uses. However, financial incentives for herbicide manufacturers are minimal in minor crops, and we should not expect them to allocate research dollars for developing herbicide-resistant varieties without some promise of risk sharing.

Finally, additional uses for herbicide-resistant crops have been envisioned and in some cases patented:

1) *The control of parasitic weeds, especially* ***Cuscuata*** and ***Striga*** spp.
2) Additional options for weed control in intercropping systems

3) Selection schemes for purifying hybrid seed

HERBICIDES AND CROPS TARGETED FOR HERBICIDE-RESISTANCE DEVELOPMENT

The following non-selective or recently commercialized herbicides have been targeted for companion development with herbicide-resistant crops:

1) bromoxynil
2) glyphosate
3) phosphinotricin
4) sethoxydim
5) imidazolinones
6) sulfonylureas

Research projects on other herbicide classes, most notably the triazines, have been initiated, but have been mostly discontinued because of technical difficulties.

The following section briefly reviews details of the genetic and biochemical mechanisms used for developing herbicide resistance to the above herbicides.

Bromoxynil. A bacterial gene, designated as *bxn* producing an enzyme detoxifying bromoxynil {3,5-dibromo-4-hydroxybenzonitrile} to its benzoic acid analog has been cloned and transferred into plants by workers at Calgene. Preliminary results from studies with transgenic tobacco plants have indicated high levels of resistance to the herbicide. This gene has been successfully expressed in several different crop species, including cotton, and transgenic plants can tolerate the 1.0 to 2.0 kg/ha doses required for weed control.

Phosphinotricin. A detoxification approach has also been used to develop phosphinotricin (PPT) resistance. PPT is a structural analog of glutamine which inhibits glutamine synthase in both bacteria and plants, resulting in a toxic build up of ammonia. Bialaphos is a nonherbicidal peptide precursor of PPT. It is thought that the herbicidally active PPT moiety is released as a result of a cellular peptidase activity. Scientists at Plant Genetic Systems (PGS) cloned a detoxifying gene, designated as *bar*, from *Streptomyces* strains producing bialaphos, and transferred this gene into plants. The *bar* gene produces an enzyme that detoxifies PPT by acetylating the herbicide to an inactive form. Results from whole plant studies indicate that a number of transformed crops can tolerate the herbicide doses needed for weed control.

Glyphosate. Several different approaches have been attempted for the development of glyphosate-resistant crops. The primary site of action of glyphosate {*N*-(phosphonomethyl)glycine} is 5-enolpyruvyl-shikimate-3-phosphate synthase (EPSPS), an important enzyme in the biosynthesis of aromatic amino acids. Both the over-expression of the EPSPS gene and the creation of specific structural gene mutations to alter the herbicide sensitivity of the enzyme have been used to create glyphosate-tolerant crops, with varying degrees of success. Workers at Calgene screened *Salmonella* spp. populations and identified a resistant strain containing a mutant EPSPS gene, designated as *aroA*. Workers at Monsanto cloned as EPSPS gene from petunia, and made site-specific mutations in the gene. However, such mutations resulted in EPSPS enzymes with reduced catalytic efficiency. Using a construct containing a mutant bacterial EPSPS gene coupled to a plant EPSPS chloroplast transit sequence, Monsanto has generated a number of glyphosate resistant plants, including tomato, soybean, and oilseed rape.

<u>Sethoxydim</u>. Investigators from the University of Minnesota have used tissue culture selection techniques to isolate corn cell lines tolerant to sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one}. The degree of resistance is correlated with levels of herbicide-insensitive acetyl coenzyme A carboxylase activity, suggesting that tolerance results from a mutational event at the putative site of action. Two inbred lines have been developed from regenerated plants which also exhibit cross tolerance to other phenyloxyphenoxy proprionate herbicides. Results from preliminary genetic studies indicated that the trait is governed by a semi-dominant nuclear gene. Both lines exhibited some phytotoxicity with field applications of sethoxydim at labelled use rates, suggesting that further selection is needed before commercialization can begin.

<u>Imidazolinones and Sulfonylureas</u>. Imidazolinone resistant corn cell lines have been isolated by workers at Molecular Genetics, Inc. in cooperation with investigators at American Cyanamid, using cell culture selection methods. Fertile plants exhibiting 100 to 300 fold increases in resistance to imidazolinones were regenerated from a single cell line. Resistance was inherited as a dominant nuclear trait, and lines containing this gene were shown to have an altered ALS enzyme with reduced herbicide sensitivity. A backcrossing program conducted at Pioneer Hybrid has resulted in the transfer of this trait into elite inbreds, and evaluations of the hybrid progeny indicate that there are no deleterious pleiotropic effects. These hybrids also exhibit cross-resistance to sulfonylurea herbicides. A similar approach has been used by workers at Allelix, Inc. to develop imidazolinone-resistant canola. Field trial results have indicated that levels of resistance are sufficient for plants to tolerate doses of herbicides needed for commercial levels of weed control.

Cell culture selection, seed mutagenesis, and gene transfer methods have been employed by DuPont scientists to develop sulfonylurea resistant plants. The ALS enzyme is the primary site of action for the sulfonylurea herbicides, and resistant plants regenerated from cell culture and selection were found to contain an ALS enzyme 100-1,000 fold more tolerant to sulfonylureas than the enzymes isolated from wild-type plants. The herbicide resistance trait was inherited as a semi-dominant nuclear gene. DNA hybridization techniques were used to clone mutant ALS genes from herbicide-resistant tobacco lines. One mutant gene was shown to confer resistance to sulfonylurea herbicides but not to imidazolinones. Another mutant gene carried two independently derived mutations, and produced an enzyme that with reduced sensitivity to the sulfonylureas as well as to the imidazolinone and triazolopyrimidines. A number of crops have been transformed with mutant ALS genes, with resulting high levels of resistance to both foliar and soil applications of sulfonylurea herbicides. Finally, SU resistant soybeans have been generated by seed mutagenesis followed by selection. The first lines to be isolated carried recessive mutations which conferred tolerance to these herbicides; subsequently isolated lines had dominant mutations which conferred increased herbicide resistance.

## TARGET CROPS

The following crops have been targeted by agrichemical and biotechnology companies for the development of herbicide-resistance:

1) sugarbeets
2) oilseed rape/Canola
3) cereals
4) rice
5) corn

6) soybeans
7) vegetables
8) cotton

Corn. The target herbicides in corn are phosphinotricin, glyphosate, sethoxydim, imidazolinones, and sulfonylureas; however, the lack of reliable corn transformation systems will be a short-term barrier to these development efforts. It is reasonable to forecast varieties that are resistant to one or more of these herbicides will be in the marketplace by the late 1990's. It is expected that Pioneer and American Cyanamid will jointly introduce imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} herbicide resistant hybrids to several regions of the Corn Belt in 1992.

Tobacco. Tobacco is used as a model system for plant transformation and as a result has been transformed with many herbicide-resistance genes, including those conveying resistance to the previously listed herbicides. Cell culture selection has also been used to develop sulfonylurea-resistant tobacco. Whether any of these resistant varieties will be commercialized in the United States is problematical because of the limited revenue opportunities and the public health issues associated with tobacco produce. Assuming favorable business decision, herbicide-resistant varieties could be introduced during the early to mid 1990's.

Tomato, Potato and Vegetables. Like tobacco, tomatoes, potatoes, and some vegetable crops have been transformed with several different herbicide-resistance genes, primarily because of the ease of using the *Agrobacterium* transformation system. It is uncertain if any herbicide-resistant varieties will be released in the near term because of limited revenue opportunities. However, it is known that several university and industry laboratories are planning to transform vegetable crops using the Arabidopsis ALS herbicide-resistance gene.

Oilseed Rape. Several companies are developing herbicide-resistant canola in Canada and oilseed rape in Europe. DuPont, American Cyanamid, Hoechst, PGS, Calgene, and Monsanto are all actively pursuing the commercialization of herbicide-resistant varieties. Initial sales of these varieties are expected in the mid 1990's.

Soybeans. As was previously mentioned, DuPont has used seed mutagenesis to develop a soybean line resistant to sulfonylurea herbicides. Backcross conversion programs have been initiated with elite North American germplasm and a commercial launch is expected in the mid 1990's. Monsanto is also developing glyphosate resistant soybean varieties produced by transformation with resistance genes. Plans have been announced for field trials in the U.S. during 1989. Commercial launches of glyphosate resistant soybeans are expected during the mid-to-late 1990's.

Cotton. DuPont, Calgene, and Monsanto are actively engaged in the research and development of herbicide-resistant cotton. Inspite of concerted efforts by these companies, significant technical hurdles have slowed the introduction of resistant varieties. Currently, only Coker varieties 312 and 315 have been routinely transformed and regenerated. Efforts with other varieties have been unsuccessful to date. Consequently, the slow backcross conversion method must be used to transfer herbicide-resistance into other varieties. Commercial introductions of herbicide-resistant cotton to several herbicides including sulfonylureas, glyphosate, and bromoxynil are expected during the mid 1990's.

Cereals - Wheat, Barley, and Rice. Primarily because of the inability to transform wheat and barley using current systems, little progress has been made in cereal herbicide-resistance research. However, it is expected that the particle gun will be used to attempt transformation of cool season cereals in the near future. Commercial introduction of herbicide-resistant cereal varieties are not expected until the late 1990's.

Japanese companies have been active in the development of herbicide-resistant rice. Commercial introduction of herbicide-resistant rice is not expected until the mid to late 1990's.

Sugarbeets. DuPont and Hilleshoeg, a European seed company, have combined resources for the development of sulfonylurea-resistant sugarbeets. In addition, others are developing sugarbeets that are resistant to glyphosate and PPT. However, commercial introduction of resistant varieties is not expected until the mid to late 1990's because of the crop's complex polyploid genetics.

## CHALLENGES FOR CROP HERBICIDE-RESISTANCE

Several challenges face us in the development and commercialization of herbicide-resistant crops. Incorporation of this technology into existing weed control strategies is the first challenge. It would be a mistake to conclude that this technology alone will dramatically change the way in which weed control is currently practiced. Reliance upon a few herbicides and herbicide-resistant varieties will limit options for weed control and will perhaps accelerate the development of herbicide-resistant weeds. Neither of these outcomes is desirable. A more pragmatic view advocates developing cultural systems with herbicide-resistant crops that augment and increase the flexibility of existing weed control strategies.

Potential new options for weed control strategies resulting from herbicide-resistant crops were previously discussed. A second challenge will be to define the marketplace benefits of these new weed control options and determine whether or not they are competitive with traditional methods in terms of reliability, environmental safety, and cost. Weed scientists and agronomists have a pivotal role to play in addressing these first two challenges. Additional research is needed, and we encourage the society to become actively involved when sufficient seed supplies of herbicide-resistant varieties become available.

A third challenge will be to develop a database on the effects of herbicide-resistance genes on agronomic performance. To a large degree, seed companies and plant breeders will determine if this technology has a major or minor impact on total crop acreage, based upon herbicide-resistance gene interactions with yield, crop quality, and other agronomic traits. It is expected that these genes will be extensively evaluated in numerous genetic backgrounds to screen for potentially deleterious pleiotropic effects before any varieties are released.

A fourth challenge is to overcome the technical difficulties which prevent genetic transformation of major American crops. Corn and soybeans planted acreage represents more than 50% of the herbicide-treated land in the United States. However, only recently has progress been made in the transformation of soybeans, and reproducible methods for corn transformation have not yet been achieved. Developing reliable gene transfer technology for these crops and others, and improving the efficiency of the procedures so many varieties can be transformed in a short period of time will be necessary for herbicide-resistance to become widely available. Without the advantages of genetic transformation, the relatively slow processes of cell culture selection and backcross conversion would limit the crops which have herbicide-resistant traits, and as a consequence the introduction of commercial varieties would proceed slowly.

# KEY ISSUES FOR CROP HERBICIDE-RESISTANCE

It is appropriate for us now to turn our attention to some of the public policy issues that surround the development and commercialization of herbicide-resistant crops. Environmental release, or the growing of transgenic, herbicide-resistant plants in the field, continues to be a concern of the USDA Animal, Plant, Health, and Inspection Service (APHIS), and of similar agencies in other countries. Primary reasons for the regulation of field experiments are concerns that the crop will become a weedy pest in succeeding seasons, that lateral gene transfer to weedy relatives will occur and that plants containing *Agrobacterium*-based DNA vectors could be plant pests. A recent symposium sponsored by the Boyce Thompson Institute for Plant Research on such regulatory considerations for genetically engineered plants concluded there were no significant risks within the United States posed by the release of herbicide resistant crops. However, some concern was expressed about gene transfer to weedy relatives from herbicide resistant sorghum, oats, sunflower, clovers, and oilseed rape. Such concerns would be heightened if commercial introductions were being contemplated for centers of origin because of the likelihood of endemic weedy relatives. Most crops grown in the United States do not have centers of origin in North America thus reducing concern for environmental release. Clearly, additional information is needed to evaluate further the risks and benefits of environmental release for some herbicide-resistant crops. Participants in the symposium recommended that maps of crop weedy relatives be prepared and that ecological and genetic studies of these species be undertaken.

Environmental release permits are not required for the field testing of herbicide-resistant crops developed using the methods of cell culture selection or seed mutagenesis. However, the USDA-APHIS requires the submission of an extensive data package in support of field testing herbicide-resistant plants if genetic transformation methods were used to produce them. Thus, it is the process, and not the characteristics of the product, that triggers the regulatory review. To date most permits have been issued for test sites of less than one-tenth acre in size. It is anticipated that submissions requesting 1- to 2-acre test sites for transgenic plants will soon be requested and granted by APHIS, but it is not known what additional information will be required to begin testing on a large acreage, pre-commercial scale.

Attention from public interest and biotechnology industry groups has already been focused on food safety and nutrition issues for products produced from transgenic plants. The Food and Drug Administration (FDA) is empowered to review the safety and nutrition of all food products and approve them for sale. However, guidelines and procedures for reviewing the safety of food products produced from transgenic plants have not been developed. Independent efforts by the FDA and the International Food Biotechnology Council, a biotechnology industry organization, have been recently undertaken to develop a regulatory framework for the review of transgenic food products. These regulatory guidelines would describe categories of risk and define tests and procedures for evaluating food safety. Release of drafts for public comment and review is expected within 18 to 24 months. However, it is anticipated that the regulatory review procedure may slow down timelines for the commercialization of transgenic herbicide-resistant crops.

Market positioning by chemical and seed companies developing herbicide-resistant crops is another issue which has created uncertainty about the future impact of this technology. In general, herbicide manufacturers have concluded that non-exclusive business arrangements with many seed companies are the best marketing strategy to exploit herbicide-resistant crops. However, most seed companies view herbicide resistance as a trait which will help them to differentiate their varieties and hybrids from those of competing seed companies, and would prefer some type of limited, exclusive business arrangement. Another unanswered question is how seed companies that are also subsidiaries of crop protection chemical companies will position themselves in the marketplace. Since a label will be required for new uses of a herbicide on resistant crops, it is expected that most herbicide-resistance genes will be developed on a non-exclusive basis so that crop protection chemical companies can recoup significant label acquisition costs. Thus herbicide-resistance technology should be widely available provided that the other challenges are successfully addressed.

Concerns for weed resistance should not be any greater for herbicide-resistant crops than for non-resistant crops, since the technology in its simplest concept enables just another form of crop selectivity. However, if improved selectivity is used as a means to avoid crop injury in succeeding seasons because of the use of long residual herbicides, or is used as a means to continually use a single herbicide, then the resulting sustained selection pressure on weed populations will accelerate the development of weed resistance.

Among the herbicides targeted for crop herbicide-resistance, the sulfonylureas and the imidazolinones are more likely to cause the development of weed resistance because of the plasticity of the target ALS enzyme and because of the physico-chemical properties of some of these compounds. However, recent experience with several other herbicide classes strongly suggests that the intensity of the selection pressure on weed populations is the most important factor in the development of weed resistance. Crop resistance to these herbicides, when incorporated into the integrated weed control strategy, should increase options for managing weed resistance.

As was previously mentioned, herbicide resistance genes may be routinely used as selection marketers to identify cells or plants containing recombinant DNA coding for other added-value traits. Whether or not these herbicide-resistant selection market genes are also exploited to increase weed control options remains an open question.

## SUMMARY

The development of herbicide-resistance is technically feasible in most agronomic crops using the techniques of biotechnology and/or seed mutagenesis. Because of the rapid pace of new developments in this technology, it is expected that herbicide-resistant varieties for several different crops will be introduced into the marketplace during the 1990's. Herbicide-resistant hybrid corn may be available to farmers as soon as 1992. With the application of this technology to major and minor acreage crops grown in the western United States, three key roles emerge for weed scientists.

1) Research leading to the development of recommendations for new weed control strategies incorporating the increased flexibility and multiple options offered by herbicide-resistant varieties;

2) Active participation in the development of public policy guidelines for the environmental release of herbicide-resistant crops; and

3) Providing local and regional forums for the continuing dialogue on both the risks associated with the use of herbicide-resistant crops such as the potential for the accelerated development of weed

resistance, and the benefits, such as the greatly improved reliability and reduced expense of chemical weed control.

The development of herbicide-resistance technology should create a marked change in weed control options in some crops, and has the potential to incrementally improve herbicide performance in all crops because of the increased selectivity and broader weed control spectra that it makes possible.

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## EFFECTS OF FALL APPLICATIONS OF GLYPHOSATE AND SC-0224 ON CORN

Larry S. Jeffery[1]

Abstract. Glyphosate {*N*-(phosphonomethyl)glycine} and SC-0224 were applied overtop of maturing corn in the fall of 1987 and 1988. Each herbicide was applied at rates of 1.67 and 2.24 kg/ha when moisture in the corn seed was approximately 45, 40, 33, and 20%. Neither herbicide affected yield or seed weight. Herbicides applied at or above 33% seed moisture reduced progeny seedling emergence, vigor, and weight. Abnormal progeny seedlings characterized by abnormal foliage pigmentation occurred. When the herbicides were applied at the 2.24 kg/ha rate, a higher ratio of abnormal seedlings occurred than when the 1.67 kg/ha rate was applied. This indicates that either more damage occurred prior to harvest or more herbicide moves into the seed and affects subsequent seedling growth. The degree of injury was approximately equal for the two herbicides. The progeny were not affected if the herbicides were applied after the black layer at the base of the seed had formed.

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# HERBICIDES AND ADJUVANTS FOR SOD CONTROL PRIOR TO NO-TILL SEEDING OF ALFALFA

D.W. Koch[1], T.D. Whitson, M.A. Ferrell, and K.J. Nix[2]

Abstract. The development of the no-till concept, which saves time, labor, and cost of reseeding would encourage more timely renovation of irrigated meadows. methyl)glycine} at three rates, A study was conducted to determine efficacy of glyphosate {*N*-(phosphono-glyphosate-2,4-D {(2,4 dichlorophenoxy)acetic acid} and glyphosate-adjuvant mixtures, applied in May and July, on control of a diverse but typical meadow sod, prior to no-till seeding of alfalfa (*Medicago sativa* L.). Ammonium sulfate (AMS) and surfactant[2] improved control of alfalfa, grasses, and dandelion (*Taraxacum officinale* Weber) at the lowest rate (0.75 lb ae/a) of glyphosate. The level of control, however, was less than from glyphosate at 1.50 lb ae/a. There was no additive effect of AMS and surfactant. A 2,4-D glyphosate treatment in July improved alfalfa, but not dandelion control, compared to the same rate of glyphosate without 2,4-D. Alfalfa seedling density and seedling height following no-till seeding was highly correlated with grass control.

## Introduction

Alfalfa is potentially the most productive forage on many irrigated meadows in the western U.S., yet meadows are infrequently renovated. Glyphosate is useful for control of competition from a diverse sod and has potential for eliminating the need for tillage prior to establishing improved forage species on these meadows. Nonionic surfactant and AMS have been suggested as enhancers of glyphosate activity, particularly with low-volume applications (2,3,4,5,6). Low volume was shown to be an advantage when using high-calcium water (1).

The objective of this study was to determine the effectiveness of glyphosate at varying rates and glyphosate in mixtures with 2,4-D, surfactant, and AMS to control a diverse sod and to aid alfalfa seedling establishment.

## Materials and Methods

The meadow sod chosen for study consisted, in order of predominance, of smooth bromegrass (*Bromus inermis* Leyss.), Kentucky bluegrass (*Poa pratensis* L.), dandelion and alfalfa (0.15 plants/ft$^2$). The experiment was a randomized complete block with four replications conducted on an irrigated meadow with sandy clay loam soil (53% sand, 19% silt, and 28% clay), a pH of 7.2 and organic matter content of 4.1%. Plot size was 10 by 27 ft. Glyphosate at 0.75, 1.50, and 2.25 lb ae/a was applied singly and in combination with spray-grade AMS at 2% w/v, non-ionic surfactant (L1700) at 0.5% v/v, or both AMS and surfactant at the same rates on May 16, 1988. Treatments were applied broadcast with a $CO_2$ pressurized knapsack sprayer delivering 10 gpa at 35 psi. The grass and alfalfa were an average 6 inches tall and dandelions in the initial bloom stage. Conditions were: air temperature, 70 F; soil temperature at 2 and 4 inches, 67 F and 60 F; wind 5-10 mph; relative humidity, 45%; and partly cloudy.

A second study with the same experimental design and replication on the same field included additional treatments of glyphosate at 0.75, 1.13, and 1.50 lb

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[2]L1700, Loveland Industries, Loveland, CO

ae/a tankmixed with 2,4-D LVE at 1.0 lb ae/a. Treatments were applied on July 18, 1988 following removal of a hay crop. Grass regrowth was 3 inches, alfalfa 6 inches, and dandelions 3 inches. Conditions were: air temperature 78 F; soil temperature at 2 and 4 inches, 65 F and 62 F; wind, 0-2 mph; and relative humidity, 35%; and clear sky. 'Apollo II' alfalfa was seeded on 10 lb/a on June 4, following the May treatments and on August 9, following the July treatments. A no-till drill equipped with fluted coulters and double disk openers spaced 8 inches was used.

Visual weed control evaluations were made on July 18 and on September 8 for the May and July treatments, respectively. At the same time, alfalfa seedling densities were determined on three randomly selected 1-ft sections of row per plot.

## Results and Discussion

With May treatment of sod, control of all components (alfalfa, grass, and dandelion) was improved with an increase in glyphosate rate from 0.75 to 1.50 lb ae/a (Table 1). There was no further improvement in control with the highest

Table 1. Effects of treatments applied May 16, 1988 on control of sod and no-till alfala seedling establishment

| Treatment | Rate | Control[1] | | | Alfalfa seedling density[1] | Alfalfa seedling height[1] |
|---|---|---|---|---|---|---|
| | | Alfalfa | Grass | Dandelion | | |
| | (lb ae/a) | (%) | | | (no./ft$^2$) | (in) |
| glyphosate | 0.75 | 25 | 33 | 38 | 10 | 3.0 |
| glyphosate | 1.50 | 59 | 81 | 75 | 24 | 4.0 |
| glyphosate | 2.25 | 63 | 91 | 85 | 42 | 7.5 |
| glyphosate + AMS | 0.75 | 43 | 62 | 46 | 17 | 4.0 |
| glyphosate + AMS | 1.50 | 51 | 84 | 74 | 33 | 5.7 |
| glyphosate + AMS | 2.25 | 49 | 82 | 71 | 26 | 6.0 |
| glyphosate + L1700 | 0.75 | 40 | 63 | 60 | 16 | 2.8 |
| glyphosate + L1700 | 1.50 | 53 | 84 | 80 | 23 | 3.3 |
| glyphosate + L1700 | 2.25 | 54 | 89 | 80 | 30 | 6.7 |
| glyphosate + AMS + L1700 | 0.75 | 44 | 74 | 45 | 27 | 6.7 |
| glyphosate + AMS + L1700 | 1.50 | 55 | 84 | 71 | 55 | 8.7 |
| glyphosate + AMS + L1700 | 2.25 | 70 | 92 | 81 | 68 | 9.7 |
| check | | 0 | 0 | 0 | 9 | 1.2 |
| LSD.05 | | 22 | 24 | 25 | 15 | 1.5 |

[1]Ratings and alfalfa seedling evaluations were on July 13, 1988.
[2]AMS was applied at 2% w/v and L1700 at 0.5% v/v.

rate of glyphosate. Control of all sod components was improved with AMS, but only with the 0.75 lb ae/a rate of glyphosate. The surfactant improved control of all sod components only at the lowest rate of glyphosate. The control with the tank mix of glyphosate at 0.75 lb ae/a and AMS or surfactant was intermediate to that of glyphosate at 0.75 and 1.50 lb ae/a. There appeared to be no additive effect of AMS and surfactant. Alfalfa seedling density and seedling vigor were directly related to degree of sod control. Stands of alfalfa were considered adequate with all but the lowest rates of glyphosate.

The same May treatments applied in July provided similar sod control and alfalfa establishment (Table 2). Addition of 2,4-D in tank mixes with 0.75 and

Table 2. Effects of Treatments applied July 18, 1988 on sod control and no-till alfalfa seedling establishment.

| Treatment | Rate | Control[1] | | | Alfalfa seedling density[1] |
|---|---|---|---|---|---|
| | | Alfalfa | Grass | Dandelion | |
| | (lb ae/a) | | (%) | | (no./ft$^2$) |
| glyphosate | 0.75 | 40 | 50 | 50 | 13 |
| glyphosate | 1.50 | 68 | 77 | 79 | 21 |
| glyphosate | 2.25 | 90 | 92 | 86 | 38 |
| glyphosate + AMS[2] | 0.75 | 56 | 67 | 65 | 20 |
| glyphosate + AMS | 1.50 | 56 | 83 | 76 | 25 |
| glyphosate + AMS | 2.25 | 72 | 88 | 83 | 27 |
| glyphosate + L1700[2] | 0.75 | 36 | 60 | 50 | 18 |
| glyphosate + L1700 | 1.50 | 64 | 74 | 70 | 26 |
| glyphosate + L1700 | 2.25 | 95 | 94 | 89 | 36 |
| glyphosate + AMS + L1700 | 0.75 | 45 | 64 | 56 | 22 |
| glyphosate + AMS + L1700 | 1.50 | 81 | 85 | 80 | 44 |
| glyphosate + AMS + L1700 | 2.25 | 72 | 86 | 83 | 49 |
| glyphosate + 2,4- LVE | 0.75 + 1.00 | 78 | 48 | 34 | 17 |
| glyphosate + 2,4-D LVE | 1.13 + 1.00 | 86 | 52 | 46 | 24 |
| glyphosate + 2,4-D LVE | 1.50 + 1.00 | 93 | 65 | 52 | 31 |
| check | | 0 | 0 | 0 | 7 |
| LSD.05 | | 17 | 21 | 19 | 12 |

[1]Ratings and alfalfa stand density evaluations were on September 8, 1988.
[2]AMS was applied at 2% w/v and L1700 at 0.5% v/v.

1.13 lb ae/a of glyphosate improved alfalfa control over that from 0.75 lb ae/a of glyphosate, but decreased dandelion control somewhat. Alfalfa seedling density was similar with the tank mix of glyphosate and 2,4-D (1.13 and 1.00 lb ae/a) as with glyphosate at 1.50 lb ae/a. Over both application dates, alfalfa seedling density was directly related to control of all sod components, but most closely related to grass control ($r = 0.75$, $P<0.01$).

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# A LINE-SOURCE SPRINKLER IRRIGATION TECHNIQUE TO STUDY ALFALFA AND WEED INTERACTIONS

Emmanuel M. Pomela, John O. Evans, Steven A. Dewey, and R. John Hanks[1]

## Introduction

Alfalfa production in Utah is intensive requiring expensive inputs. Irrigation is practiced to improve yields and reduce economic losses that often occur in drought conditions in the state. However, irrigation creates an environment favorable for weed infestations (2, 7). Weeds proliferate because of abundant moisture and if not controlled may cause significant yield losses (6, 5).

The nature of crop and weed competition is species and density dependent (1, 8). Crop yields are negatively correlated with weed density. Due to phenotypic elasticity, most weeds are common to a particular crop (8). In the intermountain region weeds common to alfalfa may not be those reported elsewhere (7). Therefore the nature of competition can be assumed different.

This investigation is designed to elicit the nature of weed and irrigation interaction on alfalfa yields. The objectives of the study were to 1) investigate the influence of irrigation amount and weed density on alfalfa yield, and 2) investigate the influence of irrigation amount on weed species composition in alfalfa.

## Materials and Methods

A line-source sprinkler irrigation system was used to provide variable water treatments. Irrigation was applied on May 7 to October 25 at about two-week intervals. Water applied at each irrigation was measured with rain-gauges (Table 1). Soil water was monitored with a neutron probe.

Herbicides were applied on a non-weedy check block on 14 April, 1988. 2,4-DB [4-(2,4-dichlorophenoxy)butyric acid, dimethylamine salt] was applied at 0.84 $kg.ha^{-1}$ and hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4-(1*H*,3*H*)-dione] at 0.56 $kg.ha^{-1}$. Treatments were applied with a bicycle sprayer equipped with 8002 nozzles and calibrated to deliver 107.57 $l.ha^{-1}$ of spray solution at 241.5 kPa of pressure and a speed of 4.43 Km/hr.

Data collected were 1) weed numbers per species, 2) combined dry matter yield for all weeds, and 3) alfalfa dry matter yield. Weed density counts were done in June 7, July 17 and August 27. Alfalfa was harvested in June 7, July 17 and September 2. Weeds were separated from the alfalfa and both were oven-dried.

### DESCRIPTION OF A LINE-SOURCE SPRINKLER IRRIGATION SYSTEM

A line-source sprinkler irrigation system produces a water application pattern which is uniform along the length of the block (plot), but uniformly variable across the block (3). The line was equipped with 60 cm risers spaced at 6.6 m apart on a 7.63 cm diameter pipe. The "Rain-bird model 30H" sprinkler head was fitted with 4.8 mm range nozzles and 2.4 mm spreader nozzles.

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When sprinklers are operating at about 276 KPa, their overlapping rotations give six plots each 2.7 m long on each side of the line. The six plots on each side of the line are represented by water levels (WL) six (6), five (5), four (4), three (3), two (2), and one (1) away from the line. The WL6 plot is the wettest and WL1 the driest.

The plot design is a modified split-block (4). The design consisted of three blocks of alfalfa, weedy check (not seeded) block and a herbicide treated block.

## DATA TREATMENT

The data analysis was by the general linear model approach. Analysis compared alfalfa blocks alone, alfalfa blocks with the weedy check block; alfalfa, weedy check and herbicide treated blocks; and herbicide treatments alone. Each analysis included a total of thirty-six units (Table 2). Table 2 represents a mixed effects model with blocks random and all other variables fixed. The analysis assumed no interaction between either blocks or halves with irrigation levels.

Table 1. Irrigation water applied before each harvest date. Quantities expressed as averages of cm of water applied.

| Harvest date | Irrigation Applied | | | | | |
|---|---|---|---|---|---|---|
| | WL1 | WL2 | WL3 | WL4 | WL5 | WL6 |
| | mm | | | | | |
| June 7[1] | 4 | 24 | 54 | 84 | 108 | 154 |
| July 17[2] | 35 | 76 | 161 | 282 | 350 | 394 |
| Sept 2[3] | 16 | 58 | 130 | 225 | 232 | 267 |
| Total | 55 | 158 | 345 | 591 | 690 | 815 |

[1] Irrigation performed May 24 and 27
[2] Irrigation performed June 11, 20, 29, July 5 and 13
[3] Irrigation performed July 28, August 4, 18, and 27

Table 2. GLM anova table for each analysis combination.

| SOV | df | Expected Mean Squares[1] |
|---|---|---|
| Block (A) | 2 | s + bcnA |
| Half (B) | 1 | s + cnAB + AcnB |
| AB | 2 | s + cnAB |
| Irrigation level (C) | 5 | s + abnC |
| Error (s) | 25 | s |

[1]Output of Number Cruncher Statistical System.

## Results and Discussion

Kochia (*Kochia scoparia* (L) Schrad #KCHSC) and tansy mustard (*Descurainia pinnata* (Walt) Britt. #DESPI) were the prevalent weeds in the study. Weed density and weed yields were negatively correlated with irrigation level. Alfalfa yield was influenced by irrigation and weeds in low irrigation treatments, but only by irrigation in high irrigation treatments.

Alfalfa yields fluctuated throughout the season in response to irrigation and weed competition (Figure 1). At low irrigation level weed competition exacerbated an already poor alfalfa response to inadequate soil moisture. In herbicide treated plots, alfalfa yields were comparatively higher in low irrigation treatments but not different from the non-treated plots at high irrigation treatments (Figure 2). This indicates some weed competition in untreated low irrigation treatments.

Alfalfa yields, when averaged across irrigation treatments, were 2.3 $t.ha^{-1}$ in June and September and 4.0 $t.ha^{-1}$ in July. The yield fluctuation reflects change in weed competition. In low irrigation treatments weeds grew well and reduced alfalfa yields. In high irrigation treatments alfalfa grew well and reduced weed invasion and yields (Figure 3). Weed species composition and density fluctuated throughout the season (Figure 4). In June total weed numbers were high and tansy mustard was the dominant weed. By July, their numbers dropped significantly. This drop is reflected by a sharp increase in alfalfa yield. By August, tansy mustard was absent in the composition but kochia captured the space vacated. Weed yields reflected the fluctuations in weed numbers.

## Summary

: Both kochia and tansy mustard were dominant in the low moisture treatments and significantly reduced alfalfa yields.
: Weed numbers and composition fluctuated throughout the season.
: Kochia became the prevalent weed as the season progressed.
: The presence of weeds was negatively correlated with soil moisture whereas alfalfa yield was positively correlated with soil moisture.
: Since species composition and density fluctuated throughout the season, the nature of weed competition could be expected to change accordingly.

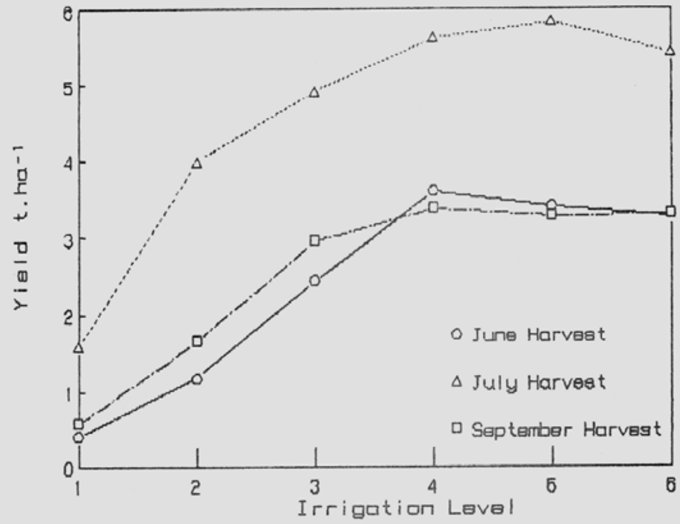


Figure 1. Alfalfa yield in three harvest periods where there was weed competition.

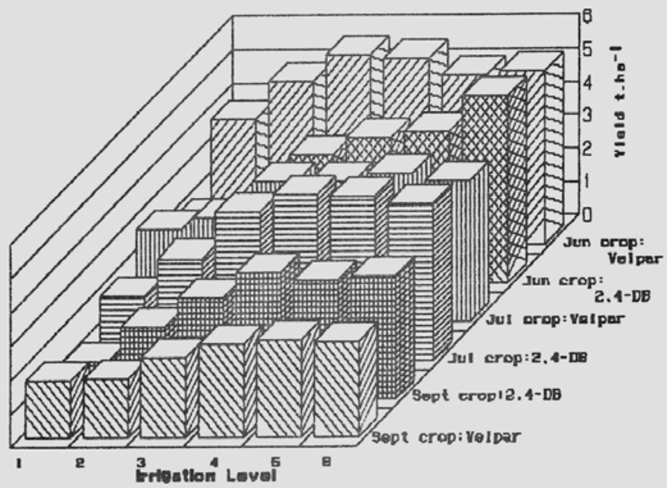


Figure 2. Alfalfa yield in three harvest periods where there was herbicide treatment

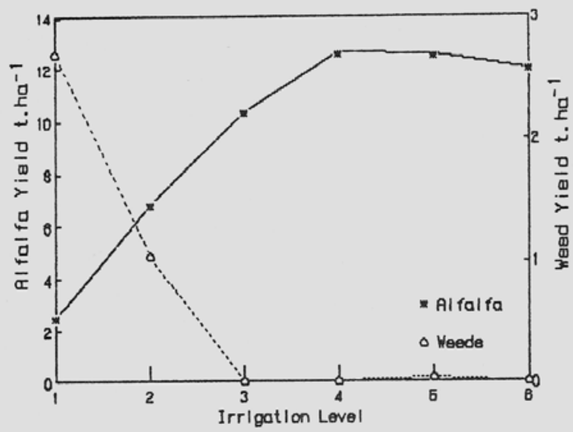


Figure 3. Total dry matter yield for alfalfa and weeds for the season

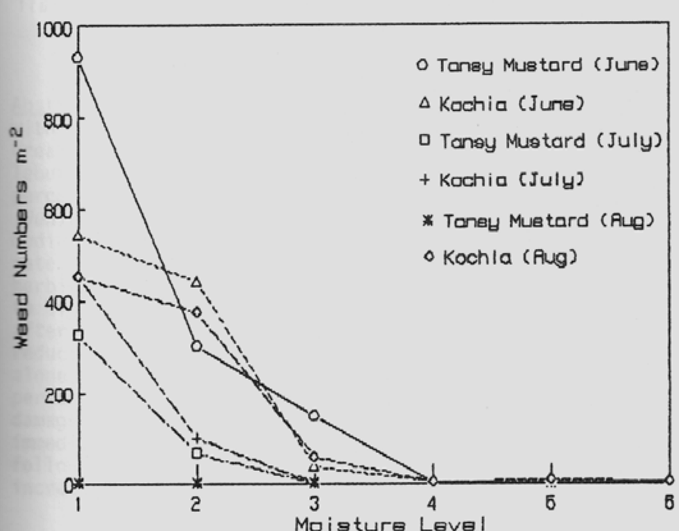


Figure 4. Weed species composition and density in alfalfa in three harvest periods

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# INHERITANCE OF SULFONYLUREA HERBICIDE RESISTANCE IN PRICKLY LETTUCE (LACTUCA SERRIOLA L.)

Carol A. Mallory, Michael J. Dial, and Donald C. Thill[1]

Abstract. A sulfonylurea herbicide-resistant (R) prickly lettuce (Lactuca serriola L., LACSE) biotype was identified in a natural population. In field and greenhouse studies, the biotype showed cross resistance to eight sulfonylurea herbicides. The resistance trait was crossed into a sulfonylurea herbicide-susceptible prickly lettuce biotype (S) and into domestic lettuce (Lactuca sativa L.). $F_1$ seedlings were treated with metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-1)amino]carbonyl]amino]sulfonyl]benzoic acid}. The surviving seedlings were allowed to self and the seeds collected. The $F_2$ seedlings were treated with metsulfuron and scored as susceptible, intermediate, or resistant in their response to the treatment. The best fit for Chi Square Analysis of the $F_2$ generation was a 1:2:1 ratio indicating the trait is controlled by a single nuclear gene with incomplete dominance.

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# ECONOMIC COMPARISON OF TEBUTHIURON AND FIRE ON PINYON-JUNIPER WOODLANDS IN SOUTHCENTRAL NEW MEXICO

Roger D. Wittie, Kirk C. McDaniel, and Allen Torell[1]

Abstract. Spring burning of pinyon-oneseed juniper woodlands previously treated with tebuthiuron {*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N*,*N*-dimethyl-urea)} was evaluated to determine treatment effects and economic returns. Tebuthiuron resulted in pinyon pine (*Pinus edulis*) mortality of 50, 58 and 78 percent at rates of 0.84, 1.26 and 1.40 kg ai/ha, respectively. Oneseed juniper (*Juniperus monosperma*) was relatively tolerant to tebuthiuron at low (10%) and medium rates (43%); however, mortality was similar to pinyon at the high (74%) rate. Few pinyon or oneseed juniper in the understory were removed by the herbicide treatments. Herbaceous production was 615,775, 1000 kg/ha from low to high herbicide rates compared to 428 kg/ha on untreated woodland three years after herbicide application when burning began. Spring burning (March 1987) reduced pinyon canopy cover by approximately 20% beyond tebuthiuron treatment alone, but trees damaged were generally small (less than 1.2 m in ht.). Sixty percent of the remaining oneseed juniper in tebuthiuron-treated areas were damaged by fire. Seedling density of pinyon and oneseed juniper were eliminated immediately after burning; however, new seedlings emerged within the first year following fire to preburning density levels. The tebuthiuron-fire treatment increased herbage production above tebuthiuron treatments alone by 13, 19 and

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38% in low, medium, and high herbicide rates respectively. Present networth treatments showed rates of 0.84 and 1.26 kg/ha did not generate sufficient forage to offset treatment cost when amortized over a 20-year horizon. Forage resulting from the 1.40 kg/ha tebuthiuron rate produced an annual net return of $0.47 per acre. Tebuthiuron fire combination was marginally profitable and provided an economic return in excess of herbicide or fire alone.

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## EFFICACY OF DICAMBA TANKMIXED WITH SULFONYL-UREAS FOR BROADLEAF WEED CONTROL IN SMALL GRAIN

Jeff Tichola[1]

Abstract. Field trials were conducted across the major wheat growing areas of the United States comparing broadleaf weed control with sulfonyl-ureas alone and tankmixes with dicamba {3,6-dichloro-2-methoxybenzoic acid}. The data was collected by university researchers and Sandoz Product Development Field Representatives over a multiple year period. A wide variety of broadleaf weed species show increased control when dicamba was tankmixed with sulfonyl-ureas compared to sulfonyl-ureas used alone. The addition of dicamba to the sulfonyl-ureas enhanced broadleaf weed control resulting in more complete kill. Bedstraw (*Galium spp.* L.), common chickweed (*Stellaria media* L.), common lambsquarters (*Chenopodium album* L.), Russian thistle (*Salola kali* L.), and wild buckwheat (*Polygonum convolvulus* L.) were some of the species showing a marked advantage of a dicamba and chlorsulfuron tankmix compared to chlorsulfuron alone. Wild buckwheat and common sunflower (*Helianthus annuus* L.) control was also improved when dicamba was tankmixed with metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid}, DPX-M6316 {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid}, DPX-L5300 {methyl 2-[[[[*N*-(4-methoxy-6-methyl-1,3-5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoate}, and DPX-M6316 + DP-L5300.

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# LOW RATES OF METRIBUZIN IN COMBINATION WITH OTHER HERBICIDES FOR BROADLEAF WEED CONTROL IN WINTER WHEAT

Veldon Sorenson[1]

Abstract. Metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one} use in winter wheat has been limited by timing and crop injury. The later timing, required to decrease crop injury, has resulted in larger weeds that are more difficult to control.

Tests initiated by Mobay Field Research have shown that early applications of metribuzin at low rates (0.0938 to 0.1406 lb ai/a or 1.5 to 2.25 oz ai/a) are safe to winter wheat and give excellent control of selected weed species. In over 56 trials with low rates (1-4 oz ai/a), the overall crop injury averaged less than 2% when applied to winter wheat at the 2-4 leaf stage. Crop thinning was negligible.

Weed control with low metribuzin rates (1-4 oz ai/a) was excellent for prickly lettuce (LACSE - *Lactuca serriola* L.), henbit (LAMAM - *Lamium amplexicaule* L.), common chickweed (STEME - *Stellaria media* (L.) Vill.), fiddleneck tarweed (AMSLY - *Amsinckia lycopsoides* (Lehm.) Lehm.), blue mustard (COBTE - *Chorispora tenella* (Pallas) DC.), and field pennycress (THLAR - *Thlaspi arvense* L.). Weed control decreased as crop stage increased beyond the 4th leaf stage and increased rates were necessary to maintain acceptable control. Mixes with other broadleaf herbicides offered more consistent and broad spectrum weed control, beyond the above species and timing.

Control of LAMAM, STEME and LACSE was consistently increased with metribuzin plus a hormone-type herbicide. Metribuzin plus sulfonylurea tank-mixes, allowed the use of lower rates and increased the consistency of control on the above listed weeds. Weed resistance will be minimized with this mixture, especially on LACSE and KCHSC. The most consistent and broad spectrum weed control of any treatment, were the three-way tankmixes of metribuzin, hormone and sulfonylurea herbicides.

Mobay recommended in November 1987, a low rate of metribuzin use in winter wheat (1.5 to 2.25 oz ai/a) be applied once the crop reached the 2-leaf stage. Metribuzin may be tankmixed with common phenoxy or hormone herbicides as well as the new sulfonylurea products in Oregon under Section 2(ee). An EPA registration is now pending for this use in Oregon, Washington, Montana, Utah, Nevada and Idaho.

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# THE USE OF SUBCLOVER MULCHES IN VEGETABLE PRODUCTION SYSTEMS

W.T. Lanini, D.R. Pittenger, W.L. Graves, and F. Munoz[1]

Abstract. A study was conducted to evaluate the use of subclover living mulches for managing weeds and insects prior to and during vegetable production. Study sites were located at Riverside and Davis, California. Subclover var. Enfield and a mixture of two subclovers, var. Geraldton and Dalkieth, were compared to cultivation, herbicide treated or untreated check plots for weed suppression,

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soil fertility, vegetable yield and quality, and insect damage. Subclover mulches reduced weed biomass compared to untreated controls, but were less effective than cultivated or herbicide treated plots. Soil fertility varied by depth but not by treatment during the two-year study period. Sweet corn (var. Jubilee) was used in both locations in 1987 and 1988. Leaf tissue calcium on subclover and untreated control plots was lower than other treatments. Vegetative growth and yield were not different between treatments in the first year, but were lower on subclover and untreated plots in the second year compared to herbicide treated or cultivated plots. Seed maggots and earworms were present in low numbers at the Riverside site, although treatment differences were not evident with either insect.

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## POTENTIAL INJURY TO ROTATIONAL CROPS FOLLOWING AN APPLICATION OF IMAZETHAPYR IN ALFALFA

J.P. Chernicky, B. Tickes, and E.S. Heathman[1]

Abstract. Research conducted with imazethapyr {(±)-2-[4,5-dihyrro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl}-5-ethyl-3-pryidinecarboxylic acid} in alfalfa (*Medicago sativa*) over a three-year period in Yuma, AZ has shown this herbicide to be effective on winter annual weeds with little or no injury to alfalfa. Before this herbicide can be registered for use in Arizona, questions on soil persistence of imazethapyr must be answered since a variety of summer and winter crops are normally grown in rotation with alfalfa. A 300 ft long by 180 ft alfalfa field was split in half and treated with imazethapyr at 0.125 and 0.25 kg/ha on December 30, 1986. The field was then divided into 5 sections. The first section received no herbicide treatment while the second section received a single application (December 30, 1986) of imazethapyr. The remaining three sections received an additional application of imazethapyr on November 6, 1987. Winter and summer crops planted included: lettuce (*Lactuca sativa*), cauliflower (*Brassica oleracea* L. (Botrytis Group)), broccoli (*Brassica oleracea* (Italica Group)); summer crops; cotton (*Gossypium hirsutum*), cantaloupe (*Cucumis melo*) and sorghum (*Sorghum bicolor*). The first and second (treated once) sections of alfalfa began a summer-winter crop rotation on April 16, 1987 through April 1989, the third section (treated twice) was rotated out of alfalfa into a winter-summer rotation on December 29, 1987 through April 1989; the fourth section was rotated out of alfalfa on April 27, 1988 into a summer-winter rotation through April 1989; the fifth section was rotated out of alfalfa on November 9, 1988 and will be terminated in April of 1989. Crop response to imazethapyr was measured by stand counts per foot row, % crop stunt, and the dry weight of 25 plants harvested within 90 days after planting. Winter and summer crop response to imazethapyr to date has been variable among crops and the rotation schedule.

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# AN ELECTRIC SHOCK COLLAR SYSTEM TO CONTAIN GRAZING ANIMALS

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Abstract. Many range weed species occur in patches. If uncontrolled the patches become larger. We are attempting to control weed patches with grazing goats. We have previously shown that goats can be contained to small areas with the Invisible Fence System, a dog containment apparatus which utilizes electric shock collars. Our objective is to modify the Invisible Fence so it can be used economically to control weeds by grazing animals.

The Invisible Fence transmitter sends current from a 12-volt battery through a single strand of 14-gauge wire which encircles a small containment area. We have designed and constructed a new transmitter costing $45 which will effectively surround a 35-acre area. An implement was made to bury wire using a hardened steel knife originally designed to apply anhydrous ammonia. Wire can be permanently buried 12.5 cm deep around weed patches at a speed of 5 mph in hard ground. The Invisible Fence collar system is presently undergoing modification in an attempt to devise inexpensive, durable shock collars.

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# THE MONTANA STATE UNIVERSITY RHIZOTRON: A VALUABLE AID IN TEACHING WEED BIOLOGY

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Abstract. Underground root observation laboratories or "rhizotrons" have been used since the early 1900's to examine root, rhizome, and stolen growth of plants growing under natural field conditions. Rhizotrons are valuable teaching aids however, there are fewer than 20 in the United States. We recently constructed a relatively low-cost rhizotron for teaching purposes at the Post Research Farm near Bozeman, MT. The MSU Rhizotron consists of ten 1.5 by 1.2 by 2.4 m chambers and two 1.5 by 1.2 by 1.2 m chambers which have one side exposed to a 1.8 by 2.4 m deep trench. The boards on the exposed wall are easily removed for inspection of underground plant parts. The common perennial weeds of Montana, Canada thistle (*Cirsium arvense* L. Scop.), leafy spurge (*Euphorbia esula* L.), field bindweed (*Convolvulus arvensis* L.), spotted knapweed (*Centaurea maculosa* Lam), Russian knapweed (*Centaurea repens* L.), and quackgrass (*Agropyron repens* L. Beauv.) were each planted in two chambers. The MSU Rhizotron is constructed entirely of wolmanized lumber and redwood which have a life-expectancy of 40 years so the prorated cost of the facility is approximately $100 per year. This low-cost investment has proven to be a valuable teaching aid for students in weed science classes, farmers, and pesticide dealers.

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# DETERMINING HERBICIDE DAMAGE TO LIGHT HARVESTING APPARATUS OF RADISHES (*Raphanus sativus*)

S.R. Eskelsen, G.D. Crabtree, R.B. Boone, and L.S. Daley[1]

Abstract. *In vivo* spectral analysis of radish leaves sought effects on radish light harvesting apparatus (LH) of the herbicides: clomazone (FMC57020; [2-(2-chlorophenyl) methyl-4,4 dimethyl-3-isoxalidinone), diuron (DCMU; [3-(3,4-dichlorophenyl)-1,1- dimethylurea)] and amitrol (*H*-1,2,4-triazole-3-amine). All herbicides used cause visual symptoms of chlorosis or damage chloroplast membranes and thus disrupt LH structure. The spectra were obtained at early stages of the chlorotic effect. The spectra was analyzed by the fourth derivative technique. The frequency of occurrence of fourth derivative maxima was analyzed statistically. Statistical analysis of peak frequency showed multiple and complex changes occurred in LH spectra in response to herbicide treatment. Amitrol effects were readily apparent and are those described here. The most prominent effect of amitrol was the narrowing and apparent red shift of LH component *Cb 670*. Further analysis of *Cb 670* revealed fine structure consisting of at least three bands (*Cb 670a, Cb 670b and Cb 670c*). The effects of amitrol on this system resulted in the loss of two fine structure bands (*Cb 670a, Cb 670c*). The result is that the remaining fine structure band (*Cb 670b*) dominates the spectral envelope of the parent band (*Cb 670*) causing parent band narrowing and red shift. Since plant response to herbicides reveals the presence of these chemicals, this effect may be useful in herbicide detection.

## Introduction

During investigations of the effects of herbicide damage on radish (*Raphanus sativus*) leaf color and chlorophyll (Chl) content, it was observed that radish leaves yielded excellent *in vivo* visible wavelength spectra. Fourth derivative analysis of these spectra gave detailed information on the components of the photosynthetic light harvesting apparatus (LH).

With the increasingly available microprocessor equipped spectrophotometers of the 1980's, room temperature intact tissue visible (VIZ) spectroscopy (spec) began to yield more information about photosynthetic structures (Brown *et al.*, 1982; Klockare and Virgin, 1983; Terashima and Saeki, 1983; Lee and Graham, 1986; Duke *et al.*, 1985; Daley, 1986). To investigate relationships of Chl content and structures *in vivo* VIZ spec can be used (Daley *et al.*, 1986, 1987 ad, 1988). Data processing advances have promoted resurgence of multicomponent analysis by spec (Brown, 1986). Plant leaf VIZ spec directly relates to LH function since leaves capture and use VIZ sunlight. Leaf VIZ spec has intense but overlapping absorbing moeties. Derivative (deriv) spec--the use of multiple-order derivatives--resolves the spectral bands of these moeties (Butler and Hopkins, 1970 ab; Brown and Schoch, 1982). Until recently liquid nitrogen temperatures were needed for adequate spectral resolution: now the new generation of UV/VIZ microprocessor equipped spectrophotometers can (by accumulating enough spectra to obtain sufficient signal/noise ratio) analyze room temperature spectra of intact leaf lamina and partially resolve Chl-protein-complex (CPX) bands (Chuhe, 1987; Daley *et al*. 1986; Daley *et al*., 1987 a-d;

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Daley *et al.*, 1988; Fisher *et al.*, 1987; Guo *et al.*, 1987; Jeong *et al.*, 1988). This method is not as rapid as comparable fluorescent spec (Walker *et al.*, 1983; Morgan and Austin, 1986; P. Daley *et al.*, 1988), nor does it yield the same kind of information (e.g. Krause *et al.*, 1988; Mohanty and Mohanty, 1988) but VIZ spec data is more readily associated with discrete LH components (Daley *et al.*, 1987a).

## Materials and Methods

Plant Materials. Radish seeds (cv. Everest) were planted in 10 cm (4 inch) pots and placed under fluorescent lights in a greenhouse (75/70 degrees F. max./min.). At emergence of the first true leaf, plants were removed and grown in a greenhouse under similar temperatures. Plants were watered and fertilized with 20:20:20 soluble fertilizer as needed. As plants reached the 3-4 leaf stage, they were randomly selected for herbicide treatment.

Herbicide treatment. Clomazone {2-(2-chlorophenyl)methyl-4,4 dimethyl-3-isoxalidinone}, diuron {*N'*-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea} and amitrol {1*H*-1,2,4-triazole-3-amine} were used to test effects on light harvesting apparatus. Two experiments were done with spray applications, one with mixed applications. In spray applications clomazone and diuron were applied at a rate of 0.5 lb. active ingredient (ai) per acre (0.56 Kg. $Ha^{-1}$); plants were sprayed with amitrol (4.22 Kg.$1^{-1}$ in water) until plants were completely wet. In the last experiment mixed applications were used. Clomazone vapor was generated by placing 1 ml of 4EC (4 lbs. $gal^{-1}$, 0.48 Kg.$1^{-1}$) on filter paper in a plastic bag containing 8 plants for about ten min. Diuron, 20 ml. of 2% diluted 4EC: water (v:v) (9.6 g.$1^{-1}$) per plant, was applied as a soil drench. Amitrol was sprayed as before. Leaves excised and examined spectroscopically at the appearance of herbicide symptoms. Data from the three treatments was pooled.

Visible spectroscopy was done using a Shimadzu 260 spectrophotometer (Shimadzu Scientific Instruments, Columbia, Maryland) with integrating sphere attachments (Daley, 1986). Leaf sections were placed with the leaf's upper surface facing the incident light beam, and held in place between a blackened copper mask with a slot (29 mm x 5 mm) and a section of glass microscope slide. Data was taken to a Hal/Symphony program where it was processed and organized. Statistical comparisons between spectral data were done by importing data from Hal/Symphony into the Statgraphics program (STSC Inc., Rockville, Maryland).

## Results and Discussion

*In vivo spectral analysis* yields much information about LH structure. Underivatized spectra in the mathematical sense contains the same information as derivatized spectra obtained from it, but the information is subtle and less apparent to the human eye in the underivatized form. Thus, 2nd-deriv spectra show features less noticeable in underivatized spectra; and 4th-deriv spectra shows features less apparent in the 2nd-deriv plots. Due to the mathematical processes involved, 2nd-deriv analysis inverts the maxima of the original data; thus, 2nd-deriv minima correspond to maxima of the original data. The 4th-deriv spectra inverts these features again restoring them to their previous orientation. The 4th-deriv traces outline groups of bands corresponding to major CPX (French *et al.*, 1972; Brown and Schoch, 1981): *Cb 640, Cb 649, Cb 660, Cb 670 and Cb 675-676; and Ca 678, Ca 684, Ca 693, Ca 697-699 and Ca 703-710.*

The spectra was analyzed by the fourth derivative technique (Fig. 1a). The frequency of occurrence of fourth derivative maxima was analyzed statistically (Fig. 1b). Statistical analysis of peak frequency showed multiple and complex changes occurred in LH spectra in response to herbicide treatment. Amitrol effects were readily apparent and are described here. The most prominent effect of amitrol was the narrowing and apparent red shift of LH component *Cb 670* (French et al., 1972). Further analysis of *Cb 670* (Fig. 2a, b) revealed fine structure consisting of at least three bands (*Cb 670a.*, *Cb 670b* and *Cb 670c*). The effects of amitrol on this system resulted in the apparent disappearance of two fine structure bands (*Cb 670a, Cb 670c*) (Fig. 2a). The narrow band of amitrol treated leaves is very similar to the middle fine structure band (*Cb 670b*) (Fig. 3) and is statistically indistinguishable from it (Table 1.). The results of these amitrol mediated events changes the spectral envelope of the parent band (*CB 670*) causing parent band narrowing and red shift. Since plant response to herbicides reveals the present of these chemicals, this apparently specific effect may be useful in herbicide detection.

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Table 1. Means (and standard deviations) of *in vivo* peaks of light harvesting components *Cb 649, Cb 660 and Cb 670* treated with amitrol, command and diuron. Variance (standard deviation$^2$) from all *Cb 670* data, except data from amitrol treated leaves, was pooled to determine if amitrol effects differed from effects of all other treatments. * *F* test significant at 0.05 in comparison with with pooled variance (Anderson, 1987 p.44). Fine structure determined through the probability plot technique as shown in Materials and Methods and Results and Discussion. Anova analysis significance at 0.99 level is indicated by superscript letters.

| | Main bands | | |
|---|---|---|---|
| | Cb 649 | Cb 660 (nm) | Cb 670 |
| control | 649.80 (0.33) | 659.47 (3.73) | 669.07 (2.08) |
| amitrol | 649.49 (0.94) | 660.46 (2.76) | 669.11 (0.41)* |
| command | 649.58 (0.40) | 661.45 (3.37) | 668.93 (1.60) |
| diuron | 649.59 (0.74) | 660.03 (2.68) | 669.47 (1.59) |
| | Fine structure of Cb 670 | | |
| | *Cb670a* | *Cb 670b* (nm) | *Cb 670c* |
| Pooled data | 667.18 (0.60)[a] | 669.38 (0.57)[b] | 670.8 (0.07)[c] |
| amitrol (from above) | none | 669.47 (0.41) | none |

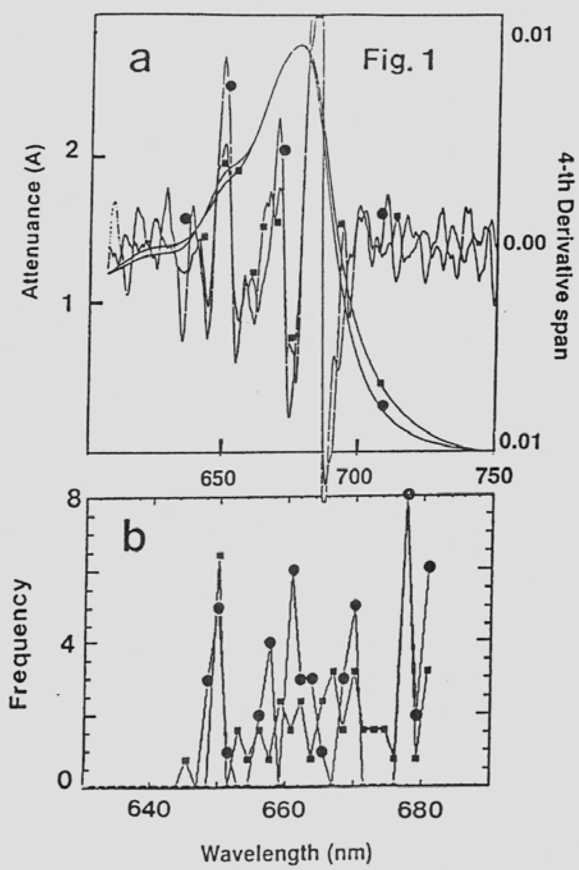


*Figure Legends*

*Figure 1. Spectral characteristics of normal (control) and amitrol treated leaves. 1a. Comparison of attenuance* in vivo *spectra and fourth derivative analysis of control and amitrol treated leaves.* In both figures the closed circles indicate spectra from amitrol treatments, the closed squares spectra of controls. The less abruptly changing curves that originate at the lower right of the figure are the attenuance (~absorbance) spectra. The more abruptly changing traces that originate at the middle right of the figure are the fourth derivative traces. Figure 1b shows frequency of fourth derivative peaks from multiple spectra of control and amitrol treated leaves.

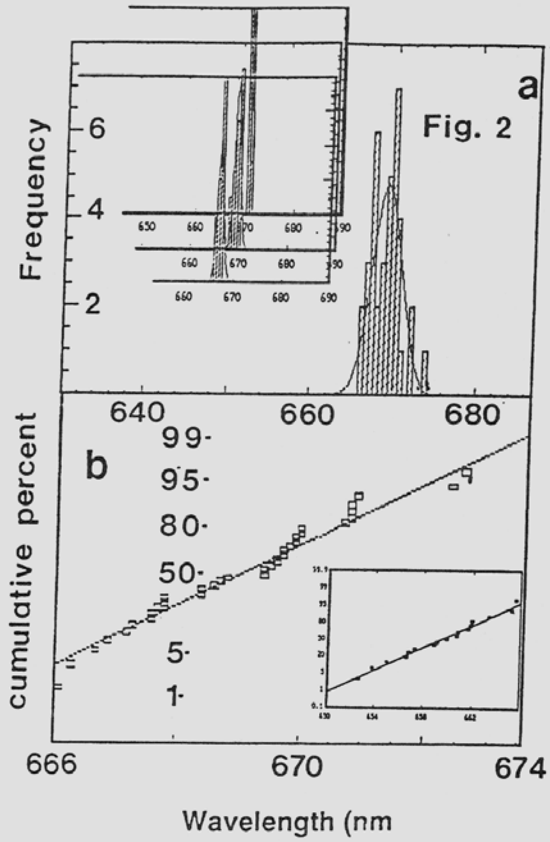


*Figure 2. Fine structure of Cb 670. Figure 2a frequency plot of fourth derivative peak maxima from pooled spectra from clomazone, control, diuron treatments.* The inset of Fig. 2a shows the three fine structure bands of *Cb 670* which are generated using a normal curve linearizing program. *Figure 2b* shows a continuous trace corresponding to normal curve that would be expected for a normal distribution of data points. The data points shown show that the curve is not homogenous, but shows fine structure. The inset of Fig. 2b shows the more linear distribution of *Cb 660* of the control which more closely represents that of a normal curve.

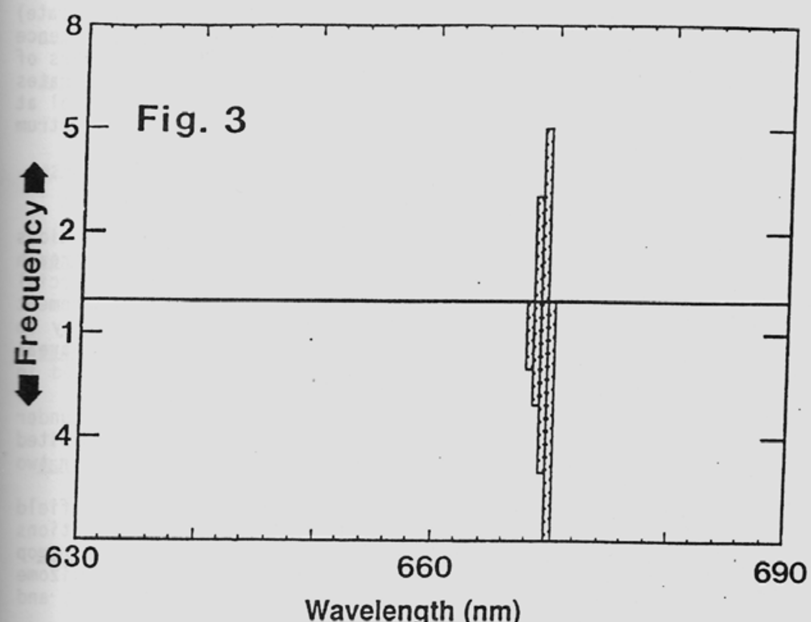


*Figure 3*. The upper part of the figure shows the frequency of fine structure *Cb 670b* from the pooled samples of clomazone, control and diuron treated *Cb 670*, generated from data shown in Fig. 2. The lower part of the figure shows the total frequency of fourth derivative peaks from *Cb 670* of amitrol treated leaves. Statistical analysis of this data is presented in Table 1.

# DPX-V9360 - SELECTIVE JOHNSONGRASS CONTROL FOR CALIFORNIA CORN

J.F. Cook[1], W.J. Steele[1], J.L. Pacheco[1]
and
L.W. Mitich[2], J.P. Orr[2]

Abstract. "Accent" Herbicide (formerly DPX-V9360) {2-(((4,6-dimethoxypyrimidin-2-yl)aminocarbonyl)aminosulfonyl)-*N*,*N*-dimethyl-3-pyridinecarboxamide monohydrate} is a new sulfonylurea herbicide being developed by DuPont for post-emergence control of annual and perennial grassy weeds in corn (*Zea mays*). Two years of testing in California have shown excellent crop tolerance at application rates up to 4.0 oz ai/acre and johnsongrass (*Sorghum halpense* (L.) Pers.) control at rates as low as .5 oz ai/acre. Further testing is planned to determine spectrum of control, crop tolerance and effects on rotational crops.

## Introduction

Johnsongrass, (*Sorghum halpense* (L.) Pers.), is one of the major noxious weeds of California. It is a perennial that has the ability to rapidly encroach into uninfested areas through (1) creeping rhizomes, (2) contaminated commercial seed, (3) field application of infested manure, (4) irrigation, and (5) movement of cut rhizome pieces by mechanical cultivation. Because of its ability to infest and survive, johnsongrass is an aggravating problem in several areas where field corn is grown, and currently registered materials are limited in their ability to effectively control this pest.

DPX-V9360, trade named "Accent", is a new sulfonylurea herbicide under development by DuPont. It is formulated as a 75% dry flowable and has exhibited excellent post-emergence control of johnsongrass and safety to field corn in two seasons of testing in the Central Valley of California.

Since 1987, seven (7) field trials were conducted with DPX-V9360 on field corn. The trials were randomized complete block designs of 3-4 replications applied by hand boom. The objectives of the trials were to (1) evaluate crop safety at rates from .25 to 4.0 oz ai/ac, (2) evaluate seedling versus rhizome borne johnsongrass control, (3) evaluate single versus split applications, and (4) determine optimum application timing (i.e. pest stage) and use rate.

## Conclusions

DPX-V9360 displayed acceptable crop safety at rates from .25 to 4.0 oz ai/ac when applied to corn stages from 2 leaf to 12 leaf. Seedling and rhizome borne johnsongrass showed similar responses to rates and timings of the product. Single applications made at the 8-10 leaf stage of johnsongrass, or split applications made at the 2-6 leaf stage and 12-leaf stage, provided considerably better control than did single applications made to 2-6 leaf johnsongrass. Results indicate the optimum timing for a single application of DPX-V9360 is the 8-10 leaf stage of the johnsongrass with consistent performance at rates as low as .5 oz ai/ac.

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[1]E.I. DuPont De Nemours & Co. (Inc.) Wilmington, DE
[2]University of California Cooperative Extension

## CALIFORNIA TRIAL LOCATIONS

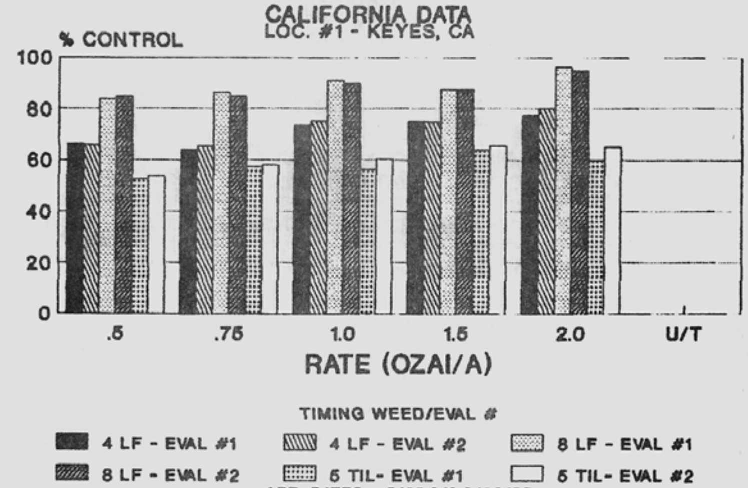
## DPX-V9360

## JOHNSONGRASS CONTROL IN FIELD CORN

| # /LOCATION | INVEST. | VARIETY (SEED RATE) | SOIL (TYPE/pH/O.M.) | RATES (OZAI) | OBJECTIVE |
|---|---|---|---|---|---|
| #1/KEYES | COOK (1988) | PIONEER 3055 (29,000) | S.L./5.9/8.9 | .5 to 2. | EFF/PHYT TIMING S. BORNE |
| #2/MADERA | STEELE (1987) | PIONEER 3138 (26,000) | S.L./7.0/1.7 | .5 to 2.0 | EFF/PHYT R. BORNE |
| #3/TYLER IS | ORR (PACHECO) (1988) | PIONEER 3377 (28,000) | EGBERT MUCK/ 4.5/50.0 | .25 to 1.5 | EFF/PHYT S. BORNE R. BORNE |
| #4/RIVERDALE | STEELE (1988) | MISSION 2999 (26,000) | L./7.6/.80 | .5 to 1.0 | EFF/PHYT EARLY/ LATE/ SPLIT |
| #5/ESCALON | COOK (1988) | GOLDEN JUBLIEE (27,000) | S.L./7.3/.9 | .75 to 4.0 | EFF/PHYT TIMIMG |
| #6/VENICE IS | COOK (1988) | PIONEER 3147 (25,000) | S.L./5.8/13.0 | .75 to 4.0 | PHYTO TIMING |
| #7/DAVIS | MITICH (PACHECO) (1988) | PIONEER 3181 (25,000) | YOLO CLAY LOAM .75/1.2 | .25 to 1.5 | EFF/PHYT |

Note - Attached graphs indicate efficacy performances for Locations #1 through Location #5 . Locations #6 and #7 are included in an all inclusive graph on crop injury.

## DPX-V9360-SEEDLING JOHNSONGRASS CONTROL
## 4 LF VRS 8 LF VRS 5 TILLER J. GRASS
CALIFORNIA DATA

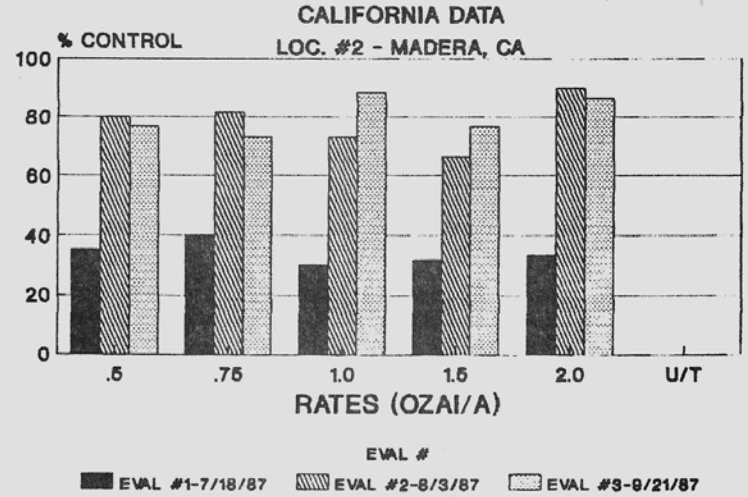



APP. DATES - 5/25,6/6,6/22/88
EVAL DATES - 7/7,8/7/88

CORN STAGE
4/8/12 LF

(70% CONTROL - MIN. GROWER ACCEPT)

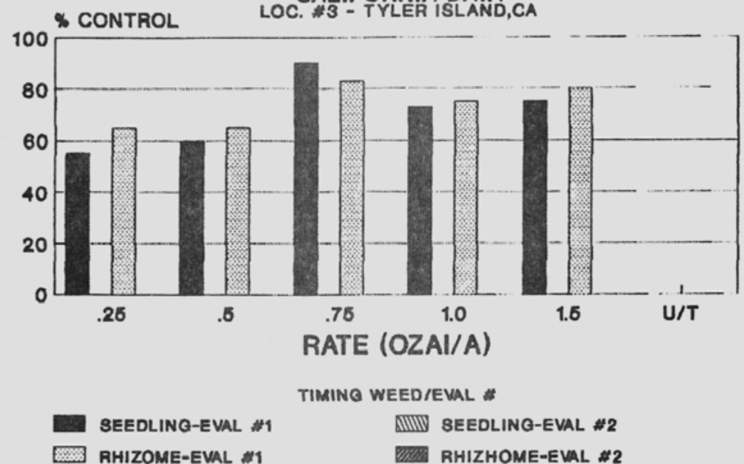
## DPX-V9360 JOHNSONGRASS CONTROL
## RHIZOME BORNE (0-12" AT APP.)
CALIFORNIA DATA




APP.DATE-7/9/87 (4-6 LF CORN)

(70 % CONTROL - MIN. GROWER ACCEPT.)

## DPX-V9360 JOHNSONGRASS CONTROL
## SEEDLING VRS RHIZOME
### CALIFORNIA DATA
LOC. #3 - TYLER ISLAND,CA

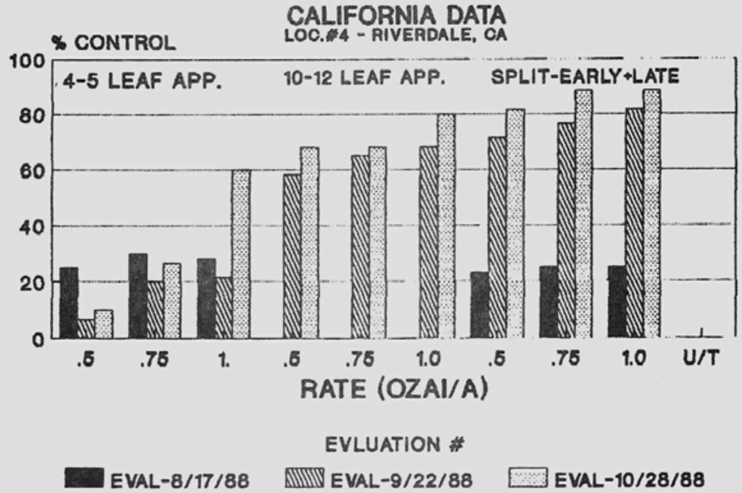



APP. DATE-5/18/88 (3 LEAF CORN)

EVAL. DATE-6/8,6/18/88

(70% CONTROL = MIN. GROWER ACCEPT)

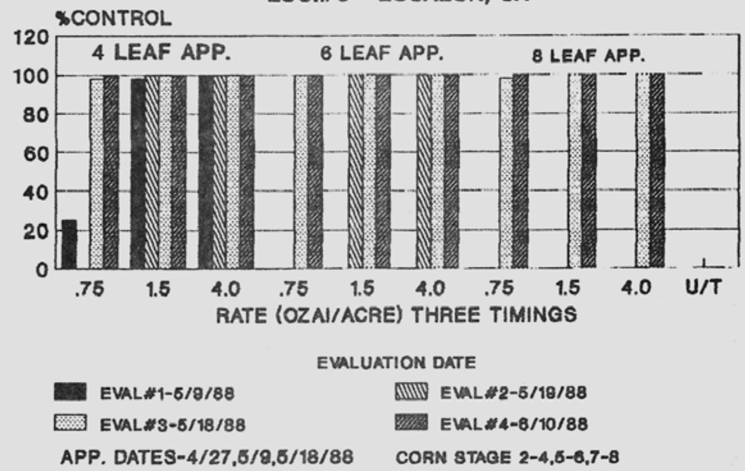
## DPX-V9360 JOHNSONGRASS CONTROL
## RHIZOME BORNE
4-5 LF VRS 10-12 LF VRS SPLIT APP.
### CALIFORNIA DATA
LOC.#4 - RIVERDALE, CA




APP. DATE-7/28/88,8/18/88

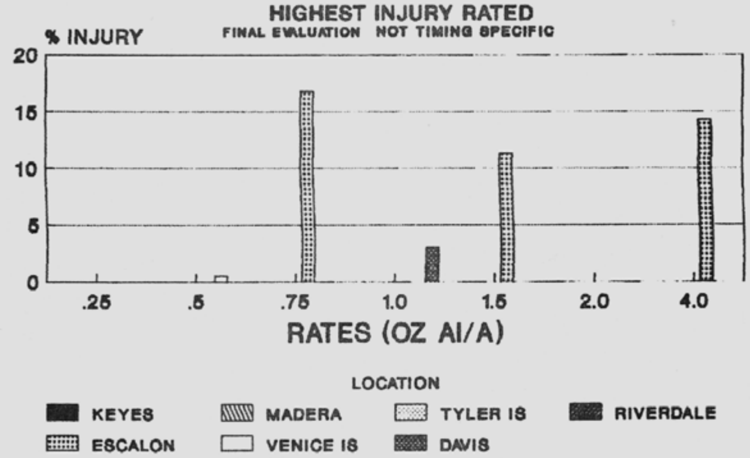
(70% CONTROL = MIN. GROWER ACCEPT.)

## DPX-V9360 JOHNSONGRASS CONTROL
## 4 LF VRS 6 LF VRS 8 LF J. GRASS
## CALIFORNIA DATA
### LOC.#5 - ESCALON, CA




(70% CONTROL = MIN. GROWER ACCEPT.)

## DPX-V9360 CROP INJURY RATINGS
## FIELD CORN - CALIFORNIA TESTS
## 7 LOCATIONS
### HIGHEST INJURY RATED




(30 % INJURY = MAX. GROWER ACCEPT.)

# INFLUENCE OF IRRIGATION METHOD ON CONTROL OF ANNUAL WEEDS

S.R. Grattan, L.J. Schwankl, and W.T. Lanini[1]

Abstract. Non-herbicide methods of weed control are gaining interest among researchers as legislative pressures on herbicide registration and use increase. In arid and semi-arid climates, which cover much of the western United States, annual weed germination in summer row crops is related to the extent to which the soil surface is wetted. We conducted two field experiments to test the influence of three irrigation methods (furrow, sprinkler, and sub-surface drip irrigation) on weed density and distribution across the beds. Barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], redroot pigweed (*Amaranthus retroflexus* L.), black nightshade (*Solanum nigrum* L.), and lambsquarters (*Chenopodium album* L.), were seeded at a constant density (50 seeds/species/ft$^2$) throughout all plots before the experiments began. In one experiment on 60-inch beds without a crop, weed distribution was directly related to the gravimetric water content in the surface 2.5 cm of soil (measured 24 hr. after an irrigation event). Total weed biomass within a 20-inch strip in the middle of the bed was 1.11, 0.13, and 0.53 tons/ac (dry wt.) for sprinkle, furrow, and sub-surface irrigated plots. In the remaining 40 in. bed section, respective biomass values were 0.96, 1.42, and 0.05 tons/ac (dry wt.). Those data indicate that total weed biomass under subsurface drip was only 20% that under furrow of sprinkle treatments. In another experiment, the field was planted with processing tomatoes where half of each plot was treated with napropamide {*N*,*N*-diethyl-2-(1-naphthalenyloxy)propanamide} and pebulate {*S*-propyl butylethylcarbamothioate} at two and six lbs/ac, respectively. Fruit yields of sprinkler, furrow, and sub-surface irrigated tomatoes treated with herbicide were not significantly different and averaged 48 tons/ac. Yields of those plots not treated with herbicide were 35, 35, and 53 tons/ac. for the respective irrigation treatments. We found in this experiment that sub-surface drip irrigation without herbicides was equally effective at controlling weeds as sprinkler and furrow irrigated plots treated with herbicides.

[1]University of California, Davis, CA

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# DEVELOPMENT OF WEED MANAGEMENT PROGRAMS FOR CARROTS

Harold M. Kempen[1]

Abstract. No varietal response occurred when treated with registered and new candidate herbicides. Trifluralin shows tolerance at rates that might control dodder. Studies showed that the linuron (Lorox 50 DF) plant-back restriction of 12 months could be reduced to 6 months for cotton. The 50 DF formulation of linuron was very safe and highly effective in carrots. Metribuzin reduced yields

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when summer-applied to 5 leaf carrots on coarse-textured soils and was less effective. Chemigation trials confirmed efficacy and safety with linuron in comparison to ground applications and offers several advantages. Mixtures of sethoxydim or fluazifop with linuron and crop oil concentration (Agridex) were too injurious but a 24-hour delay before or after linuron treatment seemed adequate to gain safety. Nutsedges and other weeds are not controllable with the loss of carrot oil (Stoddard solvent), due to regulatory costs.

## Introduction

California carrot growers have benefitted from two excellent herbicides in getting non-competitive seedlings underway. The most important has been linuron {*N*-(3,4-dichlorophenyl)-*N*-methoxy-*N*-methylurea}, with trifluralin {2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine} as an important second choice. For specific problem weeds, growers had carrot oil (or Stoddard solvent) for nutsedges and very recently fluazifop {(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid} for grasses.

In much of California's 25,000 acres, growers have used linuron pre-emergence at 0.25-0.5 lb ai/A to gain early season control of mustards and rapidly growing weeds such as Palmer amaranth (*Amaranthus palmeri*), pigweed) or purslane (*Portulaca oleracea*). This label was permitted in California through an SLN (Special Local Need) or 24(c) label. In part it has replaced preplant use of trifluralin.

Research that I did in 1963 to 1969 confirmed that carrots have excellent tolerance to linuron once they reach the 2-fern leaf stage. So growers have always used 0.75-1.5 lb ai/A post-emergence to provide control of nearly everything in the field. It has worked well.

Trifluralin was a very safe backup treatment. It does very well on grasses as well as most summer weeds so that a preplant application was very reliable. For summer plantings especially, it was often needed. Weeds that linuron will miss, such as Russian thistle (*Salsola iberica*), knotweed (*Polysonum* sp.) and grasses are controlled.

Carrot oil rounded out the arsenal of effective crop protection tools. Being more expensive, its use has been reserved for purple nutsedge (*Cyperus rotondus*) (nutgrass), a weed common in southern California which linuron does not control. In the cooler coastal regions, yellow nutsedge (*Cyperus esculentus*) control with linuron is poor and oil is needed.

In 1987 fluazifop {(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]-phenoxy]propanoic acid} was registered and now aids growers in control of volunteer cereals, annual, and perennial grasses.

Linuron was subjected to a U.S. EPA "Special Review" in the mid-1980's, and for several years we who rely on it in carrots have worried about its future in the United States. It was featured prominently in the National Academy of Science report in late 1987 which reviewed chemical residues in processed versus fresh foods. (Of course, Dr. Bruce Ames, University of California-Berkeley Department of Biochemistry cancer researcher had stated that pesticide residues that we humans consume in foods contribute 1/10,000 as much as the natural carcinogens in foods).

Prior to approval of a 1988-89 grant request from the California Fresh Carrot Advisory Board, we conducted a number of studies in carrots with various herbicides which might work on one or more of the 50 plus weeds which prevail in Kern County cropland. (See *Kern County Vegetable Weed Management Research*, 1985-1986.)

<u>Recent evaluations of herbicides in carrots</u>:

| Herbicides tested | Safety on carrots | Needs |
|---|---|---|
| Lorox 80 WP, 4 F (linuron) | Pre@ 0.5-1.0 ai<br>PoE 2-6 lf@ 1.0-2.0 ai | -chemigation label<br>-shorter plantback |
| Treflan 4 EC, 5 EC (trifluralin) | PPI 0.5-2 lb | ok |
| Carrot oil (various sources) | PoE 1.5-4 leaf to 80 g | ok |
| Fusilade 4 EC, 2000 1 EC (fluazafop) | PoE any stage | ok |
| Sencor 50 WP (metribuzin) | PoE 5 leaf? | California label a) |
| Caparol/prometryn 80 WP, 4F | Pre@ 1 ai<br>PoE@ 2-8 if 1.6 | Not registered b) |
| Antor 4 EC (diethatyl-ether) | Pre@ 2-4 lb | No registered c) |
| Tenoran 50 WP (chloroxuron) | Pre, PoE-1 leaf 1.5-3 lb ai | Dropped |
| Surflan 75 WP, 4F (oxyzalin) | Pre@ 1-2 lb | No interest |
| Sonalan 3 EC (ethalfluralin) | PPI@ bean rates | No interest |
| Prowl 4 EC (pendamethalin) | PPI@ 1-2 lb | Recent interest |
| Nortron 1.5 EC (ethofumesate) | PPI, Pre@.75-1.5 lb | No interest |

a) An IR-4 tolerance was established in 1987 by University researchers. We did three studies in 1987-88 to verify safety at the 2-9 leaf stages in Kern County. Tolerance at the suggested label pattern of 5-leaf stage may be adequate. b) Some interest from United Ag Products but contingent on Ciba-Geigy getting it re-registered with EPA. c) On hold after having an Experimental Use Permit from EPA in 1986.

Several herbicides are very safe to carrots. Carrot tolerance to pendimethalin {*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine}, oryzalin {4-(dipropylamino)-3,5-dinitrobenzenesulfonamide} and prodiamine {$N^3N^3$-di-*N*-propyl-2,4-dinitro-6-(trifluoromethyl)-m-phenylenediamine} is similar to trifluralin. American Cyanamid (March, 1989) suggested that they would be interested in supporting a Prowl IR-4 label. Ethofumesate {(±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate} has been evaluated and shows promise in terms of safety and does control nutsedges and annual morning glory. Diethatyl-ether {N-(chloroacetyl)-N-(2,6-diethylphenyl)glycine} had an EPA EUP in 1986 but registration has not proceeded since then. It works on yellow nutsedge and other metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide}/alachlor{2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide}-sensitive weeds. Prometryn {*N,N'*-bis(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine} has shown performance and safety similar to linuron and could fit if the regulatory requirements were met. Sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} is similar to fluazifop in control of grasses and labeling is expected soon.

Our studies over years have gone for naught due to lack of interest by manufacturers because carrots are a minor-acreage crop. Most of their recent efforts have gone into defending their products to meet new toxicology, groundwater and environmental safety requirements (often called "data gaps"). A year ago, some interest in prometryn registration was sparked but now that linuron is "cleared" by EPA, it has waned.

Research Objectives since 1987

Our recent research objectives were these: a. To add alternatives to the registered herbicides available; b. To further evaluate safety to carrots of Lorox 50 DF (dry flowable) formulations, as well as to metribuzin which has an EPA tolerance now through the IR-4 program; c. To evaluate varietal response; d. To get numbers so that chemigation might be permitted with linuron post-emergence; e. To shorten the *legal* plant-back restriction (12 months) to 6 months for cotton; f. To see if dodder (*cuscuta* sp.) can be safely controlled; g. To evaluate cover crops with carrot management systems; and h. To determine the effect of sequential treatments between grass herbicides and linuron. Some of these objectives were combined in research tests during 1987 and 1988 as reported below.

1. Variety-herbicide interaction trials

We included diethatyl-ether, trifluralin, oxyfluorfen {2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene} and linuron in a pre-emergence trial under sprinklers in which six varieties were planted by an excellent grower-cooperator, Kevin Pascoe. Carrot varieties included *Dominator Fancy Pak, Impact, Gold Mine, Caropak* and *Sierra*. We also looked at OT (Over-the-Top) applications of Treflan TR-10 and Gowan's Trifluralin 10G on cotyledon-stage carrots. And we looked at a 2-leaf application of metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,24-triazin-5(4*H*)-one}, prometryn, linuron, fluazifop, sethoxydim and oxyfluorfen {2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene}. Weed-free (oiled) and weedy (but weeded) plots were compared in each test.

**Pre-emergence tolerance/weed control trial on six varieties. (Lamont, CA) ***

| Herbicide | lb/a.i. | CARROTS | | | | |
|---|---|---|---|---|---|---|
| | | 1.5 lf 9/22 | 2.25lf 9/29 | 3.5 lf 10/6 | 6 lf 10/14 | 6 lf** 10/14 |
| Untreated (oiled 9/27) | 60 gpa | 0.0 | 0.3 | 2.3 | 2.3 | 91.7% |
| Untreated weedy | — | 0.0 | 0.0 | 0.0 | 0.0 | 56.7% |
| Lorox DF | 0.25*** | — | 0.0 | 0.3 | 0.0 | 76.7% |
| " | 0.5 *** | — | 0.0 | 1.0 | 0.0 | 88.3% |
| Antor 4 EC | 2.0 | 1.3 | 0.0 | 0.3 | 0.3 | 70.0% |
| " | 4.0 | 1.3 | 0.0 | 0.0 | 0.7 | 65.0% |
| Treflan 5 EC | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 85.0% |
| " | 2.0 | 0.0 | 0.0 | 0.3 | 0.0 | 86.7% |
| Goal 1.6 EC | 0.125 | 5.0 | 1.0 | 4.0 | 5.3 | 75.0% |
| " | 0.25 | 8.0 | 6.0 | 7.0 | 8.3 | 60.0% |

* Planted 8/29/88; applied pre-emergence on 9/1/88; sprinkled 9/2/88 over six varieties.
** Rated for percent cover at final rating; see weed % cover below. Others rated 0 to 10: 10 = kill.
*** Lorox 50 DF was applied pre-emergence at 0.25 lb a.i./A on 8/30/88. Weeds not heavy.
Plots were 4.5' by 4 beds. Data represent averages of three replications.

**Pre-emergence tolerance/weed control trial on six varieties. (Lamont, CA) ***

| Herbicide | lb/a.i./A | HAIRY NIGHTSHADE | | | | Y. NUTSEDGE | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 9/22 | 9/29 | 10/6 | 10/14** | 9/22 | 9/29 | 10/6 | 10/14 |
| Untreated (Oiled 9/27) | 60 gpa | 0.0 | 9.9 | 10.0 | 1.7% | 0.0 | 8.3 | 8.0 | 3.3% |
| Untreated | — | 0.0 | 0.0 | 0.0 | 33.3% | 0.0 | 0.0 | 33.3% | 8.3% |
| Lorox DF | 0.25 | – | 5.0 | 5.0 | 6.7% | – | 0.0 | 0.7 | 13.3% |
| " | 0.5 | – | 7.3 | 6.3 | 3.3% | – | 2.0 | 1.0 | 6.7% |
| Treflan 5 EC | 1.0 | 4.0 | 4.7 | 4.7 | 1.7% | 0.0 | 0.0 | 0.0 | 8.3% |
| " | 2.0 | 6.3 | 6.7 | 9.3 | 1.7% | 0.0 | 0.0 | 0.7 | 8.3% |
| Antor 4 EC | 2.0 | 4.3 | 1.3 | 1.3 | 23.3% | 7.7 | 4.0 | 4.3 | 5.0% |
| " | 4.0 | 4.0 | 4.0 | 3.0 | 23.3% | 7.7 | 5.5 | 6.0 | 5.0% |
| Goal 1.6 EC | 0.125 | 10.0 | 10.0 | 10.0 | 0.0% | 0.7 | 0.0 | 1.0 | 21.7% |
| " | 0.25 | 10.0 | 10.0 | 10.0 | 0.0% | 2.3 | 1.0 | 0.7 | 36.7% |

* See the table above for application details. Hairy nightshade 5 plants/sq. ft.; Yellow nutsedge 5-10/ sq. ft.
** Rated on percent cover of each on final rating; compare to carrot table above. Others are 0 to 10: 10 = kill; ave. of three replications.

The results of the pre-emergence test suggested that linuron pre-emergence had adequate safety to permit more than the pre-emergence field treatment of 0.25 lb ai/A, but control of hairy nightshade (*Solanum sarrachoides*) was not adequate. Trifluralin at 2 lb ai/A rates provided a higher degree of control of hairy nightshade (*solanum sarrachoides*) than linuron. Oxyfluorfen was the best on nightshade, but injured the carrots too much, reducing stand severely at both rates. Diethatyl-ether was poor on hairy nightshade, but provided fair control of yellow nutsedge. Carrot oil controlled both weeds well and only temporarily retarded the carrots at the 60 gpa rate used in this test.

Granular trifluralin was applied at the early cotyledon stage after an irrigation and then was sprinkled 24 hours later. (See the table below).

The results suggested that trifluralin is safe on carrots pre-emergence and early post-emergence, just as previous studies showed it to be safe at 4 lb ai/A preplant incorporated. I, therefore, feel that it could be used for dodder control, just as granulars are used in forage alfalfa, at about 1 lb ai/A rates. Now Trilin 5 and Trifluralin 5 formulations are available in California as well as Treflan 5 EC. Treflan TR-10 granules were better in stunting hairy nightshade (Hans) here than were Trifluralin 10-G granules. No differences in varietal susceptibility were noted.

**Granular trifluralin over cotyledon (seed-leaf) stage carrots. (Lamont, CA) ***

| Herbicide | lb/a.i./A | 9/22 | | 10/6 | | 10/14 | |
|---|---|---|---|---|---|---|---|
| | | Carr | Hans | Carr | Hans | Carr | Hans |
| Gowan Trifluralin 10 G | 1.0 | 0.0 | 0.0 | 0.0 | 2.7 | 0.0 | 2.3 |
| " | 2.0 | 0.0 | 1.7 | 0.0 | 5.0 | 0.0 | 4.7 |
| Treflan TR-10 G | 1.0 | 0.0 | 1.7 | 0.3 | 6.7 | 0.0 | 5.0 |
| " | 2.0 | 0.0 | 2.7 | 0.3 | 7.7 | 0.0 | 7.3 |
| Carrot oil on 9/27 | 40 gpa | 0.0 | 0.0 | 1.0 | 8.3 | 0.3 | 9.0 |
| Untreated | — | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* Treated 9/15 immediately after sprinkling with a salt-shaker in two directions when carrots were in mid-cotyledon stage; re-sprinkled with 0.25" in 24 hours. 85° F, Sandy Loam; ~ 0.5% O.M. Field was treated with Lorox 50 DF @ 0.5 lb a.i./A pre-emergence. All plots rated 0 to 10: 10 = kill; average of 3 replications. On 10/13, furrows were cultivated.

At the 2-leaf stage, retardation which occurs with linuron was obvious in comparison to the non-treated check. Carrot oil at 80 gpa reduced growth as much as linuron at 1 lb ai/A but recovery was quicker. Prometryn was more injurious here than in tests done in previous years; metribuzin retarded plants at both rates, and reduced stand at the 0.25 lb ai/A rate. Oxyfluorfen was less injurious here than pre-emergence but was too toxic. Sethoxydim or fluazifop showed no symptoms on any of the six varieties in test. No varietal differences were evident except that the more vigorous varieties, Gold Mine and Sierra were a bit more tolerant to prometryn and metribuzin due to being larger when treated. When rated on 11/16/88, about six weeks after treatment only metribuzin and sethoxydim treated plots at eh 2X rates showed some retardation. Yields were not obtained due to scheduling difficulties. (See ratings below).

**Tolerance to herbicides applied over 2.0 to 2.25 fern-leaf carrots (Lamont, CA) ***

| Herbicide | lb/a.i. | CARROTS (Rated 0 to 10) | | | | |
|---|---|---|---|---|---|---|
| | | 3.5 lf 10/6 | Symp. 10/6** | 6 lf 10/14 | 10/26 | 11/16 |
| Untreated (oiled 9/27) | 80.0 gpa | 2.7 | 0.0 | 1.3 | 0.0 | 0.0 |
| Untreated weedy | — | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lorox 50% DF | 1.0 | 1.0 | 0.0 | 1.3 | 0.7 | 0.3 |
| " | 2.0 | 2.0 | 1.3 | 2.0 | 2.0 | 1.0 |
| Clean Crop Prometryn 4 F | 1.0 | 1.0 | 1.0 | 1.0 | 1.7 | 0.0 |
| " | 2.0 | 1.7 | 1.7 | 3.0 | 2.7 | 0.0 |
| Sencor 75% DF | 0.125 | 1.3 | 2.3 | 1.7 | 1.3 | 0.3 |
| " | 0.25 | 2.7S | 4.7 | 3.3 | 3.7 | 2.7 |
| Goal 1.6 EC | 0.125 | 2.0 | 3.0 | 1.3 | 1.3 | 0.7 |
| " | 0.25 | 3.7 | 3.7 | 3.3 | 2.7 | 1.3 |
| Poast 1.5 EC | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| " | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Fusilade 2000 1 EC | 0.125 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| " | 0.25 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* Treated 9/29/88 at the 2.2-2.25 true leaf stage, depending on variety. Six varieties; three replications with plots 4.5 feet long and four beds wide. Planted 8/29/88 and treated pre-emergence before first irrigation with Lorox 50 DF @ 0.25 lb a.i./A. Light sandy loam soil. S = stand loss on all varieties. Rated 0 to 10: 0 = no effect; 10 = kill. Average of 3 replications.

**Herbicides effects on weeds at the 2-fern leaf stage of carrots (Lamont, CA)****

| Herbicide | lb a.i./A | Weed ratings (0 to 10; ave. 3 repl.) H. nightshade 10/6 | H. nightshade 10/14 | Y. nutsedges 10/6 | Y. nutsedges 10/14 | V. Potatoes 10/16 |
|---|---|---|---|---|---|---|
| Untreated (oiled 9/27) | 80.0 gpa | 10.0 | 10.0 | 9.0 | 8.8 | 5.0 |
| Untreated weedy | — | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lorox 50% DF | 1.0 | 10.0 | 10.0 | 3.5 | 7.0 | 3.3 |
| " | 2.0 | 9.5 | 9.3 | 5.0 | 8.7 | 4.7 |
| Clean Crop Prometryn 4 F | 1.0 | 10.0 | 10.0 | 1.9 | 2.7 | 1.3 |
| " | 2.0 | 10.0 | 10.0 | 3.0 | 6.7 | 1.3 |
| Sencor 75% DF | 0.125 | 1.5 | 2.3 | 1.4 | 3.0 | 0.0 |
| " | 0.25 | 1.5 | 5.7 | 3.8 | 6.7 | 0.0 |
| Goal 1.6 EC | 0.125 | 5.5 | 9.9 | 1.7 | 2.7 | 5.7 |
| " | 0.25 | 8.4 | 10.0 | 3.5 | 4.7 | 6.7 |
| Poast 1.5 EC | 0.3 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| " | 0.6 | 1.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| Fusilade 2000 1 EC | 0.125 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| " | 0.25 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* Hairy nightshade was 2-4" 0.5 square foot; yellow nutsedge was 2-10" 6/square foot; and volunteer potatoes were 4" and scattered. Rated 0 to 10: 0 = no effect; 10 = kill. Average of 3 replications. See the previous table for further details.

2. Plant-back tests: Four locations were treated with linuron (DF) and metribuzin (DF) to measure carrot safety, yield response and the plant-back safety to cotton. One was in the Lost Hills area on calcareous soil, one on sand, one on sandy loam and one on a heavier sandy loam. Linuron treatments were made between August 31 and September 9 to 2-leaf to 3-leaf carrots; metribuzin was applied to 5-6 leaf carrots. All plots were done in duplicate on plots 35 x 40 feet. About a month after linuron treatment a field bioassay was planted into each plot, using cotton and blackeyes evaluated before frost. Further evaluations will be made after tillage when cotton is planted in April.

Linuron/Metribuzin Yield Results (T/A Roots)

| Treatments | Sand | Sand | Hi calc. | sl | Ave. |
|---|---|---|---|---|---|
| Beacon Oil@ 40 gpa | 38.0 | 38.3 | 32.7 | 32.3 | 35.3T/A |
| Linuron@ 1 ai | 42.9 | 36.7 | 37.5 | 33.4 | 37.7 |
| Linuron@ 2 ai | 42.2 | 38.0 | 34.8 | 34.3 | 37.3 |
| Metribuzin@ 0.125 ai | 33.0 | 31.0 | 32.3 | 23.5 | 29.9 |
| Metribuzin@ 0.25 ai | 27.5 | 39.3 | 29.6 | 27.1 | 30.9 |
| LSD 0.05 | Coeff. of Variation = 9.45% | | | | 4.97 |
| (2 reps ea location) | 9-1 | 9-1 | 8-30 | 9-6 | |
| Temperature at application: | 108° | 106° | 108° | 105° | |
| Carrot size for linuron | 3 lf | 3 lf | 2 lf+ | 2 lf- | |
| Carrot size for metribuzin | 6 lf | 5 lf | 5 lf | 5 lf- | |
| Variety | FanciPak | Pakmor | Dominator | Dominator | |
| Harvest Date | 12/30/88 | 1/3/89 | 12/29/88 | 1/11/89 | |

Results to date show that linuron did not affect yield, being as good or better than the carrot oil-treated checks. Metribuzin reduced yield in most tests at the rates tested, perhaps due to lack of weed control in some fields. Linuron was much superior to metribuzin in control of weeds, controlling all weeds present in all sites, including common groundsel (*Senecio vulgaris*), black (*Solanum nisrum*) and hairy nightshades, sowthistle (*Sonchus oleraceus*), London Rocket (*Sisymbrium irio*), Palmer amaranth (pigweed), yellow nutsedge, annual morning glory, white clover (*Trifolium repens*), cheeseweed (*Malva parviflora*), hedge mustard (*Sisymbrium officinale*) and sweet clover (*Melilotus* sp.). Metribuzin totally missed the common black nightshade and sowthistle. It did fairly well on yellow nutsedge, mustards, white clover, and annual morning glory and did well on pigweeds. Lovegrass (*Eragrostis orcuttiana*) in one location was controlled by linuron but not metribuzin.

Linuron caused no symptoms on carrots at any location, despite application during 105-108° F maximum daily temperatures. Metribuzin, on the other hand, caused temporary chlorosis in the two sandier locations.

On the bioassay species, cotton and blackeyes, which were planted about 30 days after linuron application, no injury or symptoms were detected. At one location, volunteer cotton emerged with the carrots grower-treated with 0.5 lb ai/A pre-emergence; it showed symptoms on the cotyledonary leaves of 8 plants of 25, but true leaves of 3-4 leaf stage cotton was normal and plants were vigorous. Further assessment will be done in April when cotton is field-planted, but the results suggest that a six-month plant-back to cotton will be safe at normal use and 2X rates. We hope to get a label change to make it legal.

3. Chemigation trials: Two chemigation locations were used to compare linuron through solid set sprinklers versus ground application in non-replicated tests. At one on high calcium sandy loam, 1 lb ai/A was compared on 8/30/88; at the second sandier site, 1.25 lb ai/A was compared on 9/19/88. Injection was made into mainline pipe between the booster pump and the crop laterals, with water sourced from reservoirs. The table below shows data collected.

Observations during the experiments and data below confirm decades of this usage by growers prior to new regulations governing chemigation labeling. No differences were found between the two techniques of application. Chemigation provides growers several advantages: to apply linuron to fields without drying down fields to allow entry; more precise timing, allowing lower doses; severe weeds such as nutsedges do not reduce soil moisture levels which can hurt carrots prior to field entry; fossil fuel usage is reduced 90%; cost of application 50%; and compaction is eliminated, often eliminating one cultivation after ground application.

DuPont research managers have offered to label linuron usage for chemigation application when applied, post-emergence only.

Chemigation vs. Ground Application of Linuron on Carrots

| | Weed Control | | Yield (Tons/A roots) | |
|---|---|---|---|---|
| Location 1: High Calcium Sandy Loam | Chem. | Grd. | Chem. | Grd. |
| Linuron @ 2.0 lb ai/A<br>Treated 8/3/88; rated 9/12/88;<br>Variety is Dominator | 10.0 | 10.0 | 39.5 | 37.9 |
| Location 2: Sandy Loam | | | | |
| Linuron 50 DF @ 2.5 lb ai/A<br>Treated 9/19/88; rated 9/29/88;<br>Variety is Sierra | 10.0 | 10.0 | 28.6 | 28.9 |

Weeds present: Location 1: [common species] **Common groundsel, London Rocket, Sowthisle, Lanceleaf groundcherry** (*Physalis lanceifolia*), **1.5-4" [occasional] Citron 8-18"**. Carrot variety Dominator at 3" (2.25 leaf stage). (Those in **bold** were controlled by linuron.
Location 2: [common species] **London rocket 4-8"; Flixweed** (*Descurainia sophia*) **1"; Hairy nightshade 1"; Palmer amaranth 12-18"; White clover 5-8"; Sowthisle 3"; Cheeseweed 4"; Black nightshade 4-6"; Lambsquarters** (*Chenopodium album*) **12"; Prostrate pigweed** (*Amaranthus blitoides*) **8"; Tumble pigweed** (*Amaranthus albus*) **8"; Puncture vine** (*Tribulus terrestris*) **2"; Purslane 18"; [occasional] Ivyleaf morning glory** (*Ipomea hederacea*)**12"**; Volunteer onions 16"; Flaxleaf fleabane (*Conyza bonariensis*) 2"; **Yellow nutsedge 6"**; Barnyard grass (*Echimochloa crus-galli*) 6"; Orcutt's lovegrass 3"; Wheat 4"; **Shepherdspurse** (*Capsella bursa-pastoris*) **3"**; Sprangletop (*Loptochloa*) 16". Carrot variety Sierra at 3" (3-leaf stage).

4. Cover cropping: No studies were conducted with cover crops. After review of this concept of using a grass cover crop to shade seedling carrots to reduce fungus or bacterial problems in hot weather, growers were too busy to pre-irrigate and get a cover crop started in hot weather. Also a university engineer advised me that equipment for planting small seeded crops into a cover crop is not available. Further, some carrot production managers feel that grass killed with fluazifop might provide an inoculum for *Alternaria* or *Sclerotium* spp.

5. Sequential treatments: A trial was conducted to evaluate whether linuron could be used with sethoxydim, 24 hours later, 72 hours later or 24 hours prior to linuron. Fluazifop was also included in the test. Results and details appear in the tables below.

**Sequential treatment results on carrot safety and weed control***

| Treatment and dates | | | Evaluation dates | | | Weed control 9/18 | |
|---|---|---|---|---|---|---|---|
| 9/12 | 9/13 | 9/15 | 9/18 4+Lf | 9/26 6 Lf | 10/5 7 Lf | Ilmg | V.wheat |
| Lorox DF | -- | -- | 0.0 | 1.3 | 0.0 | 9.7 | 7.0 |
| 2x | | | 0.0 | 1.0 | 0.3 | 9.8 | 7.7 |
| Poast + Dash | Lorox | -- | 0.0 | 1.3 | 1.0 | 9.2 | 8.5 |
| 2x | | | 0.3 | 1.3 | 0.7 | 9.7 | 8.8 |
| Poast + COC | Lorox | -- | 0.3 | 0.7 | 0.3 | 9.2 | 8.8 |
| 2x | | | 1.0 | 1.0 | 0.7 | 10.0 | 8.8 |
| Poast + COC | -- | Lorox | 0.0 | 1.0 | 0.0 | 6.0 | 6.7 |
| 2x | | | 0.0 | 1.0 | 0.3 | 8.3 | 7.7 |
| Poast+Lorox+ COC | -- | -- | 0.7 | 1.0 | 1.0 | 9.7 | 9.5 |
| 2x | | | 2.7 | 2.7 | 3.0 | 10.0 | 9.8 |
| Lorox | Poast+COC | -- | 0.3 | 1.0 | 0.3 | 9.5 | 7.3 |
| 2x | | | 1.0 | 1.0 | 1.3 | 9.7 | 8.7 |

*Carrots 3" 3rd leaf, starting 4th on 9/12/88. Lorox @ 0.5 lb ai/A applied pre-emergence under linear sprinklers. Rated 0-10; 10 = kill, ave. 3 replications. Lorox 50% DF @ 1 lb ai; Poast @ 0.3 lb ai/A; Fusilade @ 0.125 lb ai/A.
Dash (vegetable crop oil concentrate); COC was Agridex; @ 1 qt/A.

**Sequential treatments on carrot safety and weed control***

| Treatment and dates | | | Evaluation dates | | | Weed control 9/18** | |
|---|---|---|---|---|---|---|---|
| 9/12 | 9/13 | 9/15 | 9/18 4+Lf | 9/26 6 Lf | 10/5 7 Lf | Ilmg | v.Wheat |
| Fus+COC | Lorox | -- | 0.3 | 0.7 | 0.3 | 9.5 | 8.7 |
| 2x | | | 1.3 | 1.0 | 2.0 | 9.8 | 9.7 |
| Lorox | Fus+COC | -- | 1.0 | 1.0 | 0.7 | 9.5 | 8.8 |
| 2x | | | 2.0 | 1.0 | 2.0 | 10.0 | 9.8 |
| Oil @ 40gpa | -- | -- | 1.0 | 0.3 | 0.7 | 8.7 | 9.7 |
| 2x | | | 2.0 | 0.7 | 1.0 | 10.0 | 10.0 |
| Lorox | -- | Oil @ 40gpa | 1.7 | 0.3 | 1.0 | 10.0 | 9.7 |
| 2x | | | 2.7 | 2.7 | 3.3 | 10.0 | 10.0 |

* Carrots 3" 3rd leaf, starting 4th on 9/12/88. Lorox @ 0.5 lb ai/A applied pre- emergence under linear sprinklers. Rated 0-10; 10 = kill, ave. 3 replications. Lorox 50% DF @ 1 lb ai/A; Poast @ 0.3 ai lb/A; Fusilade @ 0.125 lb ai.A.
Dash (vegetable crop oil concentrate); COC was Agridex: @ 1 qt/A.

The results suggest that a tank mixture should not be used when crop oil concentrate is added. This was true in a previous trial in 1987 (data not shown). However, a 24-hour lapse seems to make sethoxydim or fluazifop application safe to apply before or after linuron. Carrot oil 72 hours after linuron caused reduced vigor. Yield differences were not distinctly different with any of the treatments.

Excellent control of ivyleaf morning glory was obtained with all treatments except the low rate of carrot oil. Volunteer wheat was controlled with all treatments.

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## DPX-M6316 - A NEW CEREAL HERBICIDE FOR CALIFORNIA AND ARIZONA

J.L. Pacheco, A.A. Baber, D.L. Burgoyne, E.T. Cason,
J.F. Cook, F.W. Marmor, and W.J. Steele[1]

Abstract. DPX-M6316 {methyl 3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylate} is a new sulfonylurea herbicide developed by DuPont and university investigators over the past five years for the control of annual broadleaf weeds in California and Arizona wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). This herbicide has proven to be safe on essentially all major varieties of wheat and barley grown in the west, including desert durums (*Triticum turgidum* L.). When applied early postemergence to broadleaf weeds at rates of 0.25 - 0.50 oz ai/acre (17.5 - 35 g ai/ha) plus surfactant this compound has provided greater than 85% control of important weeds such as black mustard (*Brassica nigra* (L.) W.J.D. Koch), coast fiddleneck (*Amsinckia intermedia* Fisch. & Mey.), common chickweed (*Stellaria media* (L.) Vill.), common groundsel (*Senecio vulgaris* L.), common lambsquarters (*Chenopodium album* L.), desert rockpurslane/redmaids (*Calandrinia ciliata* (R. & P.)DC. var. menziesii (Hook.)Macbr.), London rocket (*Sisymbrium irio* L.), miners lettuce (*Montia perfoliata*(Donn)Howell), prostrate knotweed (*Polygonum aviculare* L.), shepherdspurse (*Capsella bursa-pastoris* (L.)Medik.) and more. Rotational crop studies indicate that any crop may be planted safely 60 days after application. This is due, in part, to the rapid breakdown of the active ingredient by microbes under aerobic soil conditions.

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# DOWNY BROME (*BROMUS TECTORUM* L.) INTERFERENCE IN WINTER WHEAT

Phillip W. Stahlman[1] and Stephen D. Miller[2]

Abstract. Field studies were conducted on an irrigated site near Torrington, Wyoming and on dryland sites near Archer, Wyoming and Hays, Kansas from 1983 to 1987 to measure the competitive effects of low to moderate densities of downy brome on winter wheat yield. Individual downy brome seeds were germinated in the greenhouse in 2.8-cm-diam by 5.1-cm-tall paper containers within four days of wheat seeding, and seedlings ranging from 1 to 3 leaves were transplanted in an equally-spaced geometric pattern, between four 30-cm wide wheat rows approximately three weeks after initiating germination. In one study, varying densities of downy brome were obtained by overseeding prior to seeding wheat. Data were standardized by converting wheat yields to percentage yield reduction compared to a weed-free control for each experiment. Indicator variables and a one-way covariance model were used to test the homogeneity of the intercepts and slopes of regression lines for each experiment by t-test comparisons. Data were then combined and stepwise regression procedures were used to generate the simplest equation that described yield loss as a function of downy brome density. Percent yield reduction for individual experiments increased linearly as downy brome density increased from 0 to 96 plants/$m^2$. Intercepts and slopes of regression lines for 4 of 5 experiments did not differ significantly. A quadratic equation gave the best fit of the combined data ($r^2$ = 0.69) and estimated that the densities of downy brome necessary to reduce wheat yield by 10, 15, and 20 percent were 24, 40, and 65 plants/$m^2$, respectively. Based on a $29.65 per hectare ($12.00/acre) herbicide treatment and a potential wheat yield of 2420 kg/ha (36 bu/acre), the economic threshold was reached at a density of approximately 36 downy brome/$m^2$ (3.3/$ft^2$) when wheat was priced at $2.50 per bushel, 30 downy brome/$m^2$ (2.8/$ft^2$) when wheat was priced at $3.00 per bushel, and 24 downy brome/$m^2$ (2.2/$ft^2$) when wheat was priced at $3.50 per bushel.

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# INFLUENCE OF DORMANT-SEASON METRIBUZIN APPLICATION ON YIELD AND QUALITY OF 18 ALFALFA VARIETIES

Jed A. Heap and Ralph E. Whitesides[1]

Abstract. Alfalfa (*Medicago sativa* L.) has been reported to exhibit a temporary phytotoxic response after the application of metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} herbicide. A field experiment was conducted to determine the influence of spring-applied metribuzin on yield and quality of eighteen alfalfa varieties.

The experiment was conducted on a weed-free variety trial in the fourth year of production and previously untreated with herbicides. Each variety was plot received an application of 0.84 kg/ha ai metribuzin in the spring before

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replicated three times. Half of each varietal alfalfa had broken dormancy. Yield and quality were measured by comparing treated and untreated portions of each varietal plot. The entire experimental area was hand-weeded to ensure no weed competition influence. Yield was measured by harvesting with a Carter Harvester. Quality was determined using Near Infrared Reflectance Spectroscopy techniques on a sub-sample collected from each plot.

A dormant-season application of metribuzin did not influence alfalfa quality, as measured by percent crude protein, in any of the 18 varieties at any of the four cuttings tested. Alfalfa yield was not influenced in 15 varieties at any of the four cuttings but was increased significantly for the varieties Vernal, Trout, and Anchor in the first cutting.

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## WEED CONTROL IN SEEDLING ALFALFA WITH BROMOXYNIL

C.P. Hicks and A.J. Luke[1]

Abstract. Research plots were established at Fort Collins, CO during 1987 and 1988 to evaluate bromoxynil {3,5-dibromo-4-hydroxybenzonitrile}, alone and in combination with other herbicides, for broad spectrum weed control in seedling alfalfa. All treatments were applied using a $CO_2$ backpack sprayer with 11002 nozzles at 20 gal/A and a pressure of 32 psi. Herbicides were applied on 5/30/87 (air temp 49 F, relative humidity 51% and soil temp 68 F) to 3 trifoliate alfalfa (var. Hytons), 4 leaf redroot pigweed (AMARE), 2- to 4-inch tall kochia (KCHSC) and 6 inch barnyard grass (ECHCG). Bromoxynil at 0.38 lb ai/A provided good control (88-90%) of redroot pigweed and kochia. The combination of bromoxynil + sethoxydim {2-[1-(ethnoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} + crop oil completely controlled barnyard grass. Slight alfalfa injury (5% or less) was observed with bromoxynil. The addition of crop oil to bromoxynil increased alfalfa injury (13%). However, alfalfa quickly outgrew this injury.

In the second trial, treatments were applied on 6/4/88 (air temp 75 F, relative humidity 36% and soil temp 70 F) to 4 to 10 trifoliate alfalfa (var. Pioneer 5432), 5 to 8 leaf common sunflower (HELAN), 4 to 6 leaf redroot pigweed, 4 to 8 inch tall common lambsquarters (CHEAL) and 3 to 5 inch tall yellow foxtail (SETLU). Bromoxynil provided excellent control (90-100%) of all broadleaf weeds. Bromoxynil + sethoxydim + crop oil resulted in 92% control of yellow foxtail. Bromoxynil + imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} + X-77 provided excellent control (>95%) of broadleaf weeds and fair control (72%) of yellow foxtail. Imazethapyr alone resulted in poor control (13%) of common lambsquarters. Extreme daily temperatures (>90 F) at and following application resulted in moderate alfalfa injury. The addition of crop oil or 2,4-DB {4-(2,4-dichlorophenoxy)butanoic acid} to bromoxynil greatly enhanced alfalfa injury. Large alfalfa (6 to 10 trifoliate) was more tolerant to bromoxynil under these extreme temperatures.

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# EFFICACY AND YIELD COMPARISON OF HERBICIDES IN SEEDLING ALFALFA IN THE CENTRAL VALLEY OF CALIFORNIA

M. Canevari[1], D. Colbert[2], R. Chavarria[1], and P. Verdegaal[1]

Abstract. Weed control is essential to assure stand establishment and produce top yield and quality alfalfa. If weeds are left uncontrolled, yields can be reduced substantially, and the stand can be weaker or even lost.

In California, 200,000 acres of alfalfa are planted annually. The majority is seeded during the fall months. Cool seasonal temperatures, rain and foggy conditions minimize alfalfa growth and favor competitive winter annual broadleaf weeds and grasses. Available herbicides are often limited by the environmental conditions present or size of newly seeded alfalfa. Certain winter annual broadleaf weeds are not effectively controlled with registered herbicides; i.e.,*Brassica* spp., *Amsinckia intermedia*, *Descurainia perinata*, *Capsella bursa-pastoris*, *Erodium* spp. and *Malva neglecta*.

An experiment was conducted in the winter of 1988 to fall planted alfalfa. Two timings of applications were made in January and February utilizing eight herbicides singly and in combinations at various rates. Ratings were made at 30 and 60 DAT and harvest yields made at 1st and 2nd cuttings. Harvest weight samples from each replication were made with separation of broadleaf and grass weeds. Estimates of gross income per acre based on quality were calculated using current hay prices listed by Hay Market News reports and San Joaquin Hay Growers Association selling prices.

## Summary

It was apparent based on the weed types and populations when both broadleaf and grass weeds are controlled, that alfalfa yields are higher at the first two harvest times. Herbicides that only controlled grass type weeds allowed the broadleaf weeds to flourish. The effects from broadleaf competition reduced the growth of alfalfa significantly at first harvest, but allowed for a faster recovery by the second cutting than when grasses were the predominant weed at first cutting.

In this trial the effects from grass competition (wild oats), *Avena fatua*, reduced alfalfa yields significantly for both 1st and 2nd harvest to a greater degree than did competition from broadleafs.

In the untreated control plots, yields ranked very low for both cuttings as did treatments from herbicides that caused crop injury and provided poor weed control.

## January treatments

Imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} and pronamide {3,5-dichloro(*N*-1,1-dimethyl-2-propynyl)benzamide} + 2,4-DB {4-(2,4-dichlorophenoxy)butanoic acid} amine provided the highest yields and best overall weed control.

Alfalfa yields were 37% greater with early vs. late treatment timings.

Alfalfa yields at 2nd harvest remained 31% greater from early application vs. late treatment timings.Imazethapyr and pronamide treatments statistically provided best grass control.

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[1]University of California Cooperative Extension Service
[2]American Cyanamid Company

DPX-M6316 {methyl 3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid} provided the best broadleaf control.

## February treatments

Imazethapyr treatments provided the highest alfalfa yield.

Imazethapyr, pronamide and paraquat {1,1'-dimethyl-4,4'-bipyridinium ion} treatments provided best control of grasses.

Pronamide + 2,4-DB treatment gave the best control of broadleaf weeds.

## SEEDLING ALFALFA WEED CONTROL TRIAL 1987-88

### Early Treatment Trial

Treatment date: 12/26/86

| | |
|---|---|
| Volume: | (8002 30 psi) 20 gpa |
| Soil temperature: | 50° F |
| Air temperature: | 52° F |
| | overcast, foggy |
| Soil moisture: | medium/high |
| | wet foliage |
| Humidity: | 87% |

| Crop/Weeds | Plants per sq/ft | Weed Size |
|---|---|---|
| Alfalfa | 24 | 2-3 trifoliate, 1/2 - 1" tall |
| Fiddleneck | .7 | 2-6" diameter |
| Redmaid | 1.2 | 2-3" diameter |
| Black mustard | 15.3 | 90% 2-5" diameter |
| | | 10% 8-12" diameter |
| Annual sowthistle | 1.5 | 3-4 leaf, 1 1/2 - 2" diameter |
| Annual bluegrass | 11.3 | 3-leaf, 2nd tiller |
| Wildoats | 3 | 50% fully tillered, 7-9" tall |
| | | 50% 1-2 tillers, 3-6" tall |
| Common chickweed | 4.8 | 1/2 - 1" tall |
| Prickly lettuce | .2 | 4-leaf, 2" diameter |
| Shepherdspurse | 3 | 4-6 leaf, 1/2 to 1 1/2" diameter |
| Fillaree | | (uneven population) 3-6" diameter |

### Late Treatment Trial

Treatment date: 1/14/87

| Crop/Weeds | Plants per sq/ft | Weed Size |
|---|---|---|
| Alfalfa | 24 | 2.5 - 3.5 trifoliate leafs |
| Black mustard | 13 | 3-6 leaf, 4-8" diameter |
| Shepherdspurse | 4 | 4-6 leaf, 1-3" diameter |
| Wildoats | 3 | 4-leaf tillered, 3-9" tall |
| Bluegrass | 13 | 3-leaf tillered, 1/2 - 2" tall |
| Chickweed | 5 | 2-5" tall |
| Fillaree/Redstem | .3 | 5-8 leaf, 4-8" diameter |
| Annual sowthistle | 1 | 3-6 leaf, 3-6" diameter |
| Fiddleneck | 1 | 8-12 leaf, 4-8" tall |
| Henbit | .7 | 6-leaf, 2" tall |
| Thyme leaf speedwell | .2 | 3-4 leaf, 1/2 - 1" tall |
| Prickly lettuce | .3 | 3-4 leaf, 1-2" tall |
| Malva | .1 | 4-6 leaf, 3" diameter |
| Common groundsel | .2 | 6-8 leaf, 2" tall |

SEEDLING ALFALFA WEED CONTROL TRIAL 1987-88
(Early Treatment)

| Treatment | Rate Lb/A | Mustard | Wildoat | Bluegrass | Chickweed | Fiddleneck | Shepherds-Purse | Sow Thistle | Filaree | Pineapple Weed | Thyme Leaf Speedwell | Henbit | Crop Injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Imazethapyr | .063 | 5.6 | 6.9 | 3.25 | 6.5 | 6.75 | 7.1 | 4.5 | 8.5 | 2.50 | 1.75 | 4.0 | .3 |
| Imazethapyr | .094 | 8.1 | 8.9 | 7.3 | 8.1 | 8.1 | 8.4 | 5.5 | 9.9 | 3.1 | 4.6 | 7.0 | 1.1 |
| Imazethapyr | .125 | 9.3 | 9.4 | 8.3 | 9.2 | 9.4 | 9.4 | 7.2 | 10.0 | 3.25 | 4.0 | 6.25 | 1.6 |
| Imazethapyr | .094 | 9.7 | 7.2 | 3.5 | 7.7 | 7.1 | 9.1 | 9.5 | 9.9 | 9.6 | 3.9 | 4.3 | 2.2 |
| + 2,4-DB | 1.0 | | | | | | | | | | | | |
| 2,4-DB | 1.5 | 9.3 | 1.3 | 0.5 | 0.5 | 4.0 | 9.0 | 9.7 | 3.6 | 9.9 | 2.5 | 2.25 | .5 |
| Pronamide | 2.0 | 6.5 | 9.7 | 9.8 | 9.7 | 9.9 | 6.0 | 1.25 | 2.5 | 1.75 | 9.9 | 10.0 | 2.5 |
| Pronamide | 1.0 | 9.5 | 8.9 | 10.0 | 9.5 | 8.7 | 7.1 | 8.5 | 3.75 | 8.2 | 9.6 | 6.1 | 2.7 |
| + 2,4-DB | 1.5 | | | | | | | | | | | | |
| DPX-M6316 | .125 oz | 9.9 | 1.0 | 0 | 1.0 | 9.9 | 8.7 | 1.0 | 1.9 | 6.4 | 4.0 | 2.5 | .3 |
| DPX-M6316 | .25 oz | 9.9 | 0.9 | 0 | 4.0 | 10.0 | 9.5 | 1.75 | 2.0 | 9.1 | 6.0 | 3.0 | 1.0 |
| DPX-M6316 | .375 oz | 10.0 | 1.25 | 0 | 6.75 | 10.0 | 9.9 | 2.25 | 2.5 | 9.9 | 9.1 | 3.0 | 1.2 |
| DPX-M6316 | .25 oz | 10.0 | 0.75 | 0.5 | 2.5 | 10.0 | 9.5 | 4.1 | 3.4 | 9.2 | 6.75 | 2.25 | 1.0 |
| + 2,4-DB | 1.0 | | | | | | | | | | | | |
| Paraquat | .125 | 7.5 | 7.4 | 8.0 | 7.7 | 7.7 | 6.6 | 5.6 | 9.4 | 9.7 | 4.25 | 1.5 | 1.0 |
| Pronamide | 1.0 | 9.25 | 9.1 | 10.0 | 9.1 | 8.3 | 7.9 | 8.9 | 4.8 | 4.75 | 9.5 | 6.7 | 2.8 |
| + 2,4-DB | 1.0 | | | | | | | | | | | | |
| Control | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .6 |
| Imazethapyr | .094 | 8.7 | 10.0 | 10.0 | 9.8 | 10.0 | 10.0 | 8.0 | 10.0 | 3.0 | 5.0 | 9.0 | 1.2 |
| + Pronamide | .5 | | | | | | | | | | | | |
| 2,4-DB | 1.0 | 9.5 | 1.0 | 0 | 0 | 4.0 | 9.5 | 10.0 | 1.0 | 9.5 | 2.0 | 2.0 | 1.5 |

Weed control scale: 0 = no control 10 = 100% weed kill
Crop injury: 0 = no injury 10 = crop dead

**Rating: 2/27/87**

## SEEDLING ALFALFA WEED CONTROL TRIAL 1987-88
(Late Treatment)

| Treatment | Rate Lb/A | Bluegrass | Mustard | Shepherds-Purse | Annual Sowthistle | Fiddleneck | Groundsel | Henbit | Wildoats | Filaree | Chickweed | Crop Injury |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Imazathapyr | .063 | 3.5 | 2.75 | 5.9 | 4.25 | 4.75 | 6.75 | 5.0 | 5.25 | 8.25 | 7.0 | 0 |
| Imazathapyr | .094 | 6.25 | 6.3 | 7.2 | 4.7 | 6.3 | 9.0 | 6.3 | 7.2 | 9.0 | 8.7 | 1.2 |
| Imazathapyr | .125 | 7.1 | 8.2 | 8.6 | 6.25 | 7.9 | 7.75 | 8.0 | 8.8 | 10.0 | 8.9 | 1.7 |
| Imazathapyr | .094 | 4.75 | 9.4 | 8.75 | 9.75 | 7.75 | 8.5 | 4.0 | 6.75 | 9.25 | 6.0 | 1.9 |
| + 2,4-DB | 1.0 | | | | | | | | | | | |
| Pronamide | 1.0 | 10.0 | 9.2 | 2.25 | 7.75 | 9.5 | 6.5 | 4.0 | 8.9 | 3.0 | 8.9 | 2.9 |
| + 2,4-DB | 1.5 | | | | | | | | | | | |
| DPX-M6316 | .125 oz | 2.0 | 9.5 | 10.0 | 4.75 | 10.0 | 9.5 | 7.0 | 2.5 | 1.5 | 3.0 | 2.1 |
| DPX-M6316 | .25 oz | 2.25 | 9.6 | 10.0 | 7.50 | 10.0 | 10.0 | 6.5 | 2.0 | 1.25 | 2.5 | 1.7 |
| DPX-M6316 | .375 oz | 2.5 | 9.6 | 10.0 | 9.0 | 10.0 | 10.0 | 6.0 | 2.0 | 1.25 | 5.0 | 2.6 |
| DPX-M6316 | .25 oz | 0.75 | 10.0 | 10.0 | 8.75 | 9.9 | 9.75 | 4.25 | 1.75 | 4.0 | 3.25 | 2.4 |
| + 2,4-DB | 1.0 | | | | | | | | | | | |
| Paraquat | .25 | 9.2 | 6.25 | 2.0 | 8.5 | 5.0 | 10.0 | 0 | 9.6 | 9.75 | 9.75 | 1.1 |
| Oxyfluorfen | .125 | 1.75 | 2.0 | 1.75 | 7.0 | 5.75 | 10.0 | 10.0 | 2.0 | 6.0 | 2.25 | 3.5 |
| Oxyfluorfen | .25 | 1.75 | 3.0 | 2.25 | 10.0 | 7.0 | 10.0 | 10.0 | 2.5 | 9.5 | 2.0 | 4.75 |
| Hexazinone | .125 | 3.75 | 3.75 | 4.25 | 8.25 | 4.5 | 10.0 | 2.5 | 1.75 | 2.75 | 7.75 | 2.5 |
| Hexazinone | .25 | 8.25 | 7.6 | 5.5 | 5.0 | 6.25 | 10.0 | 5.0 | 1.5 | 4.5 | 9.50 | 4.0 |
| Bromoxynil | .5 | 0 | 9.1 | 8.9 | 10.0 | 10.0 | 10.0 | 3.25 | 1.25 | 1.0 | 1.0 | 1.25 |
| Oxyfluorfen | .125 | 10.0 | 3.0 | 1.5 | 2.5 | 9.5 | 8.75 | 10.0 | 9.75 | 8.25 | 9.75 | 4.25 |
| + Pronamide | 1.0 | | | | | | | | | | | |
| Control | -- | 0 | 0 | 0 | 0 | 0.25 | 1.25 | .25 | 0 | 0.25 | 0 | 2.0 |

Weed control scale 0 = no control 10 = 100% weed kill
Crop Injury 0 = no injury 10 = crop dead

Rated: 3/16/87

| Treatment | Rate Lb/ai | Total Biomass 80% D.M. Yield Lb/A | FIRST CUTTING — Biomass Composition 80% D.M. per Acre: Lb Broad-leafs (%) | Lb Grasses (%) | Lb Alfalfa (%) | *Acre Gross Income | SECOND CUTTING: Total Alf. Yield Lb/A | ** Gross Income | COMMENTS First Cutting (Weeds) |
|---|---|---|---|---|---|---|---|---|---|
| Imazethapyr | .094 | 2847 | 826 (29%) | 85 ( 3%) | 1936 (68%) | $128 | 2636 | $125 | Mustard, oats, sowthistle |
| 2,4-DB | 1.5 | 3334 | 1067 (32%) | 1434 (43%) | 833 (25%) | 67 | 1404 | 67 | Oats, bluegrass, mustard fiddleneck, chickweed |
| Pronamide | 2.0 | 4130 | 3097 (75%) | 83 ( 2%) | 950 (23%) | 83 | 2000 | 95 | Mustard, sowthistle, oats |
| Pronamide + 2,4-DB | 1.0 1.5 | 2796 | 839 (30%) | 168 ( 6%) | 1789 (64%) | 126 | 2270 | 108 | Sowthistle, mustard, oats |
| DPX-M6316 | .25 oz | 3232 | 388 (12%) | 2489 (77%) | 355 (11%) | 97 | 1558 | 74 | Sowthistle, filaree, oats |
| Paraquat | .125 | 3284 | 1445 (44%) | 887 (27%) | 952 (29%) | 66 | 1943 | 92 | Sowthistle, mustard, oats |
| Pronamide + 2,4-DB | 1.0 1.0 | 2719 | 952 (35%) | 190 ( 7%) | 1557 (58%) | 82 | 1943 | 92 | Mustard, oats |
| Check | -- | 4725 | 2644 (61%) | 1647 (38%) | 434 ( 1%) | 95 | 981 | 47 | Sowthistle, chickweed, shepherdspurse, mustard fiddleneck, oats |
| Pronamide + 2,4-DB | 1.0 1.5 | 1309 | 157 (12%) | 118 ( 9%) | 1034 (79%) | 65 | 1693 | 80 | Mustard, oats |
| Paraquat | .25 | 2667 | 1601 (60%) | 53 ( 2%) | 1013 (38%) | 53 | 1751 | 83 | Mustard, sowthistle, fiddleneck, chickweed, oats |
| Oxyfluorfen | .125 | 3284 | 1675 (51%) | 1379 (42%) | 230 ( 7%) | 66 | 904 | 43 | Mustard, chickweed, oats |
| Hexazinone | .125 | 3360 | 1680 (50%) | 1277 (38%) | 403 (12%) | 67 | 1020 | 48 | Mustard, oats |
| Hexazinone | .25 | 3027 | 424 (14%) | 2331 (77%) | 272 ( 9%) | 91 | 1154 | 55 | Mustard, sowthistle, oats |
| Bromoxynil | .5 | 2770 | 471 (17%) | 2022 (73%) | 277 (10%) | 83 | 1097 | 52 | Mustard, chickweed, oats |
| Imazethapyr | .094 | 2420 | 693 (27%) | 51 ( 2%) | 1676 (71%) | 109 | 1558 | 74 | Mustard, oats |
| Check | -- | 3566 | 1890 (53%) | 1319 (37%) | 357 (10%) | 71 | 1058 | 50 | Mustard, fiddleneck, oats |

* Price per ton May 1987, first cutting
Source: Hay Market News; San Joaquin Valley Hay Association
Premium, clean alfalfa: $105 ton
First cut weedy alfalfa: $40 ton
Alfalfa/oat mix: $60 ton

** 2nd cutting
Premium, clean, leafy hay: $95 ton

# SETHOXYDIM FOR SUMMER ANNUAL GRASS CONTROL IN ARIZONA ALFALFA

B.R. Tickes[1], E.S. Heathman[2] and R. Oliver[3]

Abstract. Summer annual grassy weeds can infest Arizona alfalfa from April to October. Annual and perennial grasses may significantly reduce forage quality and stand vigor. Predominant summer annual grass weeds are *Echinochloa colonum* (Junglerice), *Echinochloa gracills* (southwestern cupgrass), *Leptochloa filiformis* (red sprangletop) and *Leptochloa uninervia* (mexican sprangletop). Pre-emergence herbicides and cultural practices have been the most common methods of controlling summer annual grasses in this region. Sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} offers an additional tool to supplement these practices. The purpose of this test was to evaluate various rates and times of application of sethoxydim for summer annual grass control in Arizona alfalfa. Research plots were established between May and July, 1988 in a four-year-old stand of non-dormant alfalfa (Cultivar CUF101) located in the Yuma Valley on silty loam soil. Weeds present were watergrass, barnyardgrass (*Echinochloa crus-galli*), prairie and southwestern cupgrass, red and mexican sprangletop at an infestation of 20 to 50 per square foot. Fifty by ten foot plots were treated with a backpack sprayer calibrated to apply 40 gallons per acre. The test contained a total of 13 treatments including an untreated check in a randomized complete block design replicated four times. Treatments were applied when the weeds were actively growing and not stressed and the alfalfa was no more than 12 inches in height. Treatments were sethoxydim applied at 0.3 lbs. ai/A and 0.5 lbs ai/A once on either 5/6/88, 6/15/88 or 7/14/88, twice on 5/6/88 and 6/15/88, or 5/6/88 and 7/14/88 or 6/15/88 and 7/14/88. All treatments included 1 qt/A mor act crop oil. Grass weeds were seedling to 3 leaf at the 5/6/88 application, seedling to tillering at the 6/15/88 application and seedling to established with 20% heading at the 7/14/88 application. Visual evaluations of percent control were made prior to 4th, 5th and 6th cuttings on 5/27/88, 7/5/88 and 7/26/88 respectively. Sethoxydim at 0.5 lb/A was more effective for summer annual grass control when applied twice during the season. A single application early in the season, May 6th or June 15th, gave only temporary control because of the constant emergence of new seedling weeds. A single application late in the season, July 14, did not prevent early season weeds from reducing forage quality. Sethoxydim tended to be more effective at the 0.5 lb/A rate than the 0.3 lb/A rate when applied once or twice. The May 6th application followed by a June 15th application at 0.3 lb/A gave significantly less control by July 26 than any other multiple application.

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Control of Summer Annual Grasses
with various Rates and Times of Application of Sethoxydim

| Rate (Lbs/A) | Date(s) of Application | Percent Control of Summer Annual Grasses on: May 27 | July 5 | July 26 |
|---|---|---|---|---|
| 0.3 | 5-6 | 89 b* | 68 b | 41 b |
| 0.5 | 5-6 | 96 c | 78 cd | 44 b |
| 0.3 | 6-15 | -- a | 79 cd | 56 bc |
| 0.5 | 6-15 | -- a | 90 e | 69 cd |
| 0.3 | 7-14 | -- a | -- a | 78 de |
| 0.5 | 7-14 | -- a | -- a | 89 ef |
| 0.3 | 5-6 and 6-15 | 89 b | 86 de | 70 cd |
| 0.5 | 5-6 and 6-15 | 94 c | 94 e | 89 ef |
| 0.3 | 5-6 and 7-14 | 86 b | 62 b | 91 ef |
| 0.5 | 5-6 and 7-14 | 97 c | 75 c | 97 b |
| 0.3 | 6-15 and 7-14 | -- a | 79 cd | 93 ef |
| 0.5 | 6-15 and 7-14 | -- a | 90 e | 99 f |
| *Untreated* | -- | *0* a | *0* a | *0* a |

*Means followed by the same letter are not significantly different by the SNK test at the .05 level of significance.

## IMAZETHAPYR FOR USE IN WESTERN U.S. ALFALFA PRODUCTION

D. Colbert, R. Nielsen, M. Risley, K. Umeda, S. Carlson[1]
H. Agamalian, M. Canevari, H. Carlson, J. Orr, S. Orloff, R. Vargas[2]
S. Heathman and B. Tickes[3]

Abstract. Imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-[*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} is in the imidazolinone herbicide family and is being developed by American Cyanamid Company for use in alfalfa and other leguminous crops. Imazethapyr is quickly absorbed by roots and foliage of susceptible weeds and translocated in the phloem and xylem to meristematic regions where it inhibits production of the branched chain amino acids.

Postemergence applications of imazethapyr have been evaluated for weed control and crop tolerance in seedling and established alfalfa in over 75 field experiments conducted in Oregon, Washington, Idaho, California, and Arizona from 1983-88. Imazethapyr was tested postemergence at 0.063, 0.094, and 0.125 lb ae/A for crop tolerance and weed control in: 1) established semidormant alfalfa; 2) established, nondormant alfalfa before the first cutting and between cuttings; and 3) seedling alfalfa.

Newly seeded and established alfalfa tolerance was excellent to postemergence applications of imazethapyr up to 0.125 lb/A. Postemergence applications of imazethapyr at 0.063 to 0.094 lb/A provided better than 85% control of the following weed species:

[1]American Cyanamid Company
[2]University of California Cooperative Extension Service
[3]University of Arizona Extension Service

Black mustard (*Brassica nigra*)
Burning nettle (*Urtica urens*)
Common chickweed (*Stellaria media*)
Common lambsquarters (*Chenopodium album*) (1-4 leaf stage)
Corn spurry (*Spergula arvensis*)
Field pennycress (*Thlaspi arvense*)
Flixweed (*Descurainia sophia*)
Hairy nightshade (*Solanum sarrachoides*)
Jimsonweed (*Datura stramonium*)
Kochia (*Kochia scoparia*)
Little mallow (*Malva parviflora*)
London rocket (*Sisymbrium irio*)
Minerslettuce (*Montia perfoliata*)
Nettleleaf goosefoot (*Chenopodium murale*)
Panicle willow weed (*Epilobium paniculatum*)
Redmaids (*Calendrinia caulescens*)
Redstem filaree (*Erodium cicutarium*)
Redroot pigweed (*Amaranthus retroflexus*)
Shepherdspurse (*Capsella bursa-pastoris*)
Swinecress (*Coronopus didymus*)
Tansy mustard (*Descurainia pinnata*)
Tumble mustard (*Sisymbrium altissimum*)
Whitestem filaree (*Erodium moschatum*)
Wild radish (*Raphanus raphanistrum*)
Wild beet (*Beta vulgaris*)

Barnyardgrass (*Echinochloa crus-galli*) (1-4 leaf stage)
Wild oat (*Avena fatua*)
Yellow foxtail (*Setaria glauca*)

The following weed species were not controlled with imazethapyr up to 0.094 lb/A.

Annual sowthistle (*Sonchus oleraceus*)
Mayweed chamomile (*Anthemis cotula*)
Prickly lettuce (*Lactuca serriola*)
Pineappleweed (*Matricaria matricarioides*)
Volunteer barley (*Hordeum vulgare*)

Follow crop studies were initiated in 1987 and 1988 in Arizona and California with imazethapyr at 0.125 and 0.25 lb/A. Alfalfa was treated in the winter, removed the following spring or fall, and appropriate rotational crops were planted. Cotton, cantaloupe, sudangrass, and tomatoes were not tolerant to imazethapyr soil residues in the spring, three months after application. In the fall, nine months after treatment, cantaloupe, lettuce, onions, and wheat exhibited less than 10% crop response; carrots, broccoli, and tomatoes exhibited from 15 to 30% crop response; and sugarbeets exhibited between 80 and 90% response.

Future research with imazethapyr will be focused on: 1) tankmixes with the broadleaf herbicides, 2,4-DB, and bromoxynil; 2) efficacy studies using liquid fertilizer and crop oil concentrates as additives, 3) follow crop studies, and 4) soil dissipation studies.

# CUTTING INTERVAL AND TIME OF IRRIGATION IN ALFALFA; YELLOW FOXTAIL INVASION AND ECONOMIC ANALYSIS

Robert F. Norris[1]

Abstract. Yellow foxtail (*Sertaria glauca* (L.) Beauv.) is the most serious summer annual weed in alfalfa (*Medicago sativa* L.) in the Central Valley of California. Alfalfa was cut on 25-day, 31-day or 37-day intervals for a three-year period. Irrigation was applied on the same day as cutting or after a delay of 7 or 14 days and again approximately one week prior to the next cutting. Alfalfa yield increased with increased length of cutting interval but was not affected by irrigation regime. Little yellow foxtail invaded at the 37-day cutting interval; invasion was intermediate at the 31-day interval and reached 20% to 30% of late season harvests at the 25-day cutting interval. Delaying irrigation following cutting reduced yellow foxtail invasion two years out of three; this effect was largest for hay cut on the 31-day interval. The yield data were incorporated into a computer spread-sheet program and a model to predict 'net' economics was developed. The model allowed for variation in harvesting and irrigation costs, and permitted variation in hay value in relation to the age of the alfalfa at cutting and on the basis of the quantity of yellow foxtail in the hay. Net hay selling price can be altered. Cutting at a 25-day interval was not justified on the basis of 'net' return; the higher value alfalfa was compromised by low overall yield and substantial yellow foxtail invasion late in the season. Hay cut at the 31-day cutting interval would provide the highest net return under most marketing conditions evaluated. Reduced alfalfa quality of longer cutting intervals compromised the return for the 37-day cutting interval unless discounts for mature hay were minimal. Yellow foxtail can be controlled economically in alfalfa by manipulation of cutting interval without necessity of using herbicides.

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# WEED CONTROL WITH CULTURAL AND CHEMICAL METHODS IN HAWAIIAN SUGARCANE

Lance T. Santo[1]

## Introduction

Cultural practices in combination with chemical methods are used to control weeds in Hawaiian sugarcane fields. The weed problem can be minimized in favorable climate and by using the best agronomic practices to obtain a healthy crop with rapid canopy closure which can compete with the weeds and shade them out. The effect of climate and agronomic practices on weed control are described, but the primary emphasis of my paper is on the use of herbicides, the foundation for controlling weeds in Hawaiian sugarcane fields.

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[1]Published as Paper No. 673 in the journal series of the Experiment Station, Hawaiian Sugar Planters Association, Aiea, HI

Preemergence herbicides are used as the primarby method of controlling weeds, while postemergence herbicides play a backup role to control misses or escapes.

## Problem Weeds

Grass weeds are more problematic than broadleaf weeds because very few postemergence herbicides will control weeds like guineagrass (*Panicum maximum*), swollen fingergrass (*Chloris inflata*), alexandergrass (*Brachiaria planteginea*), jobs tears (*Coix lacrymajobi*), or torpedo grass (*Panicum repens*) without damaging sugarcane. Dalapon {2,2-dichloropropanoic acid} and asulam {methyl[(4-aminophenyl)sulfonyl]carbamate} are herbicides that are selective to sugarcane, but neither can control all of the above grass weeds.

Vines such as Aiea morning glory (*Ipomoea triloba*) and peria (*Momordica charantia*) are the most serious problem broadleaf weeds that can grow over the sugarcane canopy. Some other problem weeds are castorbean (*Ricinus communis*) and clover (*Desmodium intortum*).

## Irrigated and Unirrigated Sugarcane

In Hawaii sugarcane is grown on about 181,000 acres of which 59% is irrigated and the remainder unirrigated (Table 1). The yield potential is about 2 tons of sugar per acre greater in the irrigated fields than in the unirrigated fields. The average sugar field for the last four years for all islands ranged from 10.2 to 14.8 tons per acre (Table 2).

**Table 1.**
Irrigated and Unirrigated Sugarcane Acreage in Hawaii

| Island | Irrigated | Unirrigated |
|---|---|---|
| Hawaii | 7,193 | 61,270 |
| Kauai | 32,466 | 10,533 |
| Maui | 43,816 | 0 |
| Oahu | 23,939 | 1,750 |
| Total | 107,414 | 73,553 |

**Table 2.**
Sugar Yields for 1985, 1986, 1987, and 1988

| Island | Sugar (tons/acre) | | | |
|---|---|---|---|---|
| | 1985 | 1986 | 1987 | 1988 |
| Hawaii | 11.1 | 11.5 | 10.2 | 10.2 |
| Kauai | 11.5 | 11.5 | 12.4 | 11.3 |
| Maui | 12.9 | 13.8 | 14.3 | 13.9 |
| Oahu | 14.8 | 14.4 | 13.8 | 12.4 |
| All Islands | 12.2 | 12.5 | 12.3 | 11.8 |

The irrigated fields are located in leeward areas with less than 50 inches of annual rainfall. Compared with the unirrigated fields, the irrigated fields have more sunlight and warmer temperatures, which result in rapid crop growth, canopy closure within four to five months, and crop maturity in about two years. The unirrigated fields are in windward locations with greater than 70 inches and as much as 200 inches of annual rainfall. In these fields, canopy closure occurs in 6 to 10 months and crop maturity in 2 to 3 years. These longer-duration open areas and wet conditions usually result in more weed growth, a condition which may require one or more additional herbicide applications than the irrigated fields to control weeds.

## Cultural Practices Affecting Weed Control

Practices that ensure fast crop growth and canopy closure will reduce the weed problem. The most critical stage is the first 2 months after planting when the crop cannot compete favorably with most weeds. Good tillage aids by creating a friable, aerated media for roots, eliminating existing weeds, and burying seeds. Ratoon fields, which are not tilled, usually require more herbicides than plant fields to achieve acceptable weed control. After planting, weeds are not mechanically cultivated; only herbicides are used.

A vigorous, high-yielding variety is planted using sets or transplants. It is essential to have uniform stands of plant or ratoon sugarcane to ensure a highstalk population for rapid canopy closure and high yield. Close seed and row spacings and rapid tillering and recumbent varieties minimize the weed problem.

Water and fertilizers must be applied on a timely basis for optimal crop growth. A healthy crop can compete favorably with most annual weeds and is less susceptible to herbicide damage. Drip irrigation reduces the number of weeds by moistening only the planted rows and keeping the interrows dry and free of weeds. Only strip application of herbicides over the planted row is required during the dry summer period. Once the crop closes-in, only the vines and perennial weeds may still be a problem, and they must be controlled before canopy closure.

## Annual Herbicide Usage in Hawaiian Sugarcane

Ametryn {*N*-ethyl-*N*'-(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine}, diuron {*N*'-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea}, and atrazine {6-chloro-*N*-ethyl-*N*'-(1-methylethyl)-1,3,5-triazine-2,4-diamine} make up about 80% of the 1.7 million pounds of active ingredients of herbicides used in Hawaii (Table 3). Other herbicides with usage exceeding 25,000 lb a.i. per year are

**Table 3.**
Herbicide Usage in Hawaiian Sugarcane Fields in 1987

| Herbicide | % of Total | Herbicide | % of Total |
|---|---|---|---|
| **Ametryn** | **27.5** | Terbacil | 0.5 |
| **Diuron** | **26.4** | Simazine | 0.4 |
| **Atrazine** | **22.8** | Asulam | 0.1 |
| Dalapon | 12.1 | Picloram | — |
| 2,4-D | 6.1 | Dicamba | — |
| Glyphosate | 2.4 | Trifluralin | — |
| Hexazinone | 1.7 | Sulfmeturon | — |

Note: 1,647,907 lb a.i. of herbicides were used in 1987.

dalapon {2,2-dichloropropanoic acid}, 2,4-D {(2,4-dichlorophenoxy)acetic acid}, glyphosate {*N*-(phosphonomethyl)glycine} and hexazinone {3-cyclohexyl-6-(di-methyl-amino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione}. The use of hexazinone, terbacil, and trifluralin is increasing because of triazine-resistant swollen fingergrass (*Chloris inflata*). Also trifluralin is replacing ametryn and diuron where transplants are planted instead of setts. The use of glyphosate and hexazinone will increase dramatically in the next few years with the loss of dalapon for grass control in sugarcane.

## Preemergence Herbicides

The basic mix consists of ametryn or diuron (for irrigated or unirrigated fields, respectively) plus atrazine at rates of about 4 lb per acre of each herbicide. The above mix will control most seedling weeds for about 5 to 8 weeks. Usually only one application after planting is required in the irrigated environment, whereas two to three applications may be required in the high-rainfall, unirrigated environment. Terbacil or hexazinone is added to the above mix at about 0.5 to 1.0 lb per acre in fields with perennial grasses or triazine-resistant swollen fingergrass.

The preemergence herbicides are usually broadcasted by tractor at 20 to 30 gpa or applied by aircraft (fixed-wing or helicopter) at 10 to 20 gpa. The above mixes can be applied over 2- to 3-month-old sugarcane and some cane damage but little or no negative effect on yield. No visible damage occurs if the mix is applied before sugarcane shoot emergence.

The mix of trifluralin (3 lb per acre) plus atrazine is used in fields planted with transplants because ametryn or diuron can stunt and delay the establishment of the plantlets. The amount of trifluralin used is related to the acreage planted with transplants. Preemergence herbicides continue to be the mainstay of our weed control program.

## Postemergence Herbicides

The postemergence herbicides commonly used are a combination of ametryn, atrazine, and 2,4-D at rates of 4,4, and 1 lb per acre, respectively. Ametryn at rates as high as 8 lb per acre may be included in the mix if guineagrass is present. Diuron is sometimes partially or entirely substituted for ametryn. Dalapon at 8 lb per acre or hexazinone at 1 to 2 lb per acre may be added if perennial grass weeds are present.

Glyphosate at 0.75 to 3 lb per acre (0.5 to 2% v/v of Roundup at 50 gpa) is spot-applied to control perennial grass weeds taller than 12 inches. Occasionally, 2,4-D is missed with glyphosate if broadleaf weeds are also present. A nonionic surfactant at 0.5% v/v is included in all of the above postemergence herbicide mixes; in addition, ammonium sulfate at 2% w/w is sometimes added with glyphosate.

The postemergence herbicide mix may be applied with a tractor as a directed-interline, broadcase application if the sugarcane is shorter than 3.5 ft. Using a knapsack with a single flat-fan nozzle, the mix is hand-applied in fields with taller sugarcane. Glyphosate is usually hand-applied with a directed stream or wiper to weeds to avoid spraying the sugarcane.

Almost complete control of most weeds is achieved in sugarcane as a result of canopy closure. Areas where weeds can escape control and multiply are on the field edges or in fallow fields. Despite the continuous use of triazines for more than 15 years, we have identified only one confirmed, triazine-resistant biotype of swollen fingergrass to date. Fortunately, this biotype is found only on edges of a few fields and is easily controlled with glyphosate.

New Herbicides with Potential in Hawaiian Sugarcane

We installed more than 100 efficacy experiments in 1988 to find a broad spectrum preemergence herbicide with little or no adverse effect on most Hawaiian commercial varieties of sugarcane. The best herbicide tests was ICIA-0179 at an application rate of 0.25 to 0.50 lb per acre (Table 4). Only a single pre-emergence application was required to control all weeds up to crop canopy closure with no adverse effect on the sugarcane.

**Table 4.**
Unregistered Herbicides with Potential for Use in Hawaiian Sugarcane Fields

| Herbicide | Application Rate Per Acre | Type |
|---|---|---|
| ICIA-0179 | 0.25 - 0.50 lb | Pre/Post |
| Metsulfuron | 0.1 - 2.0 oz | Pre/Post |
| Pendimethalin | 1 - 3 lb | Pre |
| Metolachlor | 2 - 4 lb | Pre |
| Sulfosate | 0.25 - 2.00 lb | Post |
| Glufosinate | 0.5 - 2.0 lb | Post |
| Triclopyr | 0.5 - 2.0 lb | Post |
| Fluroxypyr | 0.5 - 2.0 lb | Post |
| Bromoxynil | 0.5 - 2.0 lb | Post |

Another herbicide with strong preemergence and postemergence activity on broadleaf and annual grass weeds was metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid}. Test results indicated that preemergence applications at a rate of 1 to 2 oz of metsulfuron per acre gave equivalent control of broadleaf weeds as atrazine at 2 to 4 lb per acre. In addition, metsulfuron can control swollen fingergrass and atrazine cannot. Postemergence application of metsulfuron gave near-complete control of flowering Aiea morning glory at 0.5 oz per acre. Preemergence application did not adversely affect the sugarcane, but some varieties, such as H73-6110, were severely stunted by over-the-top postemergence application.

Other herbicides with promise are metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide} and pendimethalin {*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine} as preemergents, and sulfosate, glufosinate, fluroxypyr, triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid} and bromoxynil {3,5-dibromo-4-hydroxybenzo-nitrile} as postemergents. We are still seeking a postemergent that can be broadcast over the field to control all grass weeds and, at the same time, have no adverse effect on the sugarcane.

# UPDATE ON THE INTEGRATED PEST MANAGEMENT PROJECT FOR CROP PRODUCTION IN THE PNW

P.A. Dotray, F.L. Young, and A.G. Ogg, Jr.[1]

The Integrated Pest Management Project for crop production in the Pacific Northwest is presently in the fourth year of field research. One complete cycle of each three-year crop rotation has been completed. The project is examining the effect of crop rotation, tillage, and weed management levels on small grain and legume yield and quality while reducing soil erosion. A study within the project that examined the effect of crop rotation and tillage on surface residue has been completed, and the data is presently being utilized by the Soil Conservation Service for farmer compliance with the 1985 Farm Bill. Specific data from 1988 indicate that only 3 of the 12 rotation x tillage treatments left sufficient residue cover to meet the 30% residue criteria. However, all reduced tillage plots left more than 30% residue cover during the critical winter months. Other facets of the project that will aid in reducing soil erosion and have shown to be effective systems include the production of spring peas under reduced tillage and the use of no-till as a crop management tool. Data from the weed seed, weed biomass, and weed management level cost effectiveness studies indicate that weeds are a greater problem in reduced tillage than conventional tillage. When economic data were averaged over three years in the winter wheat, spring barley, spring pea rotation, there was no justification to increase chemical weed control above the minimum level for wheat grown in conventional tillage. However, for wheat grown under reduced tillage, it was economically justifiable to increase weed control to the moderate level. As with winter wheat, less chemical weed control was required for peas under conventional tillage than with reduced tillage. For peas grown under reduced tillage, maximum chemical weed control was economically feasible. In 1988, take-all (*Gaeumannomyces graminis*) was prevalent in all wheat in the continuous wheat rotation, whereas, the disease was almost nonexistent where wheat was grown once every three years.

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[1]Washington State University and USDA/ARS, Pullman, WA

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# INTEGRATED JOINTED GOATGRASS (*AEGILOPS CYLINDERICA*) CONTROL

P. Westra[1]

Abstract. Jointed goatgrass (AEGCY) infests more than 200,000 acres of Colorado wheatland where annual spread occurs by combine movement from field to field, and uncovered grain trucks infesting roadsides with cylinders which bow out. Ethyl-metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} shows promise for selective post emerge goatgrass control in winter wheat, but at rates of 2-3 kg/ha which may be prohibitively expensive, and beyond labeled rates. No other herbicides have shown promise for selective control in wheat. In fallow tillage studies, V-blade sweeping and disking provided 75% goatgrass control, deep plowing (8") provided 95% control (with unacceptable wind erosion problems), and chemical fallow provided 100% control. Additional studies

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[1]Plant Pathology and Weed Science, Colorado State University, Ft. Collins, CO.

showed that clomazone {2-[(chlorophenyl)methyl]-4,4-dimethyl-3-isoxazoli-dinone}, paraquat {1,1'-dimethyl-4,4'-bipyridinium ion}, Landmaster {N-(phosphonomethyl)-glycine + 2,4-D}, or Fallowmaster {N-phosphonomethyl)glycine + 3,6-dichloro-2-methoxybenzoic acid} applied at labeled rates with 0.4 to 0.5 kg/ha atrazine {6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine} provided 90-100% goatsgrass control. A single late June sweep tillage superimposed over herbicide treatments, prior to wheat planting, provided additional goatgrass control.

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## ENVIRONMENTAL FACTORS INFLUENCING ETHIOZIN BIOACTIVITY ON JOINTED GOATGRASS

R. L. Anderson[1]

Abstract. Ethiozin {4-amino-6-(1,1-dimethylethyl-3-(ethylthio)-1,2,4-triazin-5(4*H*)-one} has bioactivity on jointed goatgrass (*Aegilops cyclindrica*), but its performance has been inconsistent. This study examined several physical factors influencing ethiozin bioactivity, with the objective of identifying the environmental conditions most favorable for ethiozin control of jointed goat-grass. The study was conducted in a greenhouse with a temperature range of 18 to 30° C, utilizing a bioassay procedure measuring above ground fresh weight 21 days after initiation of the desired treatment. Environmental and plant factors affecting ethiozin bioactivity which were examined included: 1) soil texture, 2) jointed goatgrass plant population, 3) jointed goatgrass growth stage, 4) levels and timing of water application after ethiozin application, and 5) incorporation of crop residue.

Jointed goatgrass sensitivity to ethiozin was affected by soil texture with greater bioactivity occurring in coarser-texture soils. The bioactivity of ethiozin when applied to the soil surface was only minimally affected by the jointed goatgrass population, as increasing the population from 328 to 984 plants/$m^2$ reduced the percent growth inhibition (GI) by only 14% at the 0.84 kg/ha rate. Jointed goatgrass tolerance to ethiozin increased with plant size at time of application as percent GI was reduced from 86% with a preemergence application to 40% when the seedlings were at the 4-leaf stage.

The level of water necessary to move ethiozin into the germinating seed zone (2-5 cm) of the soil was also affected by soil texture. Eight mm of water were required to achieve 75% GI of jointed goatgrass in the sand, while 12 mm of water resulted in only 60% GI in the loam soil, when ethiozin was applied to jointed goatgrass at the 1-2 leaf stage.

Jointed goatgrass seedling growth was significantly reduced when crop residue was incorporated into the soil. This effect was eliminated by the addition of 67 kg/ha of N, indicating that a N tie-up by microbial decomposition of residue restricted plant growth. When crop residue and ethiozin were both incorporated in the soil, ethiozin bioactivity was eliminated, indicating that the residue absorbed the ethiozin and prevented its entry into the jointed goatgrass seedling.

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[1]USDA, ARS, Akron, CO

This study indicates that soil texture, water application level and jointed goatgrass growth stage exert the greatest influence on ethiozin bioactivity. Applying ethiozin before the jointed goatgrass seedlings reached the 2-leaf stagein soils of sandy texture when a high probability of a 8-10 mm rainfall level exists would result in the highest growth inhibition of jointed goatgrass. Incorporating crop residue into the soil without applying N may also reduce jointed goatgrass seedling vigor.

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## WINTER WHEAT CULTIVAR RESPONSE TO SMY 1500 AND METRIBUZIN

J.M. Krall, P.W. Stahlman, and S.D. Miller[1]

Abstract. Research plots were established at the Archer Research and Extension Center, Cheyenne, Wyoming in 1985 and at the Torrington Research and Extension Center, Torrington, WY from 1985 to 1988 to evaluate winter wheat cultivar response to fall or spring SMY 1500 {4 amino-6-(1,1,-dimethylethyl)-3-(ethylthio)-1,2,4-triazin-5(4*H*)-one} and/or metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} applications. Winter wheat cultivars were seeded in a loam soil with 1.3% organic matter and a 7.3 pH at Archer and a sandy loam soil with 1.2% organic matter and a 7.7 pH at Torrington. Herbicide treatments were applied broadcast with a tractor-mounted sprayer delivering 20 gpa in the fall when winter wheat was at the 2- to 3-leaf stage and in the spring when wheat had three or more tillers. At Archer, plots were not irrigated, while at Torrington plots were sprinkler irrigated. Plots were 8 ft. by 20 ft. with four replications arranged in a split block design. Visual crop injury ratings were made in May, and plots were harvested in July.

Fall application of SMY 1500 and/or metribuzin resulted in greater wheat injury and stand reduction than spring application. Vona and Wings were more susceptible to SMY 1500 and/or metribuzin than the other nine cultivars tested. A fall application of SMY 1500 to Wings resulted in a 60% stand reduction and 48% yield reduction over three trials while Vona suffered a 55% stand reduction and 55% yield reduction over four trials compared to their respective untreated check.

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[1]University of Wyoming, Torrington, WY; Kansas State University, Hays, KS; and University of Wyoming, Laramie, WY

# THE BIOLOGICAL CONTROL OF DOWNY BROME (*BROMUS TECTORUM* L.) USING SOIL BACTERIA

A.C. Kennedy, F.L. Young, and L.F. Elliott[1]

Downy brome (*Bromus tectorum*) and other *Bromus* sp. infest 5.7 million hectares in the western United States. No selective herbicide is presently available to consistently control this weed. The best control is often achieved by planting continuous spring crops for two or more years; however, this practice may not be economically feasible. Biological control offers an alternative means of controlling this weed. Soil bacteria that inhibit root growth of various grass weed species but do not adversely affect the crop have recently been isolated. These naturally-occurring soil bacteria suppress plant growth by the production of a toxin which is specific for downy brome or related plant species. They are excellent biological control agents because they are aggressive colonizers of the roots and residue. The bacteria can function as a direct delivery system for the natural "herbicide" they produce. Most of the bacteria we studied inhibited root growth, although in some cases weed seed germination also was reduced. These inhibitory bacteria cause the greatest reduction in downy brome growth at low temperatures. They are most prevalent in the soil in late fall and early spring. Application of these bacteria and the resultant suppression of the root growth of downy brome may allow the crop to out-compete the weed. Field studies were conducted at four sites in eastern Washington to evaluate the effect of the inhibitory bacteria on the growth of downy brome. Weed-inhibitory bacteria were applied to wheat fields infested with natural populations of downy brome. Downy brome and winter wheat growth and development were measured throughout the growing season. Reduction in downy brome growth varied and was dependent upon the specific bacterial strain. One strain of inhibitory bacteria reduced plant populations and above-ground growth of downy brome 31 and 53% respectively. In the same experiment, seed production of downy brome was reduced 64%. Winter wheat yields were increased by 35% with the application of the bacteria and subsequent suppression of downy brome growth. This increase in yield is similar to the yield increase expected from the elimination of a moderate infestation of downy rome. Thus far, these studies along with laboratory studies have illustrated the ability of inhibitory bacteria to suppress the growth of weeds resulting in substantial increases in winter wheat yields. This research demonstrates the use of inhibitory bacteria as biological control agents for downy brome.

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[1]USDA-ARS, Pullman, WA

# INTERROW SPACING, NITROGEN PLACEMENT, AND WILD OAT DENSITY EFFECTS ON WILD OAT AND BARLEY COMPETITION

Joan Lish and Donald Thill[1]

Abstract. The effects of band and broadcast nitrogen placements, 20 and 38 cm interrows between 15 cm paired rows, and five wild oat (*Avena fatua* L.) densities were determined for some components of barley (*Hordeum vulgare* L.) and wild oat competition in 1988 at Moscow, Idaho. Light penetration through the plant canopy to the soil surface was 32 and 18% with 0 and 140 wild oat/$m^2$ respectively. Light penetration averaged 14% with 230, 290 and 400 wild oat/$m^2$. More light penetrated the plant canopy when nitrogen was banded (23%) than broadcast (14%). Wild oat density averaged 19% higher in 38 cm interrow plots than in 20 cm interrow plots. Wild oat tillered least with 38 cm interrows and banded nitrogen, and tiller number increased with 20 cm interrows and banded nitrogen; 20 cm interrows and broadcast nitrogen; and 38 cm interrows broadcast nitrogen, respectively. Wild oat was taller with broadcast nitrogen than banded nitrogen, and wild oat was taller in plots with fewer wild oat. Wild oat biomass was at least 27% higher in broadcast nitrogen and 38 cm interrow plots than other nitrogen placement and interrow combinations. Barley spikes/$m^2$ were affected by the interaction of all main- and sub-effects. Barley spikes at the 290 and 400 wild oat/$m^2$ densities were not affected by fertilizer placement or interrow spacing. However, the number of barley spikes was reduced up to 54% with 140 wild oat/$m^2$ except with 38 cm interrows and banded nitrogen. Overall, the trend was for barley spikes to decrease with increasing wild oat density. Barley grain yield was inversely related to wild oat density; barley grain from the 140 wild oat/$m^2$ plots yielded only 46% of the plots with no wild oat. Barley grain yield was lower with broadcast nitrogen in 38 cm interrows than other fertilizer placement and interrow combinations. Wild oat height, density, and tillering ability, and light interference accounts for this low yield.

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[1]Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID

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# DICLOFOP-METHYL AND DPX-R9674 TANK MIXTURES IN WINTER WHEAT AND SPRING BARLEY

Monte D. Anderson[1]

Abstract. Field experiments were conducted in 1987 and 1988 to evaluate tank mixtures of diclofop-methyl {(±)-2-[4-(2,4-dichlorophenoxy)phenoxy]-propanoate acid} and DPX-R9674 {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]-carbonyl]amino]sulfonyl]-2-thiophenecarboxylic + methyl {2-[[[[*N*-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoate} in winter wheat and spring barley grown in eastern Washington and northern Idaho. Crop injury, wild oat (*Avena fatua* L.) control, and crop yield data were collected to determine the effect of four DPX-R9674 rates (0.012, 0.016, 0.02, 0.024 lb ai/A) on two rates of diclofop-methyl (0.75, 1.0 lb ai/A).

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[1]Hoechst-Roussel Agri-Vet Company, Spokane, WA

In winter wheat, diclofop-methyl alone averaged 95-96% wild oat control over five replicated experiments. Addition of DPX-R9674 tended to reduce wild oat control from diclofop-methyl. DPX-R9674 at 0.012 lb/A or more reduced control significantly from 0.75 lb/A of diclofop-methyl. When diclofop-methyl was at 1.00 lb/A, only the 0.024 lb/A rate significantly reduced wild oat control, compared to the wild oat herbicide applied alone.

In spring barley, diclofop-methyl alone gave 88% and 94% wild oat control with 0.75 and 1.00 lb/A rates, respectively, over three experiments. All rates of the DPX-R9674 combinations reduced wild oat control. Antagonism was increased by increasing the sulfonylurea rate. Averaged across DPX-R9674 rates, wild oat control was reduced 13% at the 0.75 lb/A rate of diclofop-methyl and 11% when the 1.0 lb/A rate was tank mixed.

Diclofop-methyl, DPX-R9674, and tank mixtures of these herbicides were not injurious to winter wheat or spring barley. Crop yields were similar among all diclofop treatments in winter wheat, but not in spring barley. Reduced wild oat control by the tank mix combinations resulted in less barley yield. Due to the heavy wild oat populations, diclofop-methyl applications in these studies yielded 20 bu/A or more than the untreated checks.

Effective use of diclofop-methyl and DPX-R9674 combinations for wild oat and broadleaf weed control will require the 1.0 lb/A rate of diclofop-methyl and moderate rates of DPX-R9674. Applications in winter wheat indicate less risk of wild oat antagonism than in spring cereals. Cooler and better moisture conditions inherent to the earlier winter wheat applications versus spring cereal applications are believed to explain the differences in DPX-R9674 antagonism of diclofop-methyl.

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## IMAZAMETHABENZ-METHYL: WEED CONTROL IN SMALL GRAINS

C.D. Youmans[1]

Abstract. Imazamethabenz-methyl {(+)methyl-6-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl)-m-toluate} is an effective postemergence wild oat (*Avena fatua*) and broadleaf herbicide for use in wheat [*Triticum aestivum* (L.)], barley [*Hordeum vulgare* (L.)] and sunflower [*Helianthus annus* (L.)]. This summary of efficacy data representing the western U.S. was collected from trials located in AZ, CA, CO, ID, MT, OR, UT, WA, and WY between the years 1985 and 1988. Imazamethabenz treatments were applied at .43 kg/ha and/or .54 kg/ha with either a back pack or tractor mounted spray boom at 93 to 280 l/ha. Plots size ranged from .003 to 4 ha. Imazamethabenz timings of applications were from the 1- to 4-leaf stage in wild oats and the 1- to 8-leaf stage in broadleaf weeds.

Imazamethabenz applications at .43 kg/ha provided 90% wild oat control in the western U.S. As the wild oat stage increased from 1 to 4 leaves, control of wild oats also increased when imazamethabenz was applied at .43 kg/ha. Applications at .54 kg/ha controlled 1 leaf wild oats 98% and control decreased to 92% when the same rate was applied to wild oats in the 4-leaf stage. Wild oat control in all western states averaged 81, 85, 90, and 92% with diclofop-methyl {(±)-2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid} (1.1 kg/ha), difenzoquat {1,2-dimethyl-3,5,-diphenyl-1*H*-pyrazolium} (.84 kg/ha), imazamethabenz (.43 kg/

[1]American Cyanamid Company, Princeton, New Jersey

ha), and imazamethabenz (.54 kg/ha), respectively. Consistency of wild oat control results are as follows: 1) diclofop-methyl (1.1 kg/ha) provided 85% or greater control 69% of the time, and 2) imazamethabenz (.54 kg/ha) provided 85% or greater control 90% of the time. Wild oat control consistency is in the following order: imazamethabenz (.54 kg/ha) > imazamethabenz (.43 kg/ha) > diclofop-methyl (1.1 kg/ha).

Wild oat control with imazamethabenz in California and Arizona averaged 93% when applied at .43 kg/ha and 95% when applied at .54 kg/ha. Wild oat control in CO, MT, UT, and WY averaged 92% at the IX rate of .43 kg/ha. Control of other labeled weeds controlled 94% or more included flixweed (*Descurainia sophia*), London rocket (*Sisymbrium irio*), and wild mustard (*Sinapsis arvensis*).

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## EDUCATION AND REGULATORY SECTION

Paul J. Ogg[1]

The Education and Regulatory Session was held on Tuesday afternoon. There were several different topics discussed in the session which will be briefly summarized in this report.

A video tape by Dr. Bruce Ames, University of California, Berkeley was shown on "Carcinogens, Anticarcinogens and Risk Assessments." The information presented was very educational and beneficial regarding the carcinogenicity of a number of commonly occurring chemicals. There is a good demand for the video tape from individuals who want to further educate the public. Copies of the video tape can be obtained from American Cyanamid Company.

Dr. Bert Bohmont, Colorado State University presented an informative talk on "Endangered Species Act and Implementation." The entire presentation is included from Dr. Bohmont for current and up-to-date information. There has been numerous proposals and discussions regarding the Endangered Species Protection Program. The final version of the Endangered Species Act will likely be in 1991 before it is operating effectively.

A symposium was presented on Good Laboratory Practices (GLP) by Bill Anliker Ciba Geigy Corporation, Ron Collins, Collins Agricultural Consultants, and Clyde Elmore, University of California.

Bill Anliker indicated that Good Laboratory Practices have been followed for many years; however, the documentation has not been thoroughly reported. There is a tremendous amount of paper work on residue trials under the GLP concept. When you have a GLP audit do not speculate, make sure that all documents are signed and dated, simplify calibrations and calculations, and don't over react until a written report is issued.

Ron Collins indicated that most residue work in 1988 was conducted in some degree under the spirit of GLP's. The frustrating points for Ron Collins was that some sponsors were very good at setting protocols while others were quite lax. It appears that most of the people writing or auditing tests do not fully understand the particular test problems. The greatest need is for training individuals in all aspects of GLP. Training is needed for the applicators, study

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[1]American Cyanamid Company, Longmont, CO. Chairman, Extension and Regulatory Section.

managers, upper managements, and quality assurance personnel. Ron Collins indicated that we should become involved; individuals with expertise should be making and setting the standards for Good Laboratory Practices. A written presentation is attached.

Clyde Elmore, University of California, indicated from a survey he conducted that GL's will be followed for residue work, but it will be very difficult to get efficacy trials conducted. The attitude of different individuals varied as to the validity, necessity, and scientific integrity of field trials conducted under GLP's versus the current systems. The general consensus was that GLP's increased paperwork, will reduce the number of cooperators, reduce the number and amount of programs due to increased time to conduct GLP trials and will ultimately lose product registrations.

The Good Laboratory Practices Symposium was informative and very educational.

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## ENDANGERED SPECIES

Bert L. Bohmont[1]

The Environmental Protection Agency (EPA) is charged with the responsibility of administering the Endangered Species Act of 1973. Little was done until 1987 when the EPA attempted to initiate a poorly thought out program using inaccurate maps and invalid data. The EPA was forced by Congress in early 1988 to suspend enforcement of Endangered Species Act and to withdraw their plan for more consideration. The EPA held a series of hearings around the United States to receive comments on the Endangered Species Protection Program in order to determine a more appropriate approach. A summary of the comments is as follows:

° **Alternatives to the cluster approach.** EPA's original cluster approach, which involved reviewing pesticides together that have similar uses, came in for heavy criticism. By a clear majority commenters favored a species-by-species approach. Some commenters suggested that each species should be examined in order of priority to take into account the urgency of protective action for a particular species.

° **Maps and labels.** Many commenters felt the maps should depict actual occupied habitats and be supplemented by habitat and species descriptions with appropriate buffer zones indicated. The original maps proposed in 1987 were poorly drawn and grossly exaggerated in most cases.

° **State programs.** Numerous commenters recommended that state and local efforts in support of the program be funded by the federal government. Several others commented that state programs should be consistent with, but not exceed federal criteria. A general comment was that the states could benefit from federal guidelines in drawing up their plans, but that the states should not be expected to take on full responsibility for EPA's program.

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[1]Coordinator Pesticide Programs, Colorado State University, Fort Collins, CO

° **Education and training.** Commenters pointed out that a program relying to a great extent on the willingness of users to comply can only achieve its goal by emphasizing education and training. Educational efforts could be developed by the Extension Service, State/Federal Wildlife agencies, registrants, or the EPA.

° **Prohibition of use.** Commenters suggested that prohibitions of use should be used only after all other approaches have been tried and failed. These alternatives include varying application methods, pesticide formulations, timing of applications, restricting use to certified applicators, and entering into protection agreements with individual landowners. Some commenters stated that limitations on use should be applied only if effective pest control alternatives are available.

° **Burden of proof.** A large number of commenters felt that a stronger link needs to be established between the use of a specific pesticide and a threat to an endangered species before limitations are placed on the use of the pesticide. Some commenters also questioned the scientific validity of the decision that a pesticide may affect an endangered species and suggested review of the opinions by the FIFRA Scientific Advisory Panel. Others, however, felt the burden of proof to demonstrate no adverse affects on endangered species should rest with the manufacturers and users.

° **Risk-benefit balancing.** A number of commenters recommended using a risk-benefit approach to endangered species protection for comparing pesticide risks to risks from development and urbanization. A large number of respondents, mentioning the negative economic impacts of the program, requested that the EPA prepare an economic impact assessment and consider compensating landowners for losses due to endangered species protection efforts. Others commented that the economic analyses are inappropriate to this program; no dollar value can be applied to the loss of a species; the Endangered Species Act does not provide for comparisons of risks and benefits in protecting listed species; and the program should be implemented rapidly.

The EPA intends to announce their plans for the **New Endangered Species Protection Program** in the spring of 1989, probably sometime in March. Based on public comments and discussions between the EPA, USDA, and the Fish and Wildlife Service, the new program will provide a strategy and direction for future efforts. The new program will be announced in the Federal Register, and the EPA will request another round of public comment prior to final implementation.

The EPA is developing a pilot program for the 1989 growing season. They will be seeking the cooperation of the states and various affected groups in conducting these voluntary pilot programs. The EPA will announce the pilot states in the near future, and over the next few months, they will be working intensely with the states to identify areas conducive to piloting either the federal program or all or part of a state-initiated program. The pilot programs will allow the EPA to field test their ideas and refine them with practical results.

The EPA is issuing revised maps for some species. The maps have been revised based on determinations by the Fish and Wildlife Service after reviewing the comments received from the public hearings. States will be provided an opportunity for initial review and then the revision will be given wider distribution and opportunity for comment either through the pilot programs or other mechanisms.

The EPA has stated that an enforceable program will probably not be in place until 1990 or 1991. A recent release from the Assistant Administrator for Pesticides and Toxic Substances outlined some of the provisions in the new proposal including:

-- Biological opinions from USDI will focus on endangered species at all sites and EPA will craft restrictions for all sites.

-- Endangered species will be "prioritized" by their likely jeopardy from pesticides. Criteria to do this include, for example, numbers left and location in relation to heavy or light pesticide use areas. The USDI will use this criteria for rank ordering a list for completion of jeopardy opinions.

-- There will be an opportunity for the public to file comments on the draft jeopardy opinions.

-- For the 1989 growing season, there will be a voluntary program covering between 50 and 100 species -- less than one quarter of the total number of endangered species -- in pilot areas.

-- By the 1990 growing season, one-half of the endangered species would be covered. No species will be covered until there are accurate maps.

-- EPA, USDA and USDI are to prepare an economic analysis of the use of various types of pesticide regulations which might be used to protect endangered species.

-- After Myron Johnsrud, USDA Administrator of the Extension Service, has reaffirmed Extension's commitment to participate in the development of a "reasonable and effective" Endangered Species Protection Program in cooperation with USDA and EPA. Dr. Johnsrud has stated that a goal for the Endangered Species Program will be to protect these species "without causing undue impact on agriculture and natural resources productivity, profitability and availability."

It will likely be at least 1991 before the final version of the Endangered Species Act is in place and all provisions of it are operating effectively.

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## GOOD LABORATORY (FIELD) PRACTICES SYMPOSIUM CONSULTANTS PERSPECTIVE

Ron Collins[1]

I was asked to speak today about Good Laboratory Practices (QA/QC) from a consultant's perspective. Many people in this room will become involved under the GLP Regulations of the Toxic Substance Control Act as proposed in the Federal

[1]Collins Agricultural Consultants, Inc., Hillsboro, OR

Register of December 28, 1987, if they have not already done so. There is a good probability that the final GLP regulation will be published in June of 1989.

Most residue work accomplished in 1988 was conducted in some degree under the spirit of GLP. There is a good probability that biological evaluation work (performance data) of herbicides will also come under the act.

In 1988 our organization was audited seven times. We conducted numerous tests in which we used the proposed GLP regulations. What was frustrating, was that some sponsors were very good at setting protocols, while others were quite lax. In many cases we found we were more knowledgeable than many of our sponsors. I could talk for hours about the disparities of what sponsors do or do not write into protocols. I have a separate frustration category for those persons who wrote the proposed GLP regulations and who have never conducted any field tests. It's always interesting when people do not understand the details of the test you are conducting. They always say, be sure and document what you have done. I won't bore you with all my gripes, other than to say, most of the problems appear to be that most of the persons writing or auditing tests do not fully understand the particular test problem. We have bench laboratory chemists writing field protocols. We have toxicology QA personnel with extensive lab experience monitoring field tests. They do not have a good understanding of the problems involved. I am an entomologist with thirty years of field experience in entomology, plant pathology, and weed science. However, that does not make me qualified to QA/QC a laboratory chemical residue analysis, and yet, we have people auditing in areas where they have little or no background training. Many sponsors send out people who look at paperwork, facilities, and protocols, but do not get involved in critical phases of the study; such as application and sampling. This is of great concern to me.

In my estimation this all boils down to training. I need training, you need training, everybody needs training--field, laboratory, and QA personnel, study managers, and upper management. I don't care who you are, or how many degrees you have, you need training in GLP. Upper management particularly needs training. I think some people see GLP as another regulation, an expense, an infringement on their work. What I think a lot of people do not realize, is GLP is a management tool to insure the quality of the research work that must be conducted.

How many people in this conference have heard of ASTM (American Society of Test Materials) or the American Society of Quality Assurance? ASTM's principal function is setting standards on everything from motor oil weights, to fasteners, to concrete. In recent years they have set standard guides for evaluating herbicides in soybeans to determining application rates and distribution patterns from aerial application equipment--some sixty-six standard test methods, practices, or guidelines for pesticides. These standards came about in ASTM by voting members from manufacturers, users, regulators, and other interested parties, who designed the standards in extensive committee meetings. The EPA has helped fund ASTM in order to help set more standards.

The American Society of quality assurance is a comparatively young organization and is principally made up of persons from toxicology and some chemists. They have lots of experience in pesticide and drug toxicology evaluation in laboratory animals. In their last national meeting, in Nashville, Tennessee, there were sessions involved in basic and advanced good laboratory practices training. In addition there were separate sessions for both FDA and EPA activities. One evening session dealt with GLP concerning agricultural chemical field applications.

Several organizations are offering training courses in the GLP provisions of the Toxic Substance Control Act. I would encourage you to attend these one-to five-day courses. Encourage management and administrators to attend these courses and authorize field personnel to attend.

I am not sure what the Weed Science Society approach is going to be regarding GLP. Obviously the entomological, pathology, and weed science societies have a great deal of expertise in the field practices that are coming under GLP, and yet two other societies--ASTM and American Society of Quality Assurance, with little or no expertise, are the ones setting the standards. It seems to me that this society and its membership had better get involved.

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## USE OF PACLOBUTRAZOL FOR AMENITY TREE GROWTH REGULATION

S.L. Kimball and R.P. Crockett[1]

Abstract. Data from 3 years of large-scale applications of paclobutrazol {[1-(4-chlorophenyl)-4,4-dimethyl-2(1,2,4-triazol-1-yl)pentan-3-ol]} show commercially acceptable growth regulation of key amenity trees. Injection methodology, timing, tree effects, treatment rates, general efficacy, and future development issues are discussed.

Maintenance of electrical lines is a primary concern of utility companies, and one of the major ongoing efforts involves tree clearance from lines. Trimming of trees from under lines is an expensive and time consuming process that must be addressed continually. Trimming trees is a manpower intensive practice that involves potential hazards from working with equipment and high voltage lines.

For over a decade since plant growth regulators were first introduced, there has been an interest in using PGR treatments to regulate the growth of trees, thereby reducing the expense and potential hazards encountered by the mechanical procedures that are presently used. Early PGR candidates that were tested for tree growth regulation involved chemicals that inhibited cell division. These candidates produced variable results and sometimes exhibited dosage-related toxicity to trees.

In the 1980's, a new generation of chemical growth regulators, including paclobutrazol {[1-(4-chlorophenyl)-4,4-dimethyl-2(1,2,4-triazol-1-yl)pentan-3-ol]}, has been tested for tree growth regulation. They function by inhibiting the production of gibberellic acid in the cells, thereby reducing cell expansion. This type of regulation effectively controls the growth of trees without the limitations of the earlier PGR compounds.

In 1987, ICI Americas received a federal registration for trunk injection of paclobutrazol (formulated as Clipper 20 UL) for amenity trees. In early 1988, Monsanto assumed marketing rights for Clipper 20 UL. Since then, Monsanto has worked closely with the utility and tree service industries to examine trees treated with paclobutrazol.

This presentation is a report of solutions to technical questions about growth regulation and injection methodology that have arisen from broad-scale testing.

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[1]Monsanto Agricultural Company, St. Louis, MO and Vancouver, WA

1. If the cambium layer is injured or portions of it killed, production of new wood and bark will cease. After several years of growth by the healthy cambium, the bark over the injured area will split due to lack of growth. Bark splitting has been observed at a low frequency in some trials that are 2 to 3 years old. A Potomac Edison report detailed observations on bark splitting, and showed that the occurrence of splitting was greater on trees injected during the dormant season. Subsequent examination of trees in 1-year-old trials revealed that vertical "streaks" of dead cambium were present in trees that didn't show bark splitting, with a frequency similar to the previously reported bark splitting. Neither series of observations determined the reason for the amount of splitting that was observed.

Asplundh Tree Expert Company subsequently sponsored a field workshop at Whitpain, PA to evaluate injection methodology and to determine if there is a correlation between currently practiced injection techniques and the observed cambial injury. In summary, it was found that the pattern of chemical movement at the time of injection and several days afterward closely corresponded to the pattern of cambium injury that had been observed in commercial trials.

Water soluble blue dye was combined with isopropanol and injected into red maples. Seventy-five ml/hole was injected at 75 psi. When the injector probe was completely sealed into sapwood, the alcohol/dye mixture was deposited in an oval shaped vertical column that extended about 12 inches below and 36 to 40 inches above the injection point in the sapwood. The only dye present at the xylem/cambium interface was immediately around the hole. With holes drilled at less than 30x, there was a slight movement of the dye across the narrowest part of the wood between the hole and the cambium. Movement of the chemical across the thinnest part of the wood was due to injection pressure.

However, if the probe was not completely sealed into the sapwood, a vertical "streak" of the dye was found at the cambium/xylem interface, ranging from 1/2 to 2 inches wide and extending from about 14 inches below the injection hole to about 36 to 42 inches above it. The dye pattern observed in the cambial zone closely matched the pattern of dead cambium observed in trees from the year-old commercial trials. Based on this evidence, cambial injury and subsequent bark splitting result at least in part from improper "seating" of the injector points at the time of application. The probes must be completely sealed into xylem tissue to avoid immediate cambial injury.

Trees were also examined several days after injection. The workshop was held during a period of severe drought, and movement of fluids in the xylem was minimal. The column of injected material did not move significantly upward from the time of injection until the examination of trees several days later. In cases where the injection holes had been drilled at 30x angles or less, the dye had diffused laterally across the thin wedge of wood between the hole and the cambium and was present in the cambial zone. This observation helps explain the Potomac Edison observation of higher incidences of bark splitting following dormant applications. During dormancy or severe drought there isn't upward movement of fluids in the xylem and, consequently, the column of injected material remains intact in its concentrated form. Passive diffusion of the concentrated alcohol carrier to the cambium results in cambial injury. Injections during periods when there isn't fluid movement in the wood (such as periods of defoliation, hard dormancy or severe drought stress) should be avoided. Also, holes should be drilled at greater angles to reduce the potential for movement into the cambial area. 45x to 60x angles should be drilled, with angles less than 45x avoided.

2. The major effect of paclobutrazol is to inhibit biosynthesis of gibberellins. Deliberate over-dosing of trees has not directly resulted in their death. However, we do know that the effects of high dosages of paclobutrazol may include severe reduction in leaf size and shoot growth.

Tree decline is in many cases the result of an accumulation of stresses placed on the organism. Some of the factors that can lead to stress include the following:

| | |
|---|---|
| root condition | trunk & crown condition |
| drought | nutrition/fertility |
| diseases | trim shock |
| pests | lightning |
| wind | age |
| chemical treatment | environment (species fit) |
| competition | shading |

To date, injections of paclobutrazol have not been shown to cause the death of healthy trees. In situations where trees have died following trimming and treatment with paclobutrazol, there has been evidence of an accumulation of stresses which have led to the tree's decline. Tree injury is greatest where severe trim techniques were associated with high dosages.

If you encounter paclobutrazol-treated trees that show phytotoxic effects, please note the various factors that may be impacting the tree, and let us know so we can better define the effects of paclobutrazol on trees.

3. Several general conclusions have been drawn as we have examined trees across the country:

A. Species response to a given treatment rate will vary according to geographic area and to the size of the tree. Paclobutrazol users should begin with label recommendations and then refine their treatments to fit the local environment. Also, late-season treatments may not show effects any sooner than treatments made the following spring. This is due to lack of chemical movement after the leaves senesce and drop from the trees.

B. Hole spacing should vary according to species and crown size. The number of holes to be drilled is determined by the diameter of the tree at breast height. Holes are drilled as close to the ground as possible to minimize potential visual effects from the treatment. In some cases this may lead to injections at the base of the tree where there is root flair. The holes will be further apart there because hole spacing and total hole number are based on the diameter at breast height, not at the root flair.

C. Most species require a range of treatment rates to accommodate crown size as well as tree size. A large crown may require 10 ml/hole and more paclobutrazol than a tree with a small crown or a crown that has been severely trimmed.

D. Much of the injection work to-date has involved treatments at or immediately after trimming. However, satisfactory growth regulation can also be obtained by treating and then trimming at a later date--even a year later. The treatment of trees several months before trimming results in an immediate effect following trimming, so the degree of trim must be reduced accordingly. Treatment of untrimmed trees results in more rapid movement of chemical up into the crown area and a more uniform distribution of material in the crown.

4. Based on this year's observations, the following issues will be addressed in 1989:

A. Rate refinement -- There will be a downward movement in treatment rates, and new recommendations will be provided before the 1989 season.

B. New Species -- will be added to the label.

C. Training -- Both utility and tree service companies can benefit from additional training on the use of paclobutrazol. This is not to down-play their ongoing efforts which are often excellent, but there are new developments and observations about tree growth regulation and injection methodology that must be adopted. A training package will insure that the information is clearly communicated.

D. Soil injection -- trials are being initiated to further define rates and recommendations for this treatment method.

5. The last issue to discuss today involves setting the right direction for development and use of tree growth regulators. Your help is vital to this process. As you have ideas, comments or concerns, we request that you communicate with us about them. The right focus for development of TGR's is the focus that will bring the greatest success for those using the products. Please help us set that focus.

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## IMAZAPYR: A TOOL FOR USE IN FORESTRY AND NOXIOUS WEED CONTROL PROGRAMS

Richard A. Beardmore and Thomas E. Nishimura[1]

Abstract. Imazapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid} has been recently labeled for site preparation and release of several new conifer species. Imazapyr has been

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[1]American Cyanamid Company, Princeton, NJ and Lake Oswego, OR

registered for site preparation of Ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*), and tolerance has been demonstrated when applied at 0.4 lb ai/a as a release treatment in the fall.

The translocation properties and broad spectrum herbicidal activity of imazapyr result in the control of numerous difficult to control weeds. Field trials with imazapyr herbicides have shown control of Desert camelthorn (*Alhagi pseudalhagi*, (Bieb.) Desv.), Russian thistle (*Salsola iberica*, Sennen & Pau), Kochia (*Kochia scoparia*, (L.) Schrad.), Russian Olive (*Elaeagnus angustifolia*, L.), Punctervine (*Tribulus terrestris*, L.), Grey rabbitbrush (*Chrysothamnus nauseosus* spp. *gaveolens*, (Nutt.) Piper), Rush Skeletonweed (*Chondrilla juncea*, L.), Diffuse knapweed (*Centaurea diffusa*, Lam.), Russian knapweed (*Centaurea repens*, L.), Yellow starthistle (*Centaurea solstitialis*, L.), Broom snakeweed (*Gutierrezia sarothrae*, (Pursh) Britt. & Rushby), Stinging nettle (*Urtica dioica*, L.), Common reed (*Phragmites australis*, (Cav.)Trin. ex Steud.), Purple loosestrife (*Lythrum salicaria*), and Salt cedar (*Tamarix ramosissima*, Ledeb.).

The following rates and timings have been proven effective weed control of the respective species.

| Weed species | Rate(kg ai/ha) | Timing |
|---|---|---|
| ALHPS - Desert camelthorn | 0.5 | Mid-post |
| SASKR - Russian thistle | 0.4 | Early post |
| KCHSC - Kochia | 0.4 | Early post |
| ELGAN - Russian olive | 0.75 | Post |
| TRBTE - Puncturevine | 0.25 | Early post |
| CYTNA - Grey rabbitbrush | 1% sol. | Spray to wet |
| CHOJU - Rush skeletonweed | 0.5 | Post |
| CENDI - Diffuse knapweed | 0.5 | Rosette-E. Post |
| CENRE - Russian knapweed | 1.0 | Early post |
| CENSO - Yellow starthistle | 0.75 | Early post |
| GUESA - Broom snakeweed | 0.75 | Post |
| URTDI - Stinging nettle | 0.5 | Post |
| PHRCO - Common reed | 1.0 | Post |
| LYTSA - Purple loosestrife | 0.5 | Post |
| TAARA - Salt cedar | 1.0 | Post |

The efficacy of imazapyr on these and other weed species offers plant control managers a valuable new tool for tough weed control problems.

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## EFFECT OF IMAZAPYR, 2,4-D AND METSULFURON METHYL ON CONIFER TOLERANCE

Douglas Belz and Thomas E. Nishimura[1]

Abstract. The effects of imazapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methyl ethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid} and combinations of either 2,4-D {(2,4-dichlorophenoxy)acetic acid} or metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid} were

[1]Forest Land Mgt. Div., WA State Dept. Nat. Res., Olympia, WA and American Cyanamid Co., Lake Oswego, OR

evaluated for their effect upon growth and injury to four species of conifer. Douglas-fir (*Pseudotsuga menziesii*), Ponderosa pine (*Pinus ponderosa*), western hemlock (*Tsuga heterophylla*) and pacific silver fir (*Abies amabalis*) showed differences in tolerance to four timings, treatment rates and by specie. Generally the most tolerant conifer was ponderosa pine, followed closely by Douglas-fir, then with moderate tolerance was pacific silver fir and least tolerant was western hemlock. Injury was more related to timing than to rate. Rate of imazapyr alone was a four-fold increase. Considerable injury along with height and diameter reduction was apparent from applications made at initiation of growth and after elongation timings. Limited visual injury and growth reduction was evident for preplant situation and application made after conifer bud set.

## Introduction

Imazapyr is a new compound to Pacific Northwest forestry. It is used in the Southeast United States at 0.125 lb. ae. for conifer release. Very little was known about its effect on conifers in PNW region. Preliminary trials suggested there might be a safe timing, but effect was not defined. The objective was to determine injury levels by three factors.

## Materials & Methods

The study is divided into three groups: seasons, seedlings and rates. Four seasons were chosen for application: PrePlant, PP, occurred three months before planting, December; Spring Tight, ST, is late winter when the buds on Douglas-fir were slightly swelling, March; Spring Flush, SF, is actively growing stage and stem elongation at about five centimeters, May; and Fall, FA, is after bud set, late August. Bud swell and elongation represent a physiological stage when injury should be most pronounced. Preplant should allow degradation of compound. Fall or after bud set is a relatively safe time to do application over conifers with products in the sulfonylurea group.

The seedlings selected represent a range of sensitivity and are likely to be treated during a conifer release program. One conifer is from high elevation, Pacific Silver Fir, two are from the coast range, Douglas-fir and Western hemlock, and one is from a dry environment, Ponderosa pine. Western hemlock is usually most susceptible to injury, and Ponderosa pine or Douglas-fir usually have the least injury.

The treatments consisted of three rates of imazapyr alone at 0.25, 0.5 and 1.0 pound active per acre and two combinations, one with 2,4-D at 2 pounds per acre and the other with metsulfuron at 0.3 pound per acre combined with a constant rate of imazapyr at 0.5 lb. ae. No-treatment plots were also included.

Subplots were sprayed at 40 gallons per acre with a $CO_2$ type applicator.

Four species of seven seedlings each were in a subplot. The treatments and seasons were replicated. Subplots were evaluated after the first and second growing season.

## Results and Discussion

The data was analyzed by Duncan's Multiple Range Test. The seasons and treatments gave an unbalanced design, so the analysis was split into two parts. There were a lot of interactions going on and that makes it hard to explain results. There are two aspects to look at in the study: 1) how season affected injury and 2) how treatment rates effected injury. A comparison will be made between a resistant specie, Douglas-fir, and a suspectable specie, western hemlock, to show differences between season and treatment effects.

A couple of easily identifiable results are:

-Imazapyr at high rate or the combinations consistently gave the worst injury and the least growth on all species.

-Western hemlock sustained highest injury levels.

-Application made during active growth period will injure conifer at an unacceptable level.

-Some conifers can tolerate imazapyr at pre-plant or fall timing.

The visual effect seen on the seedling the first year is a result of preconditioning and the treatments. As the first year progressed, the impact from the compound increased. This is typical of some of the newer compounds in that the injury is progressive and slow to see. A tree that showed chlorosis earlier might show a dead tip by winter. A seedling with brown needles might be dead the next spring. It takes a different rating scale to gauge damage and injury. The effect caused by the different imazapyr rates is subtle.

Qualitative evaluation mirrored yearly effect for height but not diameter. First year evaluation mimicked second year height accurately. There was an unequal difference between Douglas-fir and Western hemlock at second year evaluation. height was a significant factor for both species. Analysis of diameter for rate and season was not significant. Growth measurements gave a reality check of visual results. Second year is when the real injury was evident. We felt that if a seedling could sustain damage of less than or equal to chlorosis condition, than the seedling had a very good chance of recovery with normal growth the following year.

Douglas-fir is more tolerant of imazapyr than western hemlock, Figure 1 & 2. Display of injury to western hemlock was apparent by a severe reduction in height growth, especially at 1.0 lb ae. Spring tight timing at half pound and one pound active had dead trees. Sometime during the second year almost all of the seedlings died. Spring Flush had a few dead seedlings. Diameter differences between season and rate isn't much, except for application done during spring tight season. There wasn't any difference in diameter response between the two species by seasons at 1.0 lb ae. Fall application at 0.25 lb ae had the least impact on both species both for height and diameter.

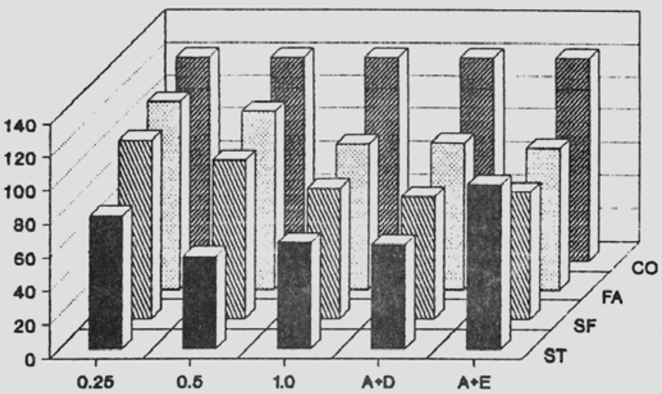
Generally as rate increased so did damage to height. Season of application had an additive effect on height. Diameter was not affected by rate. Season affected its parameter.

The combinations acted differently on specie for height and diameter response. Imazapyr plus 2,4-D had a negative impact on diameter and height by season for both species. It is comparable to 1.0 lb ae of imazapyr. Imazapyr plus metsulfuron effect on growth was erratic by season. There seems to be a buffering effect from one of the compounds. Combinations had height comparable to 1.0 lb ae imazapyr rate. Diameter was slightly less than the 0.5 lb ae. Spring flush timing usually had least height and diameter growth than either fall or spring tight timings.

Pre-plant treatment is different than other seasons. It would be a practice called site preparation where the application is done a few months before seedlings are planted. Little or no injury was evident at 1.0 lb. ae, Figure 3. The difference in growth at 0.25 lb is probably due to lack of long-term weed control. There was a statistical difference between pre-plant and control for Douglas-fir but not for western hemlock.

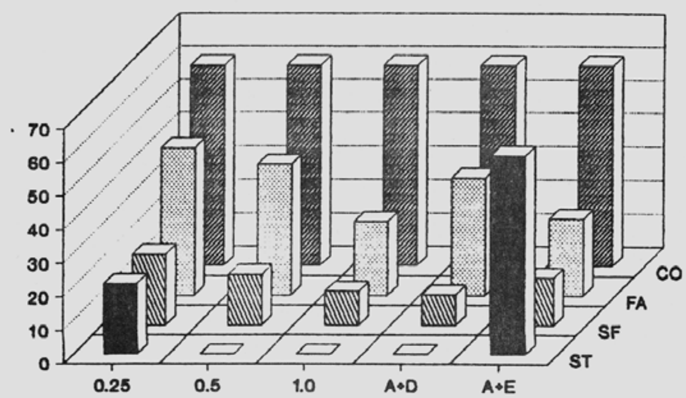
Figure 1

## Second year diameter of Western Hemlock




Diameter (mm), Rate and Season

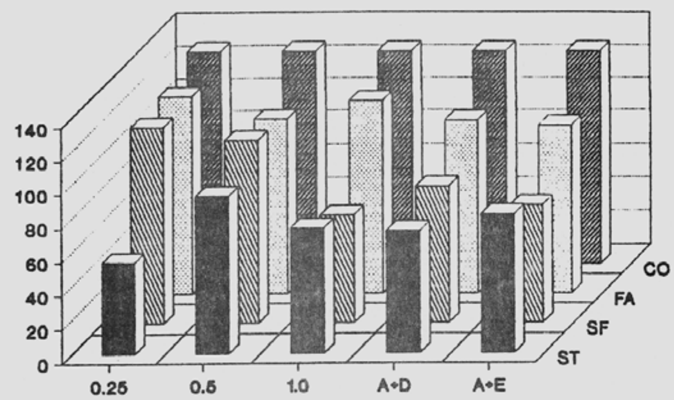
## Second year height of Western Hemlock




Height (cm), Rate and Season

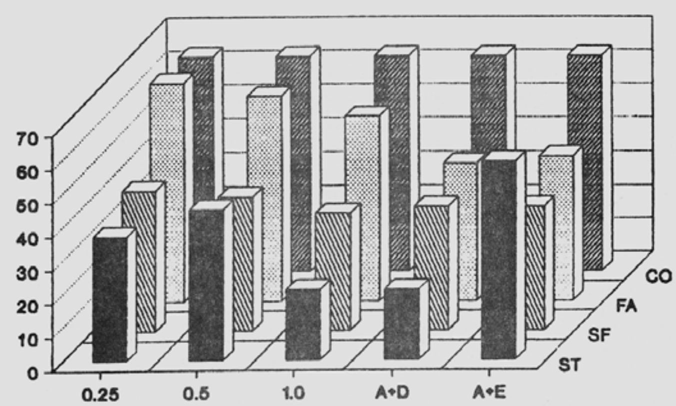
Figure 2

## Second year diameter of Douglas-fir




Diameter (mm), Rate, and Seasons

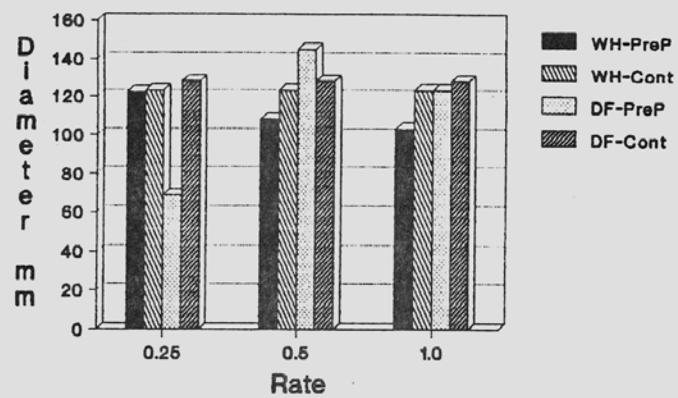
## Second year height of Douglas-fir



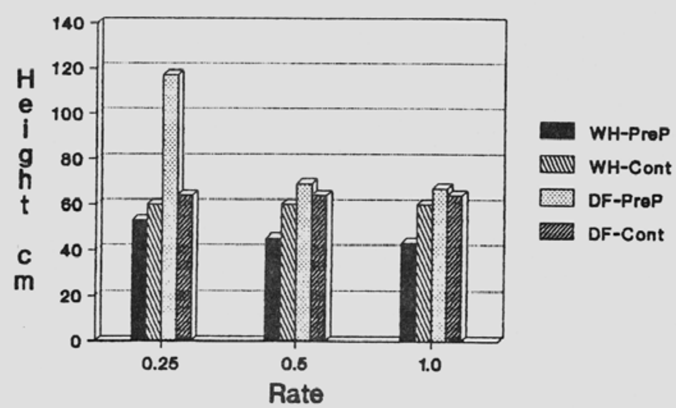

Height (cm), Rate and Seasons

Figure 3

Second year diameter of DF & WH as influenced by Pre-Plant & Arsenal rates




Second year height of DF & WH as influenced by Pre-plant and Arsenal rate



## Summary

Conifer release situation: Season of application had a greater impact on conifer damage and growth than rate of imazapyr. Fall is the only time when injury is within acceptable limits.

There is a difference in tolerance of conifers to imazapyr rate. There seems to be no safe time for western hemlock. Rates above 0.25 lb ae cause unacceptable injury. Seedling probably won't recover until the third season.

Douglas-fir can tolerate rate of 1.0 lb ae but not combinations. Ponderosa pine might tolerate 0.5 lb. ae. Injured seedlings recover the second year.

Damage to the seedling will be visible as height reduction. Damage will increase through the winter. Ranking of injury by season is: no treatment < pre-plant < fall < spring flush < spring tight.

Site preparation situation: Conifers showed no appreciable injury to any of the rates. Seedlings should be safe if adequate time is left between application and planting.

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# BIGLEAF MAPLE CONTROL: TRICLOPYR THIN-LINE AND SPOT-FOLIAR APPLICATION TREATMENTS USING IMAZAPYR, METSULFURON, AND GLYPHOSATE

P.F. Figueroa[1]

Bigleaf maple (*Acer macrophyllum* Pursh) is a hardwood that can have a significant impact on conifer growth. Bigleaf maple predominately develops from cut stumps following harvest. Sprouts develop rapidly over 2-3 years following harvest and can grow as much as 10 feet a year (Wagner 1987). Depending upon the harvest date, conifer reforestation is sometimes delayed up to one year after harvest giving bigleaf maple the opportunity to obtain height dominance.

Competition from bigleaf maple can affect both survival and growth of planted Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Graham (1986) reported a 30% reduction in Douglas-fir height growth after five years for seedlings within three feet of bigleaf maple clumps. She also reported significant mortality of Douglas-fir due to bigleaf maple competition on trees planted within one foot of stump sprouts. Wagner (1988a) demonstrated that vegetation competition through overtopping, crowding and moisture depletion can impact Douglas-fir growth. As a result of the competitive effects of bigleaf maple, Weyerhaeuser treated over 7,000 ha during 1988 to control this species (Figueroa and Terry 1988).

Primary control methods were thin-line application of triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid} and basal spray with 3% triclopyr in diesel oil (66% and 34% of the hectares treated respectively). Thin-line dosage averages 44 ml triclopyr for a cost of $.97 per clump. Thin-line application of undiluted triclopyr consistently gives 100% control of treated bigleaf maple stems. When treatment falls below 100%, it is usually caused by failure to band each stem in the clump with triclopyr and not due to poor herbicide performance.

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[1]Weyerhaeuser Company, Centralia, WA

Application of herbicide to all stems in a clump is critical for successful bigleaf maple control (Lauterbach 1988). Efforts to lower herbicide costs by reducing the volume of undiluted triclopyr increases the probability of not getting complete banding of all stems. Dilution of triclopyr with other lower cost herbicides or adjuvants is a method to lower control costs yet maintain high volume of herbicide. Lauterbach (1984, 1986) evaluated triclopyr dilution using diesel oil as a carrier. He found that dilution of triclopyr with diesel lowered bigleaf maple control by 38% compared to an undiluted triclopyr thin-line application. Additional operational trials tested the adjuvant Mor-act[R] as a dilution material. Observations of these trials showed 3:1 and 1:1 mixtures of triclopyr:Mor-act[R] could give effective control of bigleaf maple and reduced herbicide costs (Figueroa, 1988).

Alternative application methods to thin-line or basal treatments of bigleaf maple were tested by Wagner (1987). He evaluated efficacy of triclopyr, glyphosate {*N*-(phosphonomethyl)glycine}, metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid} and imazapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid} as a spot-foliar directed spray applied from the ground. His study found that spot-foliar imazapyr treatments gave virtually 100% control, and glyphosate and metsulfuron gave 71% and 51% control on bigleaf maple.

An experiment was established to further investigate alternative methods to control bigleaf maple. This trial tested triclopyr thin-line with thin-line diluted with Mor-act[R] or 2,4-DP {(±)-2-(3,4-dichlorophenoxy)propanoic acid} and ground applied spot-foliar treatments with rates of imazapyr lower than those tested by Wagner and higher rates of glyphosate and metsulfuron.

The trial was located in King County in western Washington on Weyerhaeuser's Snoqualmie district of their Cascade region (sec 13 T24N R8E). It is on a Klaus soil series which is a deep, well-drained, coarse-textured soil developing from glacial drift and outwash and rock content ranges from 30% to 70% (Webster and Steinbrenner 1974). Douglas-fir soil site is estimated at 34 meters at breast height age 50. Elevation is 335 meters on a 5% northwest slope.

The site was cable logged in summer 1985 and scarified using a three-finger clam bucket on a backhoe to scalp individual planting spots. The site was shovel planted on March 21, 1986 using 2+0 low density Douglas-fir seedlings grown at the Weyerhaeuser Mima Nursery. Across the 8 hectare site, bigleaf maple density averaged 27 clumps per hectare. At planting time the bigleaf maple was 1.1 m (se 0.1) in height, and at study installation one year later, the bigleaf was 2.9 m (se 0.2) in height with a mean crown width of 2.0 m (se 0.1).

Treatments tested in this study were as follows:

| Treatment | Rate | Method | Crown Coverage | 1988 Application Date |
|---|---|---|---|---|
| | (kg/ha) | | | |
| Check -- No Treatment | | - | - | - |
| Triclopyr | Undiluted | Thin-line | - | March 24 |
| Triclopyr/2,4-DP | 1:1 | Thin-line | - | March 24 |
| Triclopyr/Mor-act[R] | 1:1 | Thin-line | - | March 24 |
| Imazapyr | 0.6 | Spot-foliar | 180° | June 10 |
| Imazapyr | 0.6 | Spot-foliar | 360° | June 10 |
| Imazapyr | 1.1 | Spot-foliar | 180° | June 10 |
| Imazapyr | 1.1 | Spot-foliar | 360° | June 10 |
| Metsulfuron | 170 g | Spot-foliar | 180° | June 10 |
| Metsulfuron | 170 g | Spot-foliar | 360° | June 10 |
| Glyphosate | 6.7 | Spot-foliar | 360° | June 10 |

The thin-line treatments were applied using a Polyspray II[R] applicator. This sprayer dispenses a solid stream of herbicide approximately 2-5 cm wide up to a distance of 3-4 m. Each clump was treated such that all stems were banded on at least two sides. The same applicator head was used for each treatment and pressurized to the recommended maximum pump pressure for each clump to insure uniform application.

Ground applied spot-foliar treatments were mixed as a 187 L/ha application rate. R-11[R] surfactant was added to the imazapyr and metsulfuron treatments at 0.0025 percent solution. Crown area for each clump was calculated by measuring the average north-south and east-west crown width. Herbicide mixture applied to each clump was based on that fraction of a hectare the crown area occupied. Treatments were applied using a modified automatic drench syringe (Figueroa 1987) with a 0.8 m extension and an 8006 Spray Systems teejet[R] nozzle. This modified drench syringe dispenses volumes accurately to as low as 1 ml. Applications were made when wind was less than 5 km per hour. The full coverage (360° application) treatment had mix applied to all exposed foliage. The partial coverage (180° application) was applied to all exposed foliage on the western half of the clump.

Treatment differences were analyzed using analysis of variance procedures described by Steel and Torrie (1980) and hypothesis tested at the 0.05 probability level. The main effect was herbicide treatment. If F values were significant at the 5% level, differences among treatments were tested using Duncan's New Multiple Range T-test. Survival data was tested using a Chi-square test as described by Cochran and Cox (1966).

## Results

Results of the Chi-square test showed significant treatment differences (p=0.0001). Two years after treatment all triclopyr thin-line treatment had 80% control on bigleaf maple as shown in Figure 1. Complete banding of all stems in this study was evidently not attained. Many stems were growing along the ground at this site making treatment of all stems difficult. This may account for the lower than expected control. These data demonstrated that a 1:1 v:v dilution of triclopyr with either 2,4-DP or Mor-act[R] did not reduce control.

Differences between the methods of spot-foliar applications were significant using contrast comparison procedures. Partial crown coverage using metsulfuron or imazapyr showed reduced efficacy when applied to one side of the crown. This showed metsulfuron and imazapyr did not translocate laterally through the entire plant. Control was dependent upon getting the herbicide to all sides of the crown.

Metsulfuron and glyphosate were not effective for control of bigleaf maple. Imazapyr gave significant control at either rate applied as full coverage (Table 1), and imazapyr is a slow acting herbicide. After one year only 10% and 20% of the imazapyr full coverage treatments were dead (0.6 and 1.1 kg/ha respectively). By June, the second year mortality increased 40% and 60%, and at the end of the second year, mortality increased to 60% and 70% respectively. Visual assessment of crown vigor suggests possible further increase in control with imazapyr.

Analysis of variance showed significant treatment differences for bigleaf maple height and height growth (p=0.0001). As shown in Table 2, metsulfuron, glyphosate, and the 0.6 kg/ha imazapyr treatment had little effect on bigleaf maple height. The imazapyr full coverage treatments have continued to increase control after the first year and appear to be approaching the control that the triclopyr treatments have as for both height and height growth as shown in Table 3 and Figure 2.

**Table 1. Bigleaf maple herbicide screening trial after two years. Effects of treatments on bigleaf maple clump mortality.**

| Treatment | Rate | Crown Coverage | Mortality Year 1[1] | Year 1.5 | Year 2 |
|---|---|---|---|---|---|
| | (kg/ha) | (degree) | | | |
| Check - No Treatment | | - | 0 | 0 | 0 |
| Metsulfuron | 170 g | 180 | 0 | 0 | 0 |
| Metsulfuron | 170 g | 360 | 20 | 0 | 11 |
| Glyphosate | 6.7 | 360 | 0 | 0 | 22 |
| Imazapyr | 0.6 | 180 | 0 | 0 | 10 |
| Imazapyr | 1.1 | 180 | 0 | 10 | 30 |
| Imazapyr | 0.6 | 360 | 10 | 40 | 60 |
| Imazapyr | 1.1 | 360 | 30 | 60 | 70 |
| Triclopyr | 38 mL [3] | Thin-line | 60 | 80 | 80 |
| Triclopyr/2,4-DP[2] | 18 mL [3] | Thin-line | 70 | 80 | 80 |
| Triclopyr/Mor-act[2] | 15 mL [3] | Thin-line | 70 | 90 | 80 |

[1] Year 1 - 18 Aug 1987 after 1 growing season.
Year 1.5 - 22 Jun 1988 mid-year year 2
Year 2 - 25 Aug 1988 After 2 growing seasons.

[2] 1:1 dilution ratio.

[3] Triclopyr.

Table 2. Bigleaf maple herbicide screening trial after two years. Effects of treatment on bigleaf maple total height.

| Treatment | Rate | Crown Coverage | Total Height After: Year 1 | | | Year 2 | | |
|---|---|---|---|---|---|---|---|---|
| | (kg/ha) | (degree) | m | (se) | | m | (se) | |
| Check - No Treatment | | - | 3.3 | (0.2) | ab[1] | 4.2 | (0.2) | a |
| Metsulfuron | 170 g | 180 | 2.8 | (0.3) | ab | 3.2 | (0.4) | ab |
| Metsulfuron | 170 g | 360 | 2.3 | (0.5) | b | 2.4 | (0.4) | bc |
| Glyphosate | 6.7 | 360 | 2.9 | (0.2) | abc | 1.9 | (0.4) | cd |
| Imazapyr | 0.6 | 180 | 3.5 | (0.2) | a | 3.1 | (0.5) | ab |
| Imazapyr | 1.1 | 180 | 2.9 | (0.4) | b | 2.1 | (0.5) | bcd |
| Imazapyr | 0.6 | 360 | 3.1 | (0.5) | ab | 1.1 | (0.6) | de |
| Imazapyr | 1.1 | 360 | 1.6 | (0.5) | a cd | 0.5 | (0.3) | e |
| Triclopyr | 38 ml [3] | Thin-line | 0.5 | (0.4) | e | 0.4 | (0.2) | e |
| Triclopyr/2,4-DP[2] | 18 ml [3] | Thin-line | 0.8 | (0.4) | de | 0.5 | (0.1) | e |
| Triclopyr/Mor-act[2] | 15 ml [3] | Thin-line | 0.4 | (0.3) | e | 0.1 | (0.1) | e |

[1] Treatments with same letter in a column are not significantly different at p = 0.05 using Duncan's New Multiple Range T-test.

[2] 1:1 dilution ratio.

[3] Triclopyr.

Table 3. Bigleaf maple herbicide screening trial after two years. Effects of treatment on bigleaf maple height growth expressed as a percent of pre-treatment height.

| Treatment | Rate | Crown Coverage | :---- Change in Total Height ----: Year 1 | | Year 2 | |
|---|---|---|---|---|---|---|
| | (kg/ha) | (degree) | % (se) | | % (se) | |
| Check - No Treatment | | - | 34 (7) | a | 60 (8) | a |
| Metsulfuron | 170 g | 180 | 10 (5) | ab | 10 (9) | b |
| Metsulfuron | 170 g | 360 | 2 (7) | ab | -15 (14) | bc |
| Glyphosate | 6.7 | 360 | -39 (13) | cd | -34 (15) | c |
| Imazapyr | 0.6 | 180 | -15 (14) | bc | 5 (18) | b |
| Imazapyr | 1.1 | 180 | -25 (11) | bcd | -30 (17) | c |
| Imazapyr | 0.6 | 360 | -60 (16) | d | -69 (14) | d |
| Imazapyr | 1.1 | 360 | -41 (16) | cd | -83 (10) | d |
| Triclopyr | 38 ml [3] | Thin-line | -2 (10) | abc | -89 (7) | d |
| Triclopyr/2,4-DP[2] | 18 ml [3] | Thin-line | -21 (15) | bc | -95 (4) | d |
| Triclopyr/Mor-act[2] | 15 ml [3] | Thin-line | -15 (14) | bc | -98 (2) | d |

[1] Treatments with same letter in a column are not significantly different at p = 0.05 using Duncan's New Multiple Range T-test.

[2] 1:1 dilution ratio.

[3] Triclopyr.

Figure 1. Bigleaf maple mortality by treatment and year. Treatment effects two years after application.

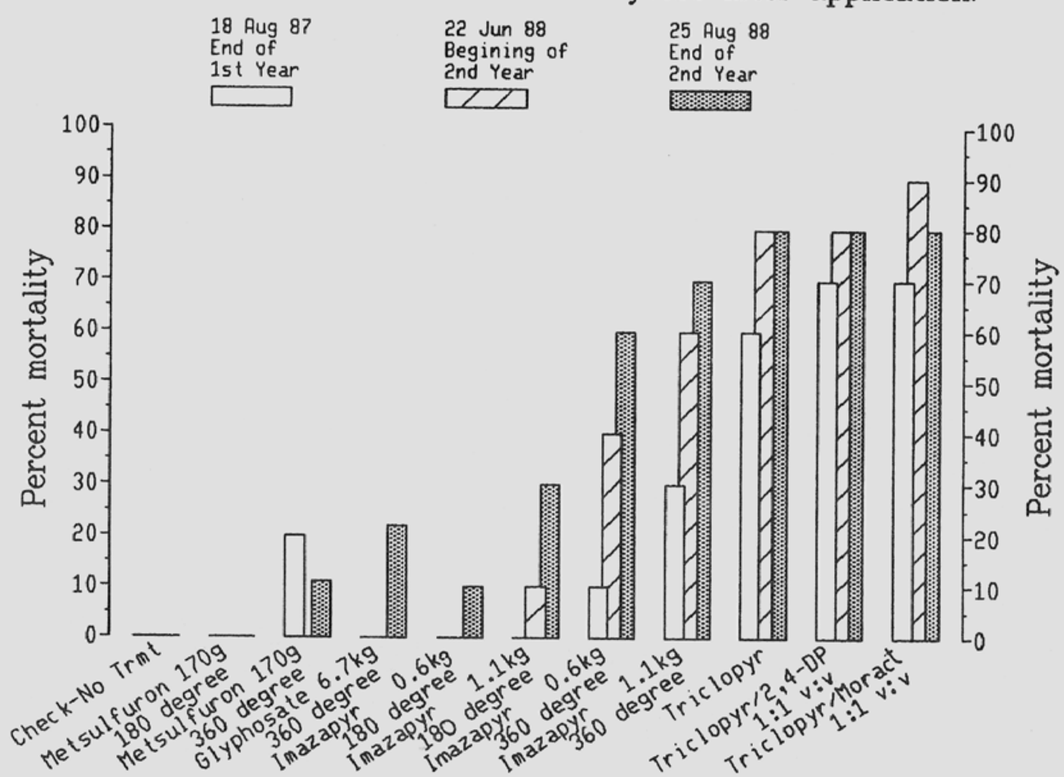
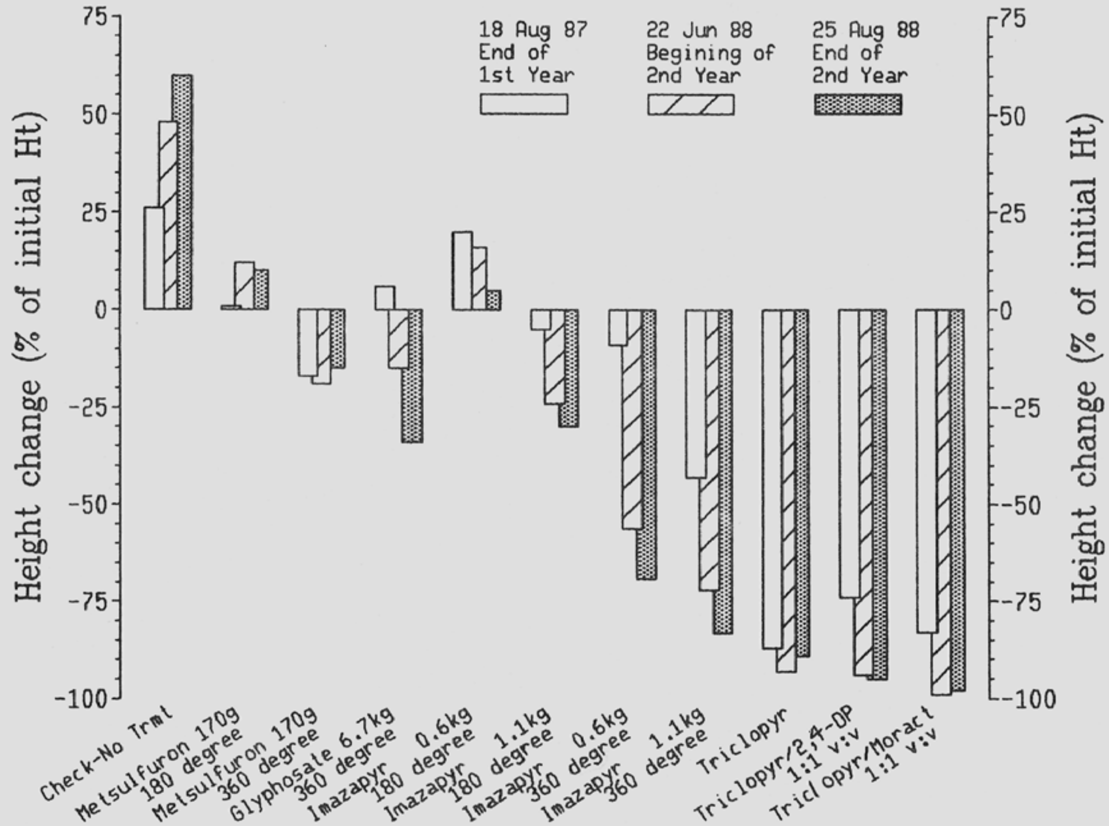


Figure 2. Bigleaf maple total height change.
Treatment effects two years after application.



Douglas-fir height was measured on a random sample of ten open-grown trees across the site to show the relative dominance bigleaf maple to the conifers. As shown in Figure 3, the bigleaf maple was significantly taller than Douglas-fir at treatment application. Two years after treatment only the triclopyr treatments and full coverage imazapyr treatments reduced average bigleaf maple height less than Douglas-fir.

Crown volume was calculated using crown width measurements and total height assuming the clump shape was a cylinder. Significant treatment differences were detected for bigleaf maple crown volume reductions [p=0.0001] (Table 4). The metsulfuron and glyphosate treatments only managed to stunt the growth of bigleaf maple and hold volume growth similar to the pre-treatment levels. As shown in Figure 4, crown volumes continue to decrease on the imazapyr treatments.

Glyphosate and metsulfuron did not give effective control of bigleaf maple as a spot-foliar treatment. These rates were higher than those tested by Wagner (1987) which were also not completely effective.

Spot-foliar treatments were not effective unless the material was applied to the full crown. Both rates of imazapyr full coverage treatments were effective controlling bigleaf maple and appear to be approaching the same degree of control as triclopyr thin-line treatments. Observations during spot-foliar treatments suggest that better control may have been obtained if the water carrier rate had been increased greater than the 187 L/ha used. This would give greater spray volumes to more fully cover the foliage. The results demonstrate a lag effect for imazapyr and additional bigleaf maple control may occur with time.

Spot-foliar treatments can be effective for control and potentially cost effective compared to thin-line treatments. The following table shows a comparison of potential herbicide costs:

| Treatment | Rate | Method | Herbicide $/Clump |
|---|---|---|---|
| Triclopyr | 44 mL | Thin-line | 0.83 |
| Triclopyr/2,4-DP | 22 mL each | Thin-line | 0.53 |
| Triclopyr/Mor-act[R] | 22 mL each | Thin-line | 0.46 |
| Imazapyr | 1.1 kg/ha | Spot-foliar | 0.08 |
| Imazapyr | 0.6 kg/ha | Spot-foliar | 0.04 |

Imazapyr spot-foliar treatments, however, will potentially have higher labor and administrative costs. Since effects take at least two years before effects are fully realized, contractor quality will be difficult to determine. Additions of dyes may be needed for visual inspection of foliage wetted during application. Since treatments would need to be applied during the active growing season, labor costs could increase due to the greater difficulty the contractors would have traversing the ground due to other vegetation.

In this study spray drift did not cause damage to the planted Douglas-fir, however, application was made with wind less than 5 km/hr. The inability for a contractor to work 8 hours a day due to wind may increase application costs. These combined costs, however, may not increase total treatment costs to the level greater than the thin-line treatments.

Dosage rates for spot-foliar treatments can be accurately dispensed either using a Spray Systems Meterjet[R] spray gun or a modified automatic drench syringe.

Table 4. Bigleaf maple herbicide screening trial after two years. Effects of treatment on bigleaf maple crown volume growth expressed as a percent of initial pre-treatment crown volume.

| Treatment | Rate | Crown Coverage | :----- Change in Crown Volume -----: Year 1 | | | Year 2 | | |
|---|---|---|---|---|---|---|---|---|
| | (kg/ha) | (degree) | % | (se) | | % | (se) | |
| Check - No Treatment | | - | 236 | (24) | a | 551 | (45) | a |
| Metsulfuron | 170 g | 180 | -13 | (12) | bc | 33 | (25) | c |
| Metsulfuron | 170 g | 360 | -22 | (25) | bc | -9 | (34) | c |
| Glyphosate | 6.7 | 360 | 110 | (45) | ab | -36 | (15) | c |
| Imazapyr | 0.6 | 180 | 243 | (129) | a | 256 | (184) | b |
| Imazapyr | 1.1 | 180 | 18 | (25) | bc | -39 | (24) | c |
| Imazapyr | 0.6 | 360 | 16 | (38) | bc | -83 | (12) | c |
| Imazapyr | 1.1 | 360 | -12 | (38) | bc | -96 | (2) | c |
| Triclopyr | 38 ml [3] | Thin-line | -99 | (1) | c | -98 | (2) | c |
| Triclopyr/2,4-DP[2] | 18 ml [3] | Thin-line | -99 | (1) | c | -99 | (1) | c |
| Triclopyr/Mor-act[2] | 15 ml [3] | Thin-line | -99 | (1) | c | -99 | (1) | c |

[1] Treatments with same letter in a column are not significantly different at $p = 0.05$ using Duncan's New Multiple Range T-test.

[2] 1:1 dilution ratio.

[3] Triclopyr.

Figure 3. Bigleaf maple and Douglas-fir total height. Treatment effects two years after application.

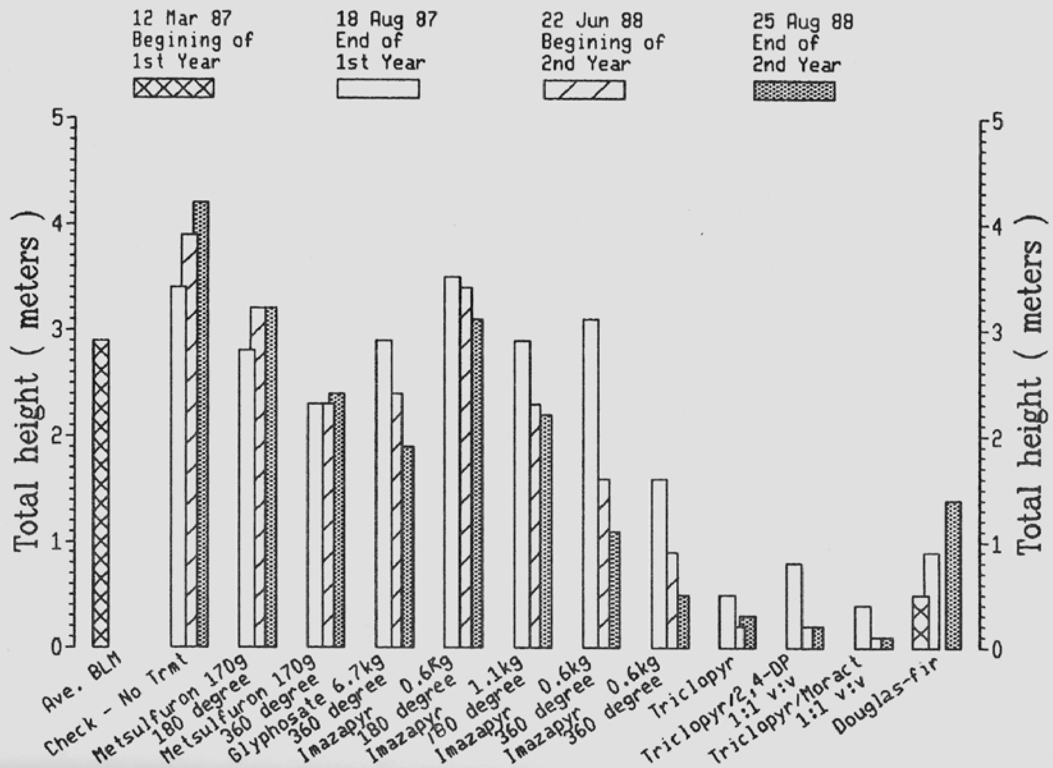
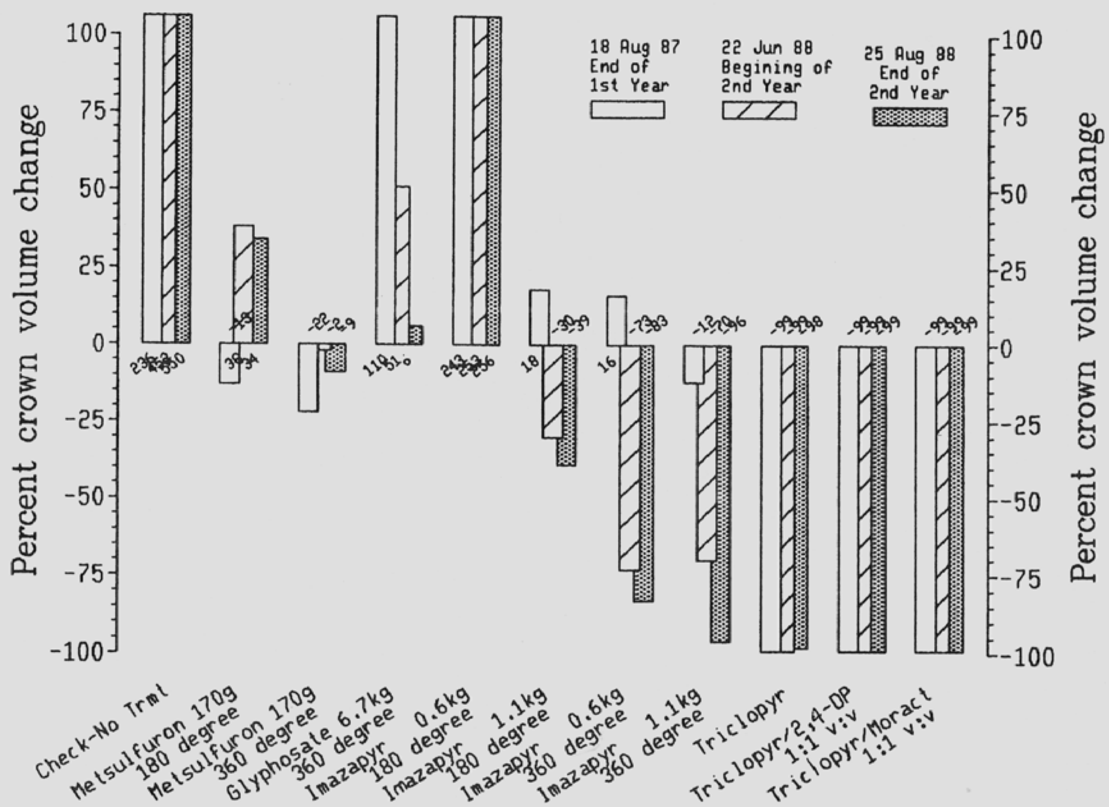


Figure 4. Bigleaf maple crown volume change.
Treatment effects two years after application.



Calibration of equipment is essential to understanding the dosage rates and treatment costs. The equipment used for both thin-line and spot-foliar applications were calibrated to dispense volumes precisely.

Wagner (1988b) examined the relationship between amount of triclopyr levels applied to bigleaf maple for thin-line application. He determined that levels as low as 2 ml triclopyr per $m^2$ of crown area would give 100% crown volume reduction for a February application date. In comparison to his results our data showed a similar trend. First and second year crown volume reduction was plotted with triclopyr delivery rate (Figure 5). Those surviving clumps had been attributed to incomplete banding of all stems. For this study, we applied triclopyr rates in excess of that needed to control bigleaf maple. Rates averaged 10.6 ml triclopyr per $m^2$ crown area and ranged between 2 and 18 ml/$m^2$.

Reduction of herbicide costs can be achieved by reducing the rates of triclopyr to the clump. Reduction of rates by reducing the nozzle size is not recommended since it will increase the probability that all stems will not get banded. Reduction of triclopyr through dilution with other less costly herbicides or adjuvants is recommended.

The results of this study were used to develop an estimate of the potential level of triclopyr volume needed to control bigleaf maple. This data was used to represent an average bigleaf maple thin-line sample for clump size and volume of application. Using the volume applied to each clump0, the minimum dilution rate was calculated assuming 2 ml/$m^2$, 4 ml/$m^2$ and 6 ml/$m^2$ were the minimum thresholds for bigleaf maple control.

Figure 6 shows that 100% of the clumps in this sample would be controlled using 45% solution of triclopyr using 2 ml/$m^2$ as a base. If 4 ml/$m^2$ was the minimum rate needed, triclopyr could be reduced to 85% solution, and if 6 ml/$m^2$ was the minimum rate required, 100% control could not be obtained. Since these were calculated and not verified using a study specifically designed to test the minimum threshold, a two-fold safety margin is recommended.

The average total volume of herbicide applied to bigleaf maple clumps further impacts the level that triclopyr could be diluted. Using 4 ml/$m^2$ as a two-fold safety margin for control, the probability of control was calculated using various application volumes to demonstrate the effect of average volume to bigleaf maple control. Figure 7 shows that application equipment that restricts material volumes to average 30 ml clump, would not attain 100% control. Using average flow volumes of 38 ml 100% control could be attained with a 85% solution using a 38 ml solution, 55% solution with 44 ml volume rate and 45% solution with an average 59 ml average solution volume rate.

## Conclusions

1. Metsulfuron and glyphosate were not effective herbicides for bigleaf maple control applied in June as spot-foliar treatments.

2. Full crown application is needed to obtain maximum control using imazapyr as a spot-foliar treatment.

3. Imazapyr applied as a spot-foliar requires at least two years to show efficacy similar to triclopyr thin-line.

4. Triclopyr diluted 1:1 v:v with Mor-act[R] or 2,4-DP was effective thin-line treatment.

**Figure 5. Bigleaf maple thin-line delivery rate comparison. Crown volume reduction by application rates of triclopyr.**

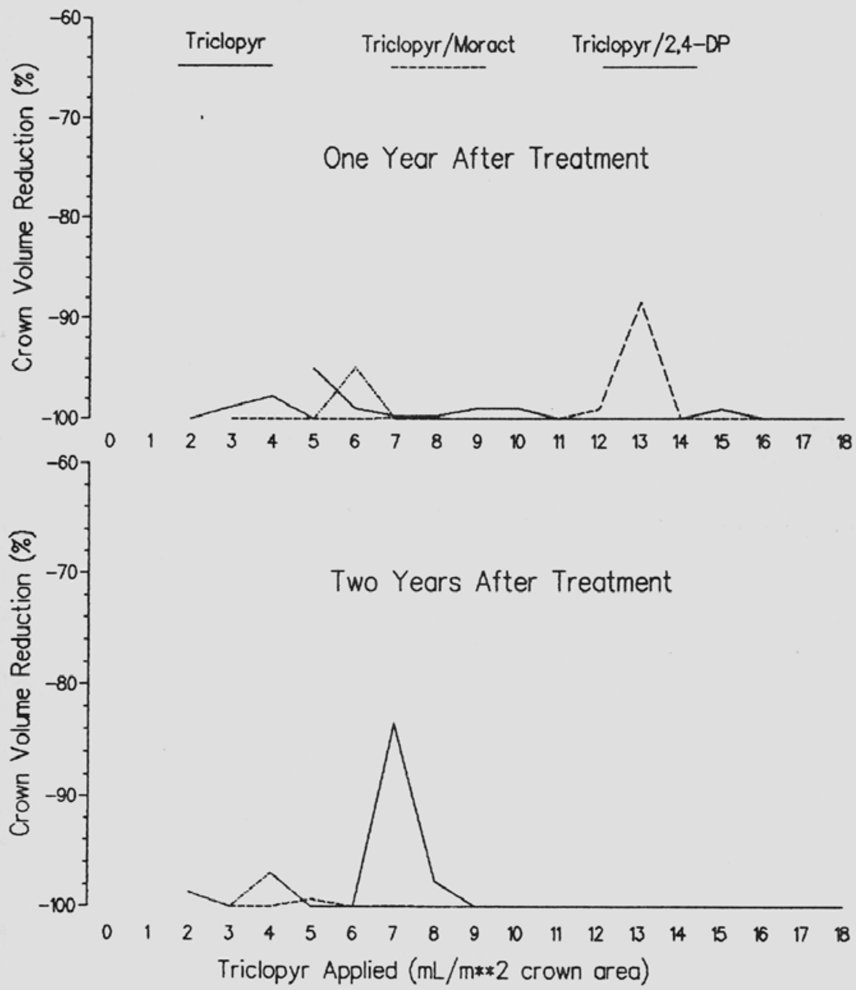


**Figure 6. Expected bigleaf maple control with triclopyr using various safety factors; assumes 2 mL/m**2 crown area is the base rate to obtain 100% control: average volume 38 mL per clump.**

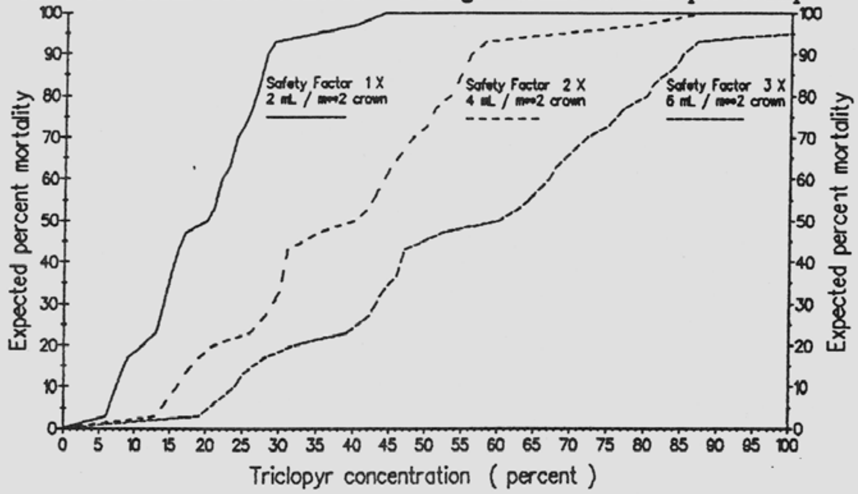
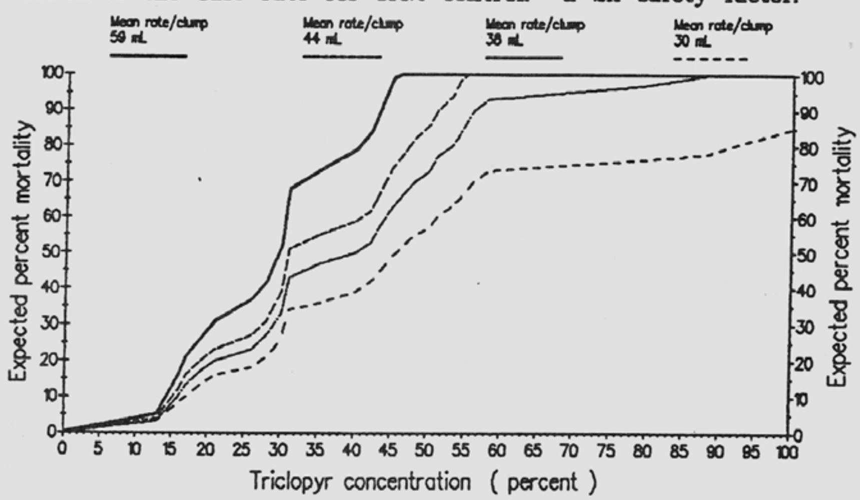



**Figure 7. Expected bigleaf maple control with triclopyr using various average application volume rates; assumes 4 mL/m**2 of crown is the base rate for 100% control: a 2X safety factor.**



5. Control of bigleaf maple can be achieved with application rates of 2 ml triclopyr per $m^2$ crown area, provided all stems are banded.

6. Triclopyr solution rates to 45% concentration are theoretically possible if delivery rates average 59 ml per clump (with a two-fold safety margin).

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# CUT SURFACE APPLICATIONS OF GLYPHOSATE OR IMAZAPYR FOR HARDWOOD CONTROL AND CONIFER THINNING

Bruce R. Kelpsas and Ron P. Crockett[1]

Abstract. Glyphosate {(*N*-(phosphonomethyl)glycine)} and imazapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid} are currently being used for individual tree treatment through cut surfaces such as frills in tree stems or cut stumps. Limited regional data exists for these compounds on important forestry species in the Pacific Northwest.

Individual trees of hardwood and conifer species were frilled or cut and treated with glyphosate or imazapyr in several trials in 1986-87 in Oregon and Washington. For standing trees, frill spacings varied by location and were either full frill (girdle) or one cut per inch of diameter (dbh). Glyphosate (3 lb ae/gal formulation) and/or two formulations of imazapyr (2 lb ae/gal and 4 lb ae/gal) were used for the treatments.

The formulations were applied to frills as either the undiluted material or diluted 1:1 with water at a nominal rate of 1 ml per frill. For cut stump treatments (glyphosate only), hardwood trees were felled and the cambial area treated with herbicide. Dosage was not controlled for cut stumps. Untreated standing trees or untreated cut stumps served as controls. Five to 15 individuals of each species were evaluated for each treatment. Trees and stumps were evaluated one year after treatment and rated for percent crown kill or stump viability.

Glyphosate was very effective in controlling both hardwoods and conifers when applied in July-September. Red alder (*Alnus rubra*), Pacific madrone (*Arbutus menziesii*), Oregon white oak (*Quercus qarryanna*), Douglas-fir (*Pseudotsuga menziesii*), Western hemlock (*Tsuqa heterophylla*) and Sitka spruce (*Picea sitchensis*) all exhibited 95-100% crown kill one year after treatment with the undiluted glyphosate formulation at either full frill or one cut/inch of diameter. Diluted glyphosate was also effective (95-100% crown kill) on alder or madrone and conifers during the same time and cut spacings. Treated stumps of alder and madrone showed 100% mortality with either dilution.

Imazapyr was also effective on both hardwoods and conifers. Bigleaf maple (*Acer macrophyllum*) treated in July or late winter (February-March) with the undiluted 2 lb ae/gal formulation exhibited 85-100% crown kill at a cut spacing of one cut/inch of diameter. Undiluted imazapyr (2 lb ae formulation) or the diluted 4 lb ae/gal formulation provided equivalent crown kill (100%) on Douglas-fir (March) or white oak (August) at one cut/inch of diameter.

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# WHERE DOES SULFOMETURON FIT IN PACIFIC NORTHWEST/ SILVICULTURE

Michael Newton and Elizabeth C. Cole[1]

## Introduction

Recent developments in reforestation and vegetation management research have demonstrated the value of intensive control of both herbs and woody competitors in early years of stand development.

In particular, the shade-intolerant conifers Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) and ponderosa pine, (*Pinus ponderosa* Laws.) have been observed to grow most rapidly and survive best with totally weed-free conditions (Newton and Preest, 1988; White and Newton, 1989).

Forest environments are most commonly occupied by large numbers of species. Numerous experiments have demonstrated that control of part of a plant community will often result in enhancement of resistant species, often to the detriment of the crop. In our vegetation management research program, we have been seeking a set of prescriptions that offer selective control of a broad spectrum of weeds in a single application with negligible damage to conifers.

Sulfometuron {2-[[[[(4,6-dimethyl-2-pyrimidinyl)carbonyl]amino]sulfonyl] benzoic acid} has been suggested as a broad-spectrum product useful for such maintenance operations in the Oregon Coast Range (Cole and Newton, 1988). This report describes additional experiments in established and newly planted stands, and outlines the opportunities for adapting sulfometuron in reforestation programs.

## Methods

Our general research approach was to establish a series of aerial application plots in a variety of vegetation types and conditions. The general site of study was the Oregon Coast Range, which we split into the North and South Coast study areas. At each North Coast site, we installed a factorial set of treatments with sulfometuron and 2,4-D {(2,4-dichlorophenoxy)acetic acid}, with two rates of sulfometuron (.11 and .22 kg/ha) with and without 2,4-D at 2.2 kg/ha. At the South Coast sites, sulfometuron was applied alone, at .11 and .165 kg/ha. At the South Coast site, sulfometuron was also compared with other herbaceous weed control products, including hexazinone at 1.65 kg/ha, atrazine plus glyphosate at 4.4 plus .42 or .4 kg/ha, and atrazine plus glyphosate at the same rates, but with 1.25% R-11 surfactant in the mixture. All treatments were applied at 92 l/ha, by Hiller-Siloy helicopter equipped with D-8 nozzles, except for one hexazinone plot, which was applied with ground equipment using the waving wand technique (Newton and Knight, 1981).

Plot size for the North Coast plots was 2 to 4 ha. The South Coast plots were approximately one-fifth ha in size, and were comprised of single helicopter swaths flown at 80 kph until the 40 ℓ batch was exhausted.

<u>Treatment sites</u>. The three North Coast sites were located to represent the range of vegetation, climate and soil conditions of the subregion. One site (McDonald) was on the foothills of the Willamette Valley, 15 km northwest of Corvallis, OR. This site is characterized by about 130 cm rainfall per year,

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with warm, dry summers. Soils are basalt-derived gravelly clay loams of the Ritner-Price series of Site Index 130 (100 years). Vegetation was that of one-year-old clearcuts, and was dominated by grapeleaf blackberry (*Rubus ursinus* C & S), snowberry, (*Symphoricarpos albus* (L.) Blake), poisonoak, (*Rhus diversiloba* T & G), Oregon grape (*Berbris aquifolium* Pursh.), sword fern (*Polystichum munitum* (Kaul.) Presl.), velvetgrass (*Holcus lanatus* L.) and woodland groundsel (*Senecio sylvaticus* L.). Douglas-fir bare-root seedlings had been planted one year before treatment.

A second site, Blodgett, is in the center of the Coast Range, with about 175 cm rainfall, moderate summers and wet winters. Soils are derived from micaceous sediments, and are of the Slickrock-Bohannon complex, clay loams 100-180 cm deep. Site index (100) is about 170 for Douglas-fir. The site had been logged four years before treatment, and planted with Douglas-fir. Vegetation was dominated by red alder (*Alnus rubra* Bong), vine maple (*Acer circinatum* Pursh), bitter cherry, (*Prunus emarginata* (Dougl.) Walp.), thimbleberry (*Rubus parviflorus* Nutt.), sword fern, and velvetgrass. The conifer plantation was codominant on much of the site, and losing position wherever maples or alder were abundant.

The third North Coast Site, Bottger Creek, is edaphically similar to the Blodgett site, but is in a somewhat higher rainfall area (200+ cm, est.). Treated areas were all three-year-old clearcuts that had been planted with Douglas-fir after broadcast burning, two years before treatment. Woody species present include those found at Blodgett, plus red huckleberry (*Vaccinium parvifolium* J.E. Sm.) and salal (*Gaultheria shallon* Pursh.). Herbs included several species of thistle (*Cirsium* (Tourn.) Hill.), pearly everlasting, (*Anaphalis margaritacea* (L.) B. & H.), California figwort (*Scrophularia californica* C. & S.), Emerson's hedge-nettle (*Stachys emersonii* Piper), blue wild rye (*Elymus glaucus* Buckle.), sword fern, and velvetgrass.

The two South Coast sites were about 130 km south of the North Coast sites, and included Cascade Foothill and the North Benson areas. The Cascade Foothill site is climatically similar to the McDonald site, but soils are shallower gravelly clay loams of basaltic origin, and of comparable productivity. The area had been clearcut and burned some 15 years previously, and supported scattered Douglas-fir advance regeneration as well as transplant Douglas-fir installed shortly before treatment. Vegetation was dominated by velvetgrass and orchardgrass (*Dactylis glomerata* L.), with clumps of poisonoak, and Canada thistle (*C. arvense* (L.) Scop.). Catsear (*Hypochaeris radicata L.*), California fescue (*Festucci californica* Vas.), trailing blackberry, and St. Johnswort (*Hypericum perforatum* L.) were also common.

The north Benson site is a two-year-old clearcut/rehabilitation unit on a deep soil of sedimentary origin resembling the Slickrock series of clay loams. Site index is approximately 190 for Douglas-fir. Vegetation other than the two-year-old plantation includes scattered salmonberry (*Rubus spectabilis* Pursh) and red elderberry (*Sambucus racimosa* L.*) and a dense herb cover consisting of bentgrass, (*Agrostis tenuis* Sibth.), velvetgrass, foxglove (*Digitalis purpurea* L.), Australian fireweed (*Erechtites prenanthoides* D.C.), catsear, and sword fern. Twenty 2-1 Douglas-fir transplants were planted in each plot to afford an opportunity to observe both newly planted and established seedlings.

The five sites were treated on different dates. The Valley Foothill site was sprayed Mar. 15, McDonald on Mar. 30, North Benson on Apr. 5, Blodgett on May 5 and Bottger Creek on May 20, 1988. At the times of treatment, those done in March and April were timed so treatment occurred before major bud swell on conifers. The Blodgett site was treated when bud elongation ranged from 0-3 cm, and the Bottger Creek site was treated when new growth had extended 3-12 cm.

Evaluation. Evaluation was done in summer, 1988 following the spring treatments. Each plot on each unit was subsampled, and percent forb, grass, shrub and fern cover ocularly estimated on one-meter-radius circular plots. These plots were located along transects with five samples in each of the .2-ha plots and 20 in each of the larger plots. Injury to Douglas-fir was evaluated on a 6-point scale: 0=no injury; 1=minor injury to foliage; 2=injury to buds; 3=minor terminal dieback; 4=major terminal dieback and loss of foliage; 5=dead. Data were analyzed by analysis of variance and multiple comparisons among means.

## Results

South Coast sites. All herbicide treatments reduced total cover to less than 50 percent. Treatments providing the greatest cover reduction were those involving sulfometuron or hexazinone (Table 1). There were no differences among the glyphosate plus atrazine treatments, indicating that surfactant did not influence degree of control with these products; these mixtures were less effective than sulfometuron at either rate, or hexazinone.

Among species group responses, forbs were reduced most completely by hexazinone, and least by atrazine and glyphosate with surfactant. Grasses were reduced most by hexazinone or sulfometuron, with less than 10 percent cover remaining. Orchardgrass resistance to the atrazine treatments led to increased ratio of this species in the absence of hexazinone or sulfometuron. Both rates of sulfometuron led to the lowest degree of residual cover of any treatments for all groups of plants other than forbs. The two rates were nearly identical in their effects.

Conifer injury was evaluated on the recently planted seedlings only. Although there were apparent differences between sites, differences among treatments were non-significant. Nevertheless, untreated seedlings had the lowest injury scores on both sites.

Hexazinone and both rates of sulfometuron provided adequate control of herbs for establishment of Douglas-fir on these sites. None of the treatments reduced shrub levels appreciably, and all treatments would be unsatisfactory for a shrub-dominated landscape.

North Coast Sites. These sites were analyzed both collectively and separately, in consideration of the differences in date of treatment. Because of differences in application date, sites are confounded with date of application, hence are not true replications. There were nevertheless a number of observations in common for all sites (Table 2).

For all sites considered together, all treatments significantly reduced plant cover compared to untreated controls. Forbs, grass, shrubs, and trailing blackberry were all reduced by all chemical treatments, but fern cover was not significantly reduced. When 2,4-D was added to sulfometuron, effects on forbs and trailing blackberries were significantly increased. Injury to Douglas-fir was also greater when 2,4-D was added to sulfometuron, but the effects of added 2,4-D were proportional to the degree of new foliage elongation. Individual site differences are discussed below.

The McDonald site, treated before any conifer buds had broken, resulted in the least damage to conifers, but also the least damage to shrubs. Damage to shrubs was limited to some formative effects on emerging foliage of hazel and maples. Poison oak was prevalent on these plots, and was inhibited to a small degree, but not to the extent of reduced cover. Conifer injury was minor, but was slightly more visible in the treated than in the control areas.

Differences in rate of sulfometuron were apparent in all classes of vegetation, but conifer injury was no higher at high rates. Addition of 2,4-D to sulfometuron resulted in reduced cover of trailing blackberries and forb, but only contributed to reduced total cover at the high rate of sulfometuron. Thus, the higher rate of sulfometuron had a greater net effect in dominance of conifers than the low rate, and addition of 2,4-D at this early date added little benefit (Table 3).

The Blodgett site also displayed substantial cover reduction from all treatments, but the four treatments did not differ significantly from each other in degree of control. Treatments with 2,4-D caused more visible injury to conifers than those without, but injury was not severe in any treatment despite emergence of many conifer buds (Table 4).

Individual species groups varied greatly in their sensitivities. Pearly everlasting, bedstraw (*Galium aparive* L.), fireweed (*Epilobium angustafolium* L.), and false hellebore were highly resistant and appeared after treatment. Figwort and foxglove were nearly eradicated by sulfometuron with or without 2,4-D; thistles were reduced by sulfometuron and nearly eradicated when 2,4-D was added. Although there were no significant differences in fern cover among treatments, those treated with sulfometuron appeared lower in vigor, and can be expected to decline next year.

Overall, residual cover other than shrubs was light and in poor vigor. Conifer injury was insignificant in any treatment.

The Bottger Creek site was treated after conifer buds were substantially elongated, and conifer injury was a major focus of concern. Injury was indeed a problem, in that nearly all of those treated with 2,4-D were injured, about a fifth of them severely. There was also evidence of widespread injury from sulfometuron, expressed as off-color foliage, (minor) and reduced incidence of second-flushing, as reported by Cole and Newton (1989) (Table 5).

All treatments reduced all classes of vegetation other than ferns and appeared to reduce vigor of ferns. Figwort and foxglove were nearly eradicated in all treatments. Among woody species, red alder was almost totally removed by addition of 2,4-D to sulfometuron, leading to near-total dominance of the conifer plantation, despite damage.

Table 2 describes the means of all North Coast treatment effects, illustrating pooled rates of sulfometuron with and without 2,4-D, compared to untreated controls. Tables 3, 4, and 5 list specific effects of all treatments on the three separate sites for evaluation of the specific effects of application timing. The reader is reminded that the floristic composition of the Blodgett and Bottger Creek sites are similar, but that the McDonald site is substantially different other than conifers.

## Discussion

Sulfometuron appears to be injurious to Douglas-fir in decreasing degree with age. Cole and Newton (1989) have reported injury to be consistent, and moderately important in newly planted Douglas-fir Christmas trees, but to be of a stunting nature somewhat different from traditional impacts of chemicals. As conifers enter their second year and beyond, their sensitivities appear to decrease--frost-like damage may occur if applied after budbreak on a portion of growing tips, especially internodal laterals. The experiments presented above demonstrate that damage is minor in established Douglas-fir, and that sulfometuron, with or without 2,4-D, will achieve a level of general vegetation management that has been difficult to achieve to date. The decision whether to add 2,4-D will largely be determined by presence of alder, in which case timing of application is very important.

Timing of treatment with sulfometuron alone appears to have relatively minor direct effect on Douglas-fir, regardless of terminal elongation status. Damage from added 2,4-D is acceptable until terminal growth of Douglas-fir reaches about 3-5 cm, after which foliage necrosis, terminal dieback, and growth check occur. Sulfometuron does not control red alder and is marginally effective on most woody species other than Rubus species. Thus, conditions requiring 2,4-D are not uncommon, and program timing will often be keyed to 2,4-D.

Rate of application of sulfometuron did not often show up as important in statistical analysis, except in the earliest application. The higher rates appeared visually to have less herbaceous biomass and for ferns to have lower vigor. Because our observations were not sensitive enough to detect very small differences, this will have to remain as an impression. In view of the residual properties of sulfometuron, a rate effect may be more evident in the following season.

When evaluating the comparative importance of improved vigor from weed control and decreased vigor resulting from conifer injury, a tradeoff is presented between short-term injury and long-term dominance. Our data are all short term in this report, and we cannot state how the conifers will recover from low-level injury. From data on glyphosate and hexazinone in related experiments, it may take four years to develop a picture of whether benefits from weeding exceed losses from injury (Newton and White, 1984). The importance of dominance in long-term competition with woody competition, such as *Rubus* species and red alder is such that short-term injury is probably of lesser importance in the present situation, provided dominance is established. These treatments have succeeded in accomplishing that.

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Table 1. Total, forb, grass, shrub, and fern cover and injury rating for South Coast plots.

| Treatment | Rate/Acre | %Total Cover | %Forb Cover | %Grass Cover | %Shrub Cover | %Fern Cover | Injury Rating |
|---|---|---|---|---|---|---|---|
| Control | 0.0 | 89 a* | 47 a | 34 a | 6 ab | 3 ab | 1.20 a |
| Glyphosate + | .37 + 4.4 lb | 41 bc | 11 bc | 23 ab | 4 b | 3 ab | 1.00 a |
| Atrazine + R-11 | .75 + 4.4 lb | 49 b | 25 b | 12 b | 5 ab | 8 a | 1.50 a |
| Glyphosate + Atrazine | .75 + 4.4 lb | 45 bc | 15 bc | 17 ab | 8 ab | 5 ab | 1.65 a |
| Hexazinone** | 1.5 lb | 27 c | 7 c | 4 b | 15 a | 0 b | 2.20 a |
| Sulfometuron | 1.5 oz | 26 c | 13 bc | 10 b | 2 b | 1 ab | 1.40 a |
| Sulfometuron | 2.25 oz | 24 c | 16 bc | 7 b | 1 b | 1 ab | 1.35 a |

* Means followed by the same letter within columns are not significantly different at $\alpha = 0.05$ using Tukey's.

** Hexazinone treatment applied only on the Valley/Cascade foothill site. R-11 was added at 1.25 percent volume/volume.

Table 2. Chemical comparisons for North Coast units. Means represent data pooled over all sites and rates.

| Chemical | Total | Grass | Forb | % Shrub Cover | Fern | RUUR* | Injury Rating | % Injured |
|---|---|---|---|---|---|---|---|---|
| Control | 89 a | 5 a | 47 a | 25 a | 11 a | 26 a | 0.23 c | 23 c |
| Sulfometuron | 42 b | 2 b | 16 b | 15 b | 9 a | 6 b | 0.53 b | 47 b |
| Sulfometuron + 2,4-D | 36 b | 3 b | 8 c | 15 b | 10 a | 2 c | 0.96 a | 64 a |

* RUUR = Trailing blackberry.

Means followed by the same letter within columns are not significantly different at $\alpha = 0.05$ using Tukey's test.

Table 3. Total, trailing blackberry (RUUR), grass, forb, fern, and shrub cover and Douglas-fir injury rating and percent of seedlings injured for MacDonald unit.

| Treatment | | Total | RUUR | % Grass Cover | % Forb Cover | Fern | Shrub | Injury Rating | % Injured |
|---|---|---|---|---|---|---|---|---|---|
| Control | | 88 a | 41 a | 3 a | 57 a | 5 a | 23 b | 0.38 | 37 |
| Sulfometuron | 1.5 oz | 59 bc | 12 bc | 1 b | 35 b | 3 a | 19 b | 0.72 | 68 |
| Sulfometuron | 3.0 oz | 46 c | 21 b | 0 b | 27 bc | 4 a | 15 b | 0.50 | 40 |
| Sulfometuron + 2,4-D | 1.5 oz + 2 lb | 63 b | 6 c | 5 a | 20 cd | 2 a | 36 a | 0.94 | 87 |
| Sulfometuron +2,4-D | 3.0 oz + 2 lb | 26 d | 4 c | 0 b | 11 d | 1 a | 14 b | 0.47 | 46 |

* Means followed by the same letter within columns are not significantly different at $\alpha = 0.05$ using Tukey's test.

Table 4. Total, trailing blackberry (RUUR), grass, forb, fern, and shrub cover and Douglas-fir injury rating and percent of seedlings injured for Blodgett units.

| Treatment | Rate/Acre | Total | RUUR | % Grass Cover | % Forb Cover | Fern | Shrub | Injury Rating | % Injured |
|---|---|---|---|---|---|---|---|---|---|
| Control | | 102 a | 19 a | 3 a | 27 a | 27 a | 44 a | 0 | 0 |
| Sulfometuron | 1.5 oz | 56 b | 2 b | 2 ab | 8 b | 19 a | 26 b | 0 | 0 |
| Sulfometuron | 3.0 oz | 44 b | 0 b | 0 b | 7 b | 21 a | 17 bc | 0.05 | 5 |
| Sulfometuron + 2,4-D | 1.5 oz + 2 lb | 43 b | 2 b | 1 b | 5 b | 27 a | 10 c | 0.14 | 12 |
| Sulfometuron + 2,4-D | 3.0 oz + 2 lb | 41 b | 0 b | 1 b | 4 b | 17 a | 18 bc | 0.32 | 21 |

* Means followed by the same letter within columns are not significantly different at $\alpha = 0.05$ using Tukey's test.

Table 5a. Total, trailing blackberry (RUUR), grass, forb, fern, and shrub cover for Bottger Creek unit.

| Treatment | Rate/Acre | Total | RUUR | % Grass Cover | % Forb Cover | Fern | Shrub |
|---|---|---|---|---|---|---|---|
| Control | | 79 a | 4 a | 12 a | 48 a | 6 a | 12 a |
| Sulfometuron | 1.5 oz | 32 b | 4 a | 7 ab | 9 b | 7 a | 9 ab |
| Sulfometuron | 3.0 oz | 16 c | 0 a | 2 b | 9 b | 2 a | 3 b |
| Sulfometuron + 2,4-D | 1.5 oz + 2 lb | 25 bc | 1 a | 7 ab | 5 b | 5 a | 7 ab |
| Sulfometuron + 2,4-D | 3.0 oz + 2 lb | 18 c | 1 a | 2 b | 4 b | 7 a | 4 b |

* Means followed by the same letter within columns are not significantly different at $\alpha = 0.05$ using Tukey's test.

Table 5b. Injury rating, percent injured and percent severely injured for Douglas-fir on Bottger Creek unit.

| Treatment | Rate/Acre | Injury Rating | % Injured | %Severely Injured |
|---|---|---|---|---|
| Control | | 0.1 | 10 | 0 |
| Sulfometuron | 1.5 oz | 1.00 | 88 | 1 |
| Sulfometuron | 3.0 oz | 0.67 | 67 | 0 |
| Sulfometuron + 2,4-D | 1.5 oz + 2 lb | 2.00 | 98 | 24 |
| | 3.0 oz + 2 lb | 2.00 | 100 | 19 |

# HEIGHT GROWTH RESPONSE IN CHRISTMAS TREES TO SULFOMETURON AND OTHER HERBICIDES

Elizabeth C. Cole and Michael Newton[1]

Christmas tree plantations use several different herbicides for weed control. Because of the importance of "appearance" to Christmas trees, it is necessary to adequately test all herbicides for conifer tolerance prior to widespread use within plantations. Some herbicides may cause visible injury to trees, while others may produce no obvious symptoms, but still result in some height growth suppression. Sulfometuron {2-[[[[(4,6-dimethyl-2-pyrimidinyl) carbonyl]amino]sulfonyl]benzoic acid}, a grass and broadleaf herbicide, has received considerable interest for Christmas tree use. However, its effects on conifers have not been fully explored. To evaluate conifer tolerance to sulfometuron, three species of Christmas trees were sprayed with sulfometuron and two other commonly used herbicides, atrazine {6-chloro-*N*-ethyl-*N*'-(1-methylethyl)-1,3,5-triazine-2,4-diamine} and hexazinone {3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione}.

The sites selected included two sites in western Oregon that had been in Christmas tree culture for several years and were previously pasturelands. Standard practices include tillage followed by planting by hand or machine. The first site, Mohnike, consisted of clay loam soils from the Knappa series. Annual precipitation is approximately 200 centimeters. The second site, Beaver Creek, has clay loam soils from the Bellpine series and an approximate annual precipitation of 100 centimeters. Plantations on the Mohnike site consisted of three-year-old noble fir (*Abies procera* Rehd.), grand fir (*A. grandis* Lindl.), and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). At Beaver Creek, Douglas-fir had been planted just prior to spraying.

The sulfometuron treatments were applied pre- and post budbreak. At the time of the post budbreak treatments, different degrees of bud swell and needle elongation occurred. At Mohnike, Douglas-fir varied from bud swell to 10 centimeters needle elongation, noble fir from bud swell to 2 centimeters, and grand fir from bud swell to 2.5 centimeters. Rain and water-soaked soils prevented machine planting at Beaver Creek until mid-April. As a result, no budbreak had occurred for the post budbreak treatments; a few of the seedlings had swollen buds. For all sites, soils were almost saturated for the post budbreak treatments. Above normal rains fell in late April and early May.

## Treatment Procedures

All treatments were randomly assigned within a site. Four rates of sulfometuron (0.05, 0.11, 0.16, and 0.21 kg a.i./ha) were tested at pre- and post-budbreak timings. In addition, atrazine (4.5 kg/ha), hexazinone (2.2 kg/ha), and untreated control plots were included. The atrazine and hexazinone were applied pre-budbreak. Treatments are listed in Table 1.

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Table 1. Treatments for Christmas tree plots.

| Treatment | Rate a.i./Hectare | Timing |
|---|---|---|
| Atrazine | 4.5 kg | Pre-budbreak |
| Hexazinone | 2.2 kg | Pre-budbreak |
| Sulfometuron | 0.05, 0.11, 0.16, 0.21 kg | Pre-budbreak |
| Sulfometuron | 0.05, 0.11, 0.16, 0.21 kg | Post budbreak |
| Untreated Control | 0 | |

All herbicide applications were made using a nitrogen pressurized precision sprayer with a hand-held boom mounted with seven nozzles (80015 teejet). Plots were 3.2 by 12.6 meters (0.004 ha/ 0.01 acre).

Seedlings on each plot were measured in fall 1988, at the end of the height growing season. Current total height, height at the time of treatment (height last year), and number of buds on the terminal were measured. Injury to seedlings was ocularly rated using a six-point scale:

0--no visible injury
1--minor injury to foliage
2--injury to foliage and buds
3--slight terminal dieback
4--severe terminal dieback and loss of one-third of foliage
5--dead

Current height and growth were analyzed using analysis of covariance with height last year as the covariate and multiple comparisons among the means for adjusted means. Bud count and injury rating were analyzed using analysis of variance and comparisons among means. Vegetation control will be discussed briefly; then species will be discussed separately.

## Results

Vegetation. In general, the high rates of sulfometuron, atrazine, and hexazinone treatments were similar in terms of cover reduction. The low rates of sulfometuron were generally not as effective. For grass control, the early treatments were more effective, but for some species of forbs (such as thistles), the later treatments had better control. All herbicides worked more effectively as preemergence herbicides rather than postemergence. When used as a preeemergent, no differences were found among rates of sulfometuron.

Noble fir. Herbicide treatments caused little injury to noble fir seedlings. The highest rate of sulfometuron post budbreak had the highest injury rating (0.20), but was not significantly greater than the untreated control seedlings (Table 2b).

Most of the treatments were not significantly different from the control seedlings in terms of total height and height growth. However, the high rates of sulfometuron had significantly shorter seedlings with less height growth (Table 2a) when compared to the low rates of sulfometuron and the other treatments. There were no differences in timing of applications.

Grand fir. There were no differences among treatments for height, height growth, injury rating, or bud count (Tables 3a and b). No trends among the height measurements were apparent.

Three-year-old Douglas-fir. Although the injury rating was not significantly different among treatments (Table 4b), there were some visible differences in injury among the treatments. The high rates of sulfometuron post budbreak caused some tip dieback in the lower crowns of the seedlings. Although this injury is considered minor in forest plantations, it would reduce the quality and value of Christmas trees for current year sales.

The hexazinone plots had the tallest average seedlings and seedlings with the best height growth (Table 4a). Most of the difference was due to the seedlings' ability to "second flush". Seedlings in the sulfometuron treatments were significantly shorter and had significantly less height growth than the other treatments. Although some of these were not significantly different from the untreated seedlings, there is a definite trend of growth reduction due to sulfometuron applications. The average height and height growth of the post budbreak applications were all less than the prebudbreak applications. In addition, the higher the rate, the shorter the seedlings were and the less height growth was made. The lowest rate of application was not significantly different from the atrazine treatment and had taller seedlings and greater height growth than the controls.

First-year Douglas-fir. All treatments were associated with some degree of injury to Douglas-fir seedlings, but no treatment caused severe injury (Table 5b). Injury was primarily limited to chlorosis of needles and slight stunting. There was a slight but nonsignificant trend for a greater degree of injury to occur with the sulfometuron prebudbreak treatments. These treatments were applied the same day as planting.

For seedling growth, total height and height growth (both adjusted for initial height) for the seedlings in the atrazine plots were significantly greater than all other treatments, including the control plots (Table 5a). Hexazinone and sulfometuron at 0.05 kg/ha also produced good results and were significantly different from most other treatments. Although differences in height and height growth were slight, the proportional differences were great. The atrazine-treated seedlings had twice the height growth of the treatments with the least height growth. In addition, most of the sulfometuron treatments had significantly shorter seedlings and less growth than the atrazine and hexazinone treatments, indicating some degree of growth suppression associated with the sulfometuron applications.

## Summary

Only grand fir seedlings exhibited no reduction in height growth among the sulfometuron treatments. Noble fir seedlings had growth reduction at the highest rates of sulfometuron, especially with the post budbreak applications. Douglas-fir appeared to be the most sensitive species. The established seedlings showed a significant trend of growth reduction with increasing rate of application of sulfometuron and with later application. Although the trends were not as strong with the newly-planted Douglas-fir, there were some reductions in height growth associated with the sulfometuron treatments. Seedlings in the atrazine treatments (newly-planted seedlings, and the hexazinone treatments (three-year-old Douglas-fir) exhibited the best growth and vigor.

Table 2a. Height, adjusted height, initial height, height growth, and adjusted height growth for noble fir.

| Treatment | Rate kg /Ha | Time | Hgt | Adj. Hgt | HATT | HG | Adj. Hgt Growth* |
|---|---|---|---|---|---|---|---|
| Control | 0.0 | | 84 | 83 a | 52 | 32 | 31 a |
| Atrazine | 4.5 | Pre | 76 | 78 abc | 50 | 26 | 27 ab |
| Hexazinone | 2.2 | Pre | 84 | 82 a | 52 | 31 | 31 a |
| Sulfometuron | 0.05 | Pre | 84 | 78 abc | 55 | 29 | 27 ab |
| | 0.11 | Pre | 79 | 78 abc | 52 | 27 | 27 ab |
| | 0.16 | Pre | 74 | 73 cd | 52 | 22 | 22 bc |
| | 0.21 | Pre | 76 | 75 bcd | 52 | 24 | 24 bc |
| | 0.05 | Post | 76 | 80 ab | 49 | 28 | 29 a |
| | 0.11 | Post | 76 | 78 abc | 52 | 27 | 27 ab |
| | 0.16 | Post | 74 | 74 cd | 51 | 23 | 23 bc |
| | 0.21 | Post | 70 | 71 d | 51 | 20 | 20 c |

* Hgt=Total Height (cm); Adj. Hgt=Height (cm) adjusted for initial height as covariate; HATT=Height (cm) at time of treatment; HG=Height growth (cm); Adj. Hgt Growth=Height growth (cm) adjusted for covariate.

Table 2b. Injury rating and bud count for noble fir.

| Treatment | Rate /Ha | Time | Injury Rating | Bud Count |
|---|---|---|---|---|
| Control | 0.0 | | 0.06 ab* | 12 ab |
| Atrazine | 4.5 kg | Pre | 0 b | 13 ab |
| Hexazinone | 2.2 kg | Pre | 0 b | 14 ab |
| Sulfometuron | 0.05 kg | Pre | 0.03 b | 13 ab |
| | 0.11 kg | Pre | 0.03 b | 14 ab |
| | 0.16 kg | Pre | 0.13 ab | 13 ab |
| | 0.21 kg | Pre | 0.20 a | 15 a |
| | 0.05 kg | Post | 0.03 b | 14 ab |
| | 0.11 kg | Post | 0 b | 13 ab |
| | 0.16 kg | Post | 0 b | 13 ab |
| | 0.21 kg | Post | 0 b | 10 b |

* Means followed by the same letter within columns are not significantly different at $\alpha$=0.05 using Tukey's.

Table 3a. Height, adjusted height, initial height, height growth, and adjusted height growth for grand fir.

| Treatment | Rate kg /Ha | Time | Hgt | Adj. Hgt | HATT | HG | Adj. Hgt Growth* |
|---|---|---|---|---|---|---|---|
| Control | 0.0 | | 96 | 95 a | 55 | 41 | 41 a |
| Atrazine | 4.5 | Pre | 88 | 89 a | 53 | 35 | 35 a |
| Hexazinone | 2.2 | Pre | 99 | 92 a | 59 | 41 | 38 a |
| Sulfometuron | 0.05 | Pre | 99 | 96 a | 56 | 43 | 42 a |
| | 0.11 | Pre | 85 | 90 a | 51 | 34 | 36 a |
| | 0.16 | Pre | 91 | 94 a | 52 | 39 | 40 a |
| | 0.21 | Pre | 84 | 91 a | 49 | 35 | 38 a |
| | 0.05 | Post | 99 | 94 a | 57 | 42 | 40 a |
| | 0.11 | Post | 96 | 92 a | 56 | 39 | 38 a |
| | 0.16 | Post | 94 | 92 a | 55 | 39 | 38 a |
| | 0.21 | Post | 85 | 94 a | 48 | 37 | 40 a |

* Hgt=Total Height (cm); Adj. Hgt=Height (cm) adjusted for initial height as covariate; HATT=Height (cm) at time of treatment; HG=Height growth (cm); Adj. Hgt Growth=Height growth (cm) adjusted for covariate.

Table 3b. Injury rating and bud count for grand fir.

| Treatment | Rate /Ha | Time | Injury Rating | Bud Count |
|---|---|---|---|---|
| Control | 0.0 | | 0.12 a * | 23 a |
| Atrazine | 4.5 kg | Pre | 0.07 a | 26 a |
| Hexazinone | 2.2 kg | Pre | 0.14 a | 25 a |
| Sulfometuron | 0.05 kg | Pre | 0.23 a | 25 a |
| | 0.11 kg | Pre | 0.27 a | 21 a |
| | 0.16 kg | Pre | 0 a | 28 a |
| | 0.21 kg | Pre | 0.07 a | 24 a |
| | 0.05 kg | Post | 0 a | 24 a |
| | 0.11 kg | Post | 0.06 a | 22 a |
| | 0.16 kg | Post | 0.07 a | 31 a |
| | 0.21 kg | Post | 0.07 a | 28 a |

* Means followed by the same letter within columns are not significantly different at $\alpha$=0.05 using Tukey's.

Table 4a. Height, adjusted height, initial height, height growth and adjusted height growth for three-year-old Douglas-fir.

| Treatment | Rate kg /Ha | Time | Hgt | Adj. Hgt | HATT | HG | Adj. Hgt Growth* |
|---|---|---|---|---|---|---|---|
| Control | 0.0 | | 136 | 150 bc | 75 | 61 | 67 bc |
| Atrazine | 4.5 | Pre | 153 | 156 b | 82 | 71 | 72 b |
| Hexazinone | 2.2 | Pre | 198 | 167 a | 102 | 96 | 84 a |
| Sulfometuron | 0.05 | Pre | 160 | 155 b | 86 | 74 | 72 b |
| | 0.11 | Pre | 137 | 150 bc | 76 | 61 | 66 bc |
| | 0.16 | Pre | 149 | 147 bcd | 85 | 64 | 63 bcd |
| | 0.21 | Pre | 131 | 150 bc | 72 | 59 | 66 bc |
| | 0.05 | Post | 177 | 154 b | 97 | 80 | 71 b |
| | 0.11 | Post | 145 | 140 de | 86 | 59 | 57 de |
| | 0.16 | Post | 140 | 143 cde | 81 | 58 | 60 cd |
| | 0.21 | Post | 127 | 137 e | 77 | 50 | 54 e |

* Hgt=Total Height (cm); Adj. Hgt=Height (cm) adjusted for initial height as covariate; HATT=Height (cm) at time of treatment; HG=Height growth (cm); Adj. Hgt Growth=Height growth (cm) adjusted for covariate.

Table 4b. Injury rating and bud count for three-year-old Douglas-fir.

| Treatment | Rate /Ha | Time | Injury Rating | Bud Count |
|---|---|---|---|---|
| Control | 0.0 | | 0.08 a * | 18 b |
| Atrazine | 4.5 kg | Pre | 0.43 a | 31 a |
| Hexazinone | 2.2 kg | Pre | 0.23 a | 27 ab |
| Sulfometuron | 0.05 kg | Pre | 0.10 a | 25 ab |
| | 0.11 kg | Pre | 0 a | 24 ab |
| | 0.16 kg | Pre | 0.28 a | 24 ab |
| | 0.21 kg | Pre | 0.43 a | 23 ab |
| | 0.05 kg | Post | 0.08 a | 31 a |
| | 0.11 kg | Post | 0.36 a | 18 b |
| | 0.16 kg | Post | 0.39 a | 25 ab |
| | 0.21 kg | Post | 0.56 a | 22 ab |

* Means followed by the same letter within columns are not significantly different at $\alpha$=0.05 using Tukey's.

Table 5a. Height, adjusted height, initial height, height growth, and adjusted height growth for first-year Douglas-fir.

| Treatment | Rate kg /Ha | Time | Hgt | Adj. Hgt | HATT | HG | Adj. Hgt Growth* |
|---|---|---|---|---|---|---|---|
| Control | 0.0 | | 56 | 56 cd | 44 | 12 | 12 cd |
| Atrazine | 4.5 | Pre | 65 | 63 a | 47 | 18 | 18 a |
| Hexazinone | 2.2 | Pre | 64 | 58 bc | 52 | 13 | 13 bc |
| Sulfometuron | 0.05 | Pre | 61 | 59 b | 47 | 14 | 15 b |
| | 0.11 | Pre | 55 | 54 d | 46 | 9 | 9 d |
| | 0.16 | Pre | 52 | 53 d | 43 | 9 | 9 d |
| | 0.21 | Pre | 55 | 55 cd | 44 | 11 | 11 c |
| | 0.05 | Post | 49 | 55 cd | 39 | 11 | 10 d |
| | 0.11 | Post | 51 | 56 c | 40 | 12 | 11 c |
| | 0.16 | Post | 56 | 57 bc | 43 | 13 | 13 b |
| | 0.21 | Post | 55 | 54 d | 46 | 9 | 9 d |

* Hgt=Total Height (cm); Adj. Hgt=Height (cm) adjusted for initial height as covariate; HATT=Height (cm) at time of treatment; HG=Height growth (cm); Adj. Hgt Growth=Height growth (cm) adjusted for covariate.

Table 5b. Injury rating and bud count for first-year Douglas-fir.

| Treatment | Rate /Ha | Time | Injury Rating | Bud Count |
|---|---|---|---|---|
| Control | 0.0 | | 0.50 ab* | 11 ab |
| Atrazine | 4.5 kg | Pre | 0.38 ab | 13 a |
| Hexazinone | 2.2 kg | Pre | 0.41 ab | 11 ab |
| Sulfometuron | 0.05 kg | Pre | 0.29 ab | 13 a |
| | 0.11 kg | Pre | 0.28 ab | 12 ab |
| | 0.16 kg | Pre | 0.76 a | 10 b |
| | 0.21 kg | Pre | 0.35 ab | 10 b |
| | 0.05 kg | Post | 0.30 ab | 9 b |
| | 0.11 kg | Post | 0.20 b | 12 ab |
| | 0.16 kg | Post | 0.35 ab | 11 ab |
| | 0.21 kg | Post | 0.56 a | 12 ab |

* Means followed by the same letter within columns are not significantly different at $\alpha$=0.05 using Tukey's.

# SEASONAL EFFICACY COMPARISON OF TWO GLYPHOSATE FORMULATIONS

Elizabeth C. Cole and Michael Newton[1]

The glyphosate [isopropylamine salt of *N*-(phosphonomethyl) glycine] formulation (Roundup) traditionally used in forestry has contained 13% surfactant. The formulation to be used in forestry in the future contains no surfactant (Accord). To determine whether the two formulations are comparable in efficacy, a study comparing the two formulations on four species at different times of application was established in the Oregon Coast Range.

The site selected was logged in 1982 and planted with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). Vegetation on the site consisted of red alder (*Alnus rubra* Bong.), salmonberry (*Rubus spectabilis Pursh*), thimbleberry (*R. parviflorus* Nutt.), trailing blackberry (*R. ursinus* Cham. & Schlecht), and bracken fern (*Pteridium aquilinum* (L.) Kuhn). Other shrubs and herbaceous plants were present in minor quantities. At the time of treatment, red alder was 2.5 to 4 meters tall, salmonberry 0.5 to 1 meter tall, thimbleberry 0.5 to 1.2 meters tall, and bracken fern 1 to 2 meters tall.

## Treatment Procedures

Each formulation was tested in a complete factorial experiment with three replications, plus three replications of an untreated control. Application rates were 0.84 and 1.68 kg ae/ha, and applications were made in June, July, August, September, and October. Formulation, dosage, and timing are shown in Table 1. All treatments were applied at 93.5 l/ha (10 gpa), the nominal rate for aerial application. The 8.84 by 4.57 meter plots (0.01 acre) were sprayed with a backpack sprayer equipped with a single adjustable hollow cone nozzle and using the "waving wand" technique. Prior to treatment, up to ten shrubs of each major shrub species were tagged for later evaluation.

Table 1. Seasonal efficacy comparison of two glyphosate formulations.

| Formulation | Rate/Hectare Acid. Equiv. | Date |
|---|---|---|
| Accord[R] * | 0.84 kg<br>1.68 kg | June, July,<br>Aug, Sept, Oct |
| Roundup[R] | 0.84 kg<br>1.68 kg | June, July,<br>Aug, Sept, Oct |
| Untreated Control | 0.0 | |

* 1/2% v/v R-11 or its equivalent added

[1]Oregon State University, Corvallis, OR

## Results

Tagged shrubs were ocularly rated for percent crown reduction and stem dieback in summer 1988. In addition, bracken fern cover reduction was estimated, and Douglas-fir trees were rated for injury. The Douglas-fir rating was based on a six-point scale:

0--no visible injury
1--minor injury to foliage
2--injury to foliage and buds
3--slight terminal dieback
4--major terminal dieback and loss of at least one-third of crown
5--dead.

Data were analyzed using analyses of variance and comparisons among means.

*Salmonberry.* All herbicide treatments significantly reduced crowns of salmonberry when compared to the untreated controls (Table 2). Crown reduction ranged from 70 to 100 percent, with the higher rate being significantly more effective. Efficacy in July was less than that of the other months tested. For stem dieback, results were similar to those for crown reduction, except some controls. Rate had a significant impact of the low rates of application were not significantly different from theon efficacy with the high rate causing almost 25 percent greater stem dieback (pooled over months and formulations) than the low rate. As with crown reduction, a decrease in stem dieback was apparent with the July applications. No significant differences were found between formulations.

*Thimbleberry.* For crown reduction, most of the herbicide treatments were significantly different from the control plots (Table 3). Results ranged from 30 to 100 percent, with the lower reductions corresponding to the lower rates of application. July had the least crown reduction and September the most. For stem dieback, results were highly variable due to the resprouting ability of thimbleberry. Some shrubs had 100 percent stem dieback, but were vigorously resprouting, while other shrubs would have moderate dieback and less sprouting. Crown reduction among these shrubs would be similar. As a result, only those treatments with greater than 65 percent stem dieback were significantly different from the control plots. The high rate of application resulted in significantly greater stem dieback than the low rate. Efficacy decreased in July and was best in August. No differences were found between formulations.

*Red Alder.* All of the high rate treatments significantly reduced crowns of red alder (Table 4), but most treatments at the low rate were not significantly different. Crown reduction was best in June and decreased as the growing season progressed. Rate significantly affected the results with the high rate resulting in over 20 percent greater decrease in crowns (pooled over month and formulation). Trends with stem dieback were similar to those for crown reduction, except only a few treatments were significantly different from the control plots. When means were pooled over rate and formulation, June applications resulted in at least a two-fold increase in stem dieback over the other months. No differences were found between formulations.

*Bracken Fern.* With the exception of the October applications, all high rate treatments were significantly different from the untreated controls (Table 5). Cover reduction was significantly less with the October applications. A slight decrease in efficacy was also noted with the July applications, but it was not significant. Increasing the rate of application significantly increased cover reduction. No differences between formulations were found.

Table 2. Percent crown reduction and stem dieback for salmonberry.

| Treatment | Rate/ Hectare | Month | Salmonberry % Crown Reduction | Salmonberry % Stem Dieback |
|---|---|---|---|---|
| Control | 0.0 | | 15 f* | 7 g |
| Accord® | 0.84 kg | June | 92 abcd | 71 abcd |
| | 1.68 kg | | 100 a | 90 a |
| | 0.84 kg | July | 70 e | 19 ef |
| | 1.68 kg | | 87 abcde | 46 def |
| | 0.84 kg | Aug | 96 abc | 52 bcdef |
| | 1.68 kg | | 97 abc | 78 abcd |
| | 0.84 kg | Sept | 92 abcd | 60 abcde |
| | 1.68 kg | | 100 a | 90 a |
| | 0.84 kg | Oct | 91 abcd | 51 cdef |
| | 1.68 kg | | 98 ab | 73 abcd |
| Roundup® | 0.84 kg | June | 77 cde | 29 efg |
| | 1.68 kg | | 97 abc | 47 cdef |
| | 0.84 kg | July | 76 de | 45 def |
| | 1.68 kg | | 79 bcde | 53 abcdef |
| | 0.84 kg | Aug | 97 abc | 62 abcde |
| | 1.68 kg | | 98 ab | 88 ab |
| | 0.84 kg | Sept | 77 cde | 29 efg |
| | 1.68 kg | | 99 a | 67 abcd |
| | 0.84 kg | Oct | 88 abcde | 54 abcdef |
| | 1.68 kg | | 99 a | 84 abc |

* Means followed by the same letter within columns are not significantly different at $\alpha=0.05$ using Tukey's.

Table 3. Percent crown reduction and stem dieback for thimbleberry.

| Treatment | Rate/ Hectare | Month | Thimbleberry % Crown Reduction | Thimbleberry % Stem Dieback |
|---|---|---|---|---|
| Control | 0.0 | | 14 f* | 17 d |
| Accord ® | 0.84 kg | June | 82 ab | 55 abcd |
| | 1.68 kg | | 75 abc | 63 abcd |
| | 0.84 kg | July | 30 ef | 31 cd |
| | 1.68 kg | | 59 bcde | 51 abcd |
| | 0.84 kg | Aug | 81 ab | 55 abcd |
| | 1.68 kg | | 91 ab | 64 abcd |
| | 0.84 kg | Sept | 89 ab | 40 bcd |
| | 1.68 kg | | 100 a | 90 a |
| | 0.84 kg | Oct | 74 abcd | 36 bcd |
| | 1.68 kg | | 91 ab | 42 abcd |
| Roundup® | 0.84 kg | June | 47 cdef | 33 cd |
| | 1.68 kg | | 86 ab | 67 abc |
| | 0.84 kg | July | 40 def | 35 bcd |
| | 1.68 kg | | 77 abc | 63 abcd |
| | 0.84 kg | Aug | 73 abcd | 39 bcd |
| | 1.68 kg | | 80 abc | 83 ab |
| | 0.84 kg | Sept | 84 ab | 60 abcd |
| | 1.68 kg | | 93 a | 64 abcd |
| | 0.84 kg | Oct | 66 abcd | 70 abc |
| | 1.68 kg | | 90 ab | 63 abcd |

* Means followed by the same letter within columns are not significantly different at $\alpha=0.05$ using Tukey's.

Table 4. Crown reduction and stem dieback for red alder.

| Treatment | Rate/ Hectare | Month | Red Alder % Crown Reduction | Red Alder % Stem Dieback |
|---|---|---|---|---|
| Control | 0.0 | | 0 f* | 0 f |
| Accord® | 0.84 kg | June | 64 abc | 52 abcd |
| | 1.68 kg | | 82 a | 69 a |
| | 0.84 kg | July | 31 cdef | 15 def |
| | 1.68 kg | | 61 abcd | 47 abcde |
| | 0.84 kg | Aug | 39 cde | 21 cdef |
| | 1.68 kg | | 63 abc | 45 abcde |
| | 0.84 kg | Sept | 32 cdef | 19 cdef |
| | 1.68 kg | | 41 cde | 36 abcdef |
| | 0.84 kg | Oct | 24 def | 9 ef |
| | 1.68 kg | | 42 bcde | 29 bcdef |
| Roundup® | 0.84 kg | June | 50 abcde | 39 abcdef |
| | 1.68 kg | | 79 ab | 65 ab |
| | 0.84 kg | July | 32 cdef | 19 cdef |
| | 1.68 kg | | 40 cde | 24 cdef |
| | 0.84 kg | Aug | 22 ef | 5 f |
| | 1.68 kg | | 43 bcde | 17 cdef |
| | 0.84 kg | Sept | 18 ef | 10 ef |
| | 1.68 kg | | 62 abc | 54 abc |
| | 0.84 kg | Oct | 28 cdef | 27 bcdef |
| | 1.68 kg | | 42 bcde | 34 abcdef |

* Means followed by the same letter within columns are not significantly different at $\alpha$=0.05 using Tukey's.

Table 5. Cover reduction for bracken fern and Douglas-fir injury rating.

| Treatment | Rate/ Hectare | Month | Bracken Fern % Cover Reduction | Douglas-fir Injury Rating |
|---|---|---|---|---|
| Control | 0.0 | | 7 b * | 0.12 e |
| Accord® | 0.84 kg | June | 72 a | 3.22 a |
| | 1.68 kg | | 86 a | 3.10 a |
| | 0.84 kg | July | 52 ab | 1.20 cde |
| | 1.68 kg | | 92 a | 3.00 a |
| | 0.84 kg | Aug | 93 a | 2.43 abc |
| | 1.68 kg | | 98 a | 2.83 ab |
| | 0.84 kg | Sept | 88 a | 0.67 de |
| | 1.68 kg | | 90 a | 1.00 cde |
| | 0.84 kg | Oct | 48 ab | 0 e |
| | 1.68 kg | | 40 ab | 0 e |
| Roundup® | 0.84 kg | June | 60 ab | 2.33 abc |
| | 1.68 kg | | 97 a | 3.11 a |
| | 0.84 kg | July | 60 ab | 2.00 abcd |
| | 1.68 kg | | 97 a | 2.50 abc |
| | 0.84 kg | Aug | 57 ab | 1.83 abcd |
| | 1.68 kg | | 96 a | 1.71 abcd |
| | 0.84 kg | Sept | 68 a | 0.67 de |
| | 1.68 kg | | 84 a | 1.43 bcde |
| | 0.84 kg | Oct | 55 ab | 0.11 e |
| | 1.68 kg | | 57 ab | 0 e |

* Means followed by the same letter within columns are not significantly different at $\alpha=0.05$ using Tukey's.

*Douglas-fir Injury.* Month of application was the most significant factor affecting injury to Douglas-fir (Table 5). June applications resulted in the most severe injuries, with July and August applications causing slightly less injuries. Injury was significantly decreased with the September and October applications, which were not significantly different from the controls. Injury in June, July, and August included injury to foliage, buds, and some terminal dieback. With September and October, no terminal dieback was noted, and injury was limited to foliage and buds. Increasing the rate of application caused significantly greater injury. No significant differences were found between formulations, although the Accord product caused slightly greater injury.

## Summary

No differences were found between formulations of glyphosate as Accord and Roundup for any of the species evaluated. For salmonberry and thimbleberry, rate of application was more important than month of application, although decreases in efficacy were observed in July. For red alder, both rate and month of application were significant factors. Efficacy was best in June and with the high rate of application. With bracken fern, month of application seemed to be more important. For Douglas-fir, applications in June, July, and August caused severe injury to trees. Injury to Douglas-fir with October applications appeared negligible.

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# WEED CONTROL WITHOUT HERBICIDES -- A BLM PERSPECTIVE SIX YEARS LATER

Diane E. White[1]

The Bureau of Land Management in Oregon has been enjoined from the use of herbicides for six years. The consequences of this action have been significant for the forest managers in this area. This paper will describe the alternative methods being used to control unwanted vegetation.

The most commonly used method of controlling wood plants is cutting at the base with a chainsaw or other cutting implement. This method can be successful with non-sprouting shrubs. In addition, a window was found in mid-summer where red alder (*Alnus rubra*) 10 cm or more in diameter, could be cut and no sprouting occurs. Cutting other shrubs is significantly less successful.

Cutting snowbrush (*Ceanothus velutinus*) results in resprouting back to the original height within two years, and is considered ineffectual unless cutting is done frequently. A more successful method is handpulling individual shrubs. This method is expensive and labor intensive. It may be conducted when the shrubs are less than four years old.

Cutting and hand pulling young red alder trees has been unsuccessful. Cutting results in vigorous resprouting, and hand pulling all the acres invaded by alder, is not possible because of both labor and economical impracticality.

Bigleaf maple (*Acer macrophyllum*) is one of the most aggressive competitors in the region. Cutting is followed by vigorous resprouting--at all times of the year. Covering the stump with black plastic can result in 90% control. The plastic must be heavy and well secured. If there is any point of failure--a

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small rip for example, sprouts will grow vigorously. The most expensive measure is also the most effective--that is plucking out the stumps with heavy equipment during or immediately after logging.

Broadcast burning succeeds in removing the tops of competing shrubs but rarely affects root systems. It is credited with providing one year of weed control. Another method that has been tried is piling slash around shrubs such as vine maple (*Acer circinatum*) then burning the piles. This results in a hotter, more intense burn than a broadcast burn, but seems not to provide additional control.

Another unsuccessful method, was using explosives to blast foliage off shrubs. This resulted in normal growth the following year.

Animals, such as sheep and cattle, have been used on a trial basis with some success. Grazing animals are most effective on herbaceous vegetation, but will eat some low growing shrubs. Cattle have been used for conifer release on gentle, sloping ground, and sheep can be used on steeper slopes. Animals require intensive management. They eat competing vegetation almost constantly, and if they run out of that type of forage, they will start eating crop trees.

The most successful method of controlling herbaceous weeds is with paper mulch. This is a square of heavy paper (three layers) usually 60 cm on a side which is placed around the base of the conifer seedling. This results in weed control for two years. On some sites mulching a plantation will result in 90% or more survival while not mulching would result in only 20% survival. This method costs about $120/ha, and it is only applied when absolutely required. Hoeing has been attempted and can result in less than one year of weed control.

The BLM in western Oregon has prepared a Final Environmental Impact Statement to comply with NEPA legislation. The EIS will be available to the public in December 1988, and we hope to have the injunction against herbicide spraying lifted in 1989.

# RESISTANCE TO SULFONYLUREA HERBICIDES: MECHANISMS OF RESISTANCE AND CROSS RESISTANCE

J.C. Cotterman, L.L. Saari, M.M. Primiani, and J.L. Saladini[1]

Abstract. Biotypes of kochia (*Kochia scoparia* (L.) Schrad.) that are resistant to chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]benzenesulfonamide} have been discovered at isolated locations throughout the U.S. wheat growing region, including several western states. In addition to kochia, three samples of Russian thistle (*Salsola iberica* Sennen & Pau) and one of common chickweed (*Stellaria media* (L.) Vill.) that are resistant to chlorsulfuron have also been discovered. In most cases, the resistant plants occurred in fields of either continuous wheat or wheat-fallow-wheat rotation which had been treated several times consecutively with chlorsulfuron and/or the methyl ester of metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]amino]sulfonyl]benzoic acid}. In addition, several cases of resistant kochia have been identified in right-of-ways treated with the methyl ester of sulfometuron{2-[[[[(4,6-dimethyl-2-pyrimidinyl)carbonyl]amino]sulfonyl]benzoic acid}.

Chlorsulfuron, metsulfuron, and sulfometuron belong to the sulfonylurea class of herbicides which act by inhibiting acetohydroxyacid synthase (AHAS) activity (EC 4.1.3.18), thereby resulting in decreased biosynthesis of branched chain amino acids. The imidazolinones are another class of herbicides that inhibit AHAS activity and therefore have the same mode of action. *In vitro* AHAS assays were used to determine that the basis of resistance is an altered AHAS enzyme with reduced sensitivity to inhibition by sulfonylureas and imidazolinones. The resistant biotypes exhibit cross resistance at the enzyme and whole-plant levels to several sulfonylureas, imidazolinones, and triazolopyrimidines. The degree of cross resistance depends on the specific herbicide. Herbicides with other modes of action effectively control these resistant biotypes except that triazines do not control triazine-resistant kochia.

Other possible mechanisms of resistance were also investigated. In whole-plant studies, there was no difference between resistant and susceptible kochia biotypes in the absorption or translocation of foliar-applied $^{14}C$-chlorsulfuron. In excised kochia shoots, there was no difference in the rate of $^{14}C$-chlorsulfuron metabolism between resistant and susceptible biotypes.

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# WHEAT AND WILD OAT DENSITY, CANOPY, AND LIGHT INTERACTIONS

D.E. Cudney, L.S. Jordan, J.S. Holt, and A.E. Hall[1]

Abstract. Wild oat (*Avena fatua* L.) and wheat were studied at the University of California, Riverside Experiment Station for their density and canopy interactions. Both replacement series and additive series experiments were used. This allowed measurement of the relative competitiveness of wild oat in wheat as well as the effects of increasing wild oat density on wheat yield. Replacement series studies demonstrated that wild oat and wheat were equivalent in competitiveness. On a per plant basis, one wild oat was equivalent to one wheat plant, even though the wild oat had less biomass and leaf area. The yield response of wheat to increasing wild oat density was correlated to relative wild oat density, such that relative wheat yield was proportional to relative wild oat density. This model provides predicted values for wheat yield that are intermediate to those of earlier models. Wild oat reduced light interception and growth of wheat. Wild oat grew significantly taller than wheat and had a greater portion of its canopy above 60 cm after wheat stem elongation. A mathematical model was developed which indicated that interference from wild oat could be explained by reduced leaf area of wheat at early growth stages and low wild oat densities, and reduced light penetration at later growth stages and with higher densities of wild oat. It is postulated that wild oat may be able to maintain competitive equivalence to wheat through superior late season height and leaf distribution characteristics.

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# EFFECT OF NITROGEN FERTILIZERS ON NITRATE AND SOLUBLE OXALATE CONCENTRATION IN KIKUYUGRASS

M. Coburn Williams and Burton J. Smith[1]

Abstract. Kikuyugrass (*Pennisetum clandestinum* Hochst. ex Chiov.) is a tropical pasture grass that may accumulate toxic levels of soluble oxalates and nitrates. Osteodystrophia in horses (oxalates) and methemoglobinemia in cattle and swine (nitrates) have been caused by grazing kikuyugrass. A study was conducted to evaluate the effect of fertilization with urea and $KNO_3$ on oxalate and nitrate accumulation. Kikuyugrass pastures in Panama and Hawaii were treated with urea at 56 and 112 kg N/ha. Plants in the greenhouse were treated with urea and $KNO_3$ at 112 kg N/ha. Plants from Hawaii and Panama were collected weekly for 7 weeks and greenhouse plants were sampled eight times over 72 hours. All plants were analyzed for percent nitrate (as $KNO_3$) and percent soluble oxalates.

Fertilization with urea and $KNO_3$ did not affect soluble oxalate concentration in kikuyugrass sampled from the field or greenhouse. Fertilization with urea at 112 kg N/ha significantly increased nitrate levels in kikuyugrass

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in Panama two weeks after treatment (0.44%), but nitrate levels generally remained below 0.1% in both treated and untreated plants. Nitrate levels in kikuyugrass from Hawaii ranged from 0.7% to 1.0% in untreated plants and 1.3% to 2.1% in fertilized plants. Differences between rates were not significant. Plants treated with urea in the greenhouse contained 0.4% nitrate 72 hours after treatment. Plants treated with $KNO_3$ assayed 0.26%, 1.84%, and 2.36% nitrate, respectively, 4, 24, and 72 hours after treatment. Plants that contain 0.5% to 1.5% nitrate (as $KNO_3$) may be toxic to livestock, and nitrate levels over 1.5% are potentially lethal.

Fertilization with urea or $KNO_3$ had no affect on soluble oxalate concentration in kikuyugrass, but urea increased nitrate concentration to toxic levels in plants in Hawaii. Fertilization with $KNO_3$ at 112 kg N/ha produced potentially lethal levels of nitrate in kikuyugrass within 24 hours.

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## EFFECT OF DURATION OF WATER-STRESS ON THE PERFORMANCE OF FOUR HERBICIDES ON GREEN FOXTAIL

Rick A. Boydston[1]

Abstract. In a 2-year field study, fenoxaprop {(±)-2-[4-[(6-chloro-2-benzoxazolyl)oxy]phenoxy]propanoic acid}, fluazifop {(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid}, haloxyfop{(2-[4-[[3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid)}, and sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one}allpartially controlled green foxtail (*Setaria faberi*) when soil moisture was kept near field capacity. A low soil water content (5 to 6%) for approximately 1 week before and after herbicide application reduced the control of green foxtail by all four herbicides. Green foxtail plants that were water-stressed for one week or more before herbicide application and watered immediately after herbicide application were controlled similar to plants that were never stressed. In growth chamber studies, water-stressed green foxtail that was watered within 24 hours after fluazifop application was controlled equal to non-stressed plants. Withholding water for periods greater than 24 hours after herbicide application reduced the control of green foxtail by fluazifop.

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## RELATIVE AGGRESSIVENESS OF SPRING BARLEY AND WILD OAT

R.M. Evans, D.C. Thill, L.S. Tapia, and B. Shafii[1]

Abstract. Wild oat (*Avena fatua* L., AVEFA) is considered one of the world's worst cereal crop weeds. Virtually all Idaho cropland used for barley production is infested with wild oat, and Idaho barley growers spend 10 to 25 million dollars annually to control the weed. An addition series experiment was conducted in 1988 to determine the relative aggressiveness of spring barley (*Hordeum*

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*vulgare* L., HORVU) var. 'Steptoe' and wild oat, and to determine the effect of barley and wild oat density on barley grain yield. The experiment was designed as a randomized complete block split block, repeated measures with four replications. Biomass samples were collected beginning 14 days after emergence and continued at 14-day intervals until physiological maturity of the barley. Average barley and wild oat plant densities ranged from 0 to 624 plants/$m^2$ and 0 to 581 plants/$m^2$, respectively. Regression analysis was used to describe the relationship between the dependent (above ground biomass) and independent (species density) variables. Barley biomass was affected significantly by intraspecific (barley on barley) and interspecific (wild oat on barley) competition at all harvest times except harvest 1. Barley aggressiveness remained constant through the growing season. Wild oat aggressiveness increased continually through the growing season, but always was less than barley aggressiveness. Wild oat had a negative effect on barley grain yield at all barley densities. However, the effect of wild oat was greatest at the lowest density of barley.

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## RESPONSE OF PEAS AND LENTILS TO SUBLETHAL DOSES OF SULFONYLUREAS, 2,4-D AND BROMOXYNIL

S.J. Halstead, D.R. Gealy, and A.G. Ogg, Jr.[1]

Abstract. Aerial applications of sulfonylurea herbicides alone and in combination with other herbicides for weed control in winter wheat fields may result in herbicide drift onto sensitive pea and lentil crops in adjacent fields. Potential drift injury to lentils and peas was simulated by applying herbicide treatments with a logarithmic sprayer. A field trial was established at the Palouse Conservation Field Station near Albion, WA. Before experimental treatments were established, triallate {[*S*-(2,3,3-trichloro-2-propenyl)bis(1-methylethyl)carbamothioate]} and metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} were applied pre-plant incorporated (May 14) and early-postemergence (June 11) respectively to the entire study area to control weeds. Experimental treatments of thiameturon {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid}, bromoxynil {3,5-dibromo-4-hydroxybenzonitrile}, DPX-R9674, thiameturon + bromoxynil, or DPX-R9674 + 2,4-D {(2,4-dichlorophenoxy)acetic acid} were made to emerged lentils (13 cm) and peas (20 cm) on June 21, 1988. Treatments were arranged in a randomized complete split block with four replicates. An untreated control for each plot provided a basis for growth reduction. The sprayer was calibrated to dilute the herbicide concentration by 2-fold at 8 m intervals. Herbicide concentrations ranged from 0.0625 of the recommended use rate (X) on wheat to final concentrations of 0.002 of the labeled rate. Transpiration was measured one and eight days after treatment (DAT). Plant height, dry weight, leaf area index, number of blossoms, and canopy closure were measured 14 to 20 DAT. Symptoms of chlorosis or epinasty appeared on both lentils and peas within 10 days of application. A chlorotic gradient occurred on plots treated with the sulfonylureas. Concentrations at 1/16X produced severe yellowing whereas con-trations of 1/64X did not differ visually from the untreated check. Peas were

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more tolerant than lentils to the phytotoxic effects of the herbicides. Bromoxynil did not affect growth at any of the concentrations tested. At the higher concentrations, all factors measured for lentils were reduced significantly when compared to untreated controls. Reductions in bloom number were highly correlated with final grain yields. Lentil grain yield was reduced by fifty percent over a range of 1/16 to 1/64 of the recommended use rate for all herbicide treatments except bromoxynil.

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## SPRING BARLEY INTRASPECIFIC AND WILD OAT INTERSPECIFIC COMPETITION AFFECT SPRING BARLEY CULM NUMBER

L.S. Tapia, D.C. Thill, R.M. Evans, and B. Shafii[1]

Abstract. The effect of wild oat (*Avena fatua* L.) and spring barley (*Hordeum vulgare* L. var. 'Steptoe') population density on spring barley growth is not understood clearly. A field experiment was conducted in 1988 to study the effects of five wild oat and five spring barley plant densities on different spring barley growth parameters. Wild oat and spring barley were seeded perpendicular to each other in rows spaced 9 cm apart. The addition series experiment was designed as a randomized complete block, split block with repeated measures in time. Above ground plant samples were collected from 0.25 by 0.25 m areas for growth analysis, 14 days after emergence and at 14-day intervals until physiological maturity of barley. Analysis of variance and discriminant analysis were used to describe relationships between dependent (barley tiller and barley culm number) and independent (species density, species proportion, and sample times) variables. Wild oat and spring barley densities ranged from 0 to 610 and 0 to 608 plants/$m^2$, respectively. Barley culm number decreased with decreasing barley density, but was not affected by wild oat density at 14 days after emergence. Both intra- and interspecific competition affected tiller number 14 days after emergence at 347 and 550 barley plants/$m^2$ and across wild oat densities. At 28 days after emergence barley tiller number at only the lowest barley density was impacted negatively by increasing wild oat density. Like at 14 days after emergence, barley culm number decreased with decreasing barley density at 56 days after emergence. Spike number at 56 days after emergence was correlated highly (r = 0.94) with barley culm number at the same harvest. Spike to culm ratios ranged from 0.62 to 0.86 at 56 days after emergence.

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[1]Idaho Agricultural Experiment Station, Moscow, ID

# EFFECTS OF RUSSIAN KNAPWEED ON MYCORRHIZAL FUNGI

D. Eric Hanson and K. George Beck[1]

Abstract. Russian knapweed (*Centaurea repens* L.) is a serious pest of rangeland and disturbed areas and over time, forms single-species stands. This effect appears in part to be due to allelopathy. Germination inhibitors have been isolated from Russian knapweed foliage.

Experiments were conducted to test the effects of Russian knapweed aqueous extract on mycorrhizal fungi colonization of Corn (*Zea mays*) and grass seed germination. Corn was allowed to grow for ten days after germination and was then irrigated with Russian knapweed extract for 80 days. A randomized complete block design with fifteen reps was used, and treatments were 0% (distilled water), 10%, 50%, and 100% aqueous extract. Dilutions were made with distilled water. After 90 days, corn was harvested; shoot height and dry weight, root dry weight, and percent mycorrhizal colonization were determined.

The aqueous extract stimulated shoot height and weight. All treatment stalk weight were greater than controls. The 100% extract treatment caused root weight to decrease.

The 10% extract treatment, caused increased mycorrhizal colonization. All colonization levels were greater than 90%.

[1]Colorado State University, Fort Collins, CO

# ELEVATED CANOPY AND SOIL TEMPERATURES RESULTING FROM BURNING STUBBLE AND SUBSEQUENT JOINTED GOATGRASS (*Aegilops cylindrica* Host.) SEED GERMINATION RESPONSE

Blake D. Willis, Steven A. Dewey, and John O. Evans[1]

Abstract. Jointed goatgrass (*Aegilops cylindrica* Host.) is a winter annual weed spreading rapidly throughout Utah and other wheat producing states. Selective herbicides have not been developed to control jointed goatgrass in small grains, making cultural techniques the primary means of management. Field burning was investigated as a possible cultural practice to reduce goatgrass seed viability.

Plots were established in goatgrass infested winter wheat stubble and in a Conservation Reserve Program (CRP) grass planting in the fall of 1988. Stubble density levels were 5, 8, and 10.5 tons/ha in winter wheat plots; and 3, 5.5, and 8.5 tons/ha in CRP plots. Stubble weights were varied by spreading additional wheat straw over existing stubble. Temperatures in burning stubble plots were monitored continuously (10 times per second) with thermal couples set at 2.5 and 30 cm above, and 2.5 cm below the soil surface. Each treatment was replicated 6 times.

Canopy temperatures 2.5 and 30 cm above the soil surface reached almost 700 C in high residue plots, and exceeded 400 C for 10 to 60 seconds in all plots. Soil temperatures 2.5 cm below the surface did not exceed 50 C.

[1]Utah State University, Logan, UT

Laboratory flame tests reveal goatgrass germination reduction from 100% at room temperature, to 20% and 15% after a 1-second exposure to 400 C and 600 C flame temperatures, respectively. Germination dropped to 0% after a 5-second exposure to 400 C or a 3-second exposure to 600 C.

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## GROWTH ANALYSIS OVER TIME OF MAYWEED CHAMOMILE (*Anthemis cotula*) INTERFERENCE WITH PEAS (*Pisum sativum*)

R.H. Stephens and A.G. Ogg, Jr.[1]

Abstract. Mayweed chamomile (*Anthemis cotula*) is a weedy species found in the dry pea (*Pisum sativum*) fields of the Palouse. Besides competing with peas for resources, mayweeds' accelerating growth rate late in the summer as the peas senesce causes serious harvest problems. A growth analysis and replacement series experiment was conducted in the summer of 1986 (dry year) and repeated in 1988 (wet year). The plant proportions used were 3:1, 2:2, and 1:3, as well as monocultures of both species, and 7 destructive harvests were taken about 10 days apart from 4 replications. Species density was constant at 144 plants per square meter, and planting boards were used as templates to ensure an equidistant spacing. Data were analyzed by analysis of variance and regression methods.

The relative crowding coefficients (RCC) for total dry weight, plant height, and leaf area were generally larger for peas than for mayweed. By the third harvest, pea RCC values were increasing rapidly while those for mayweed declined, but during the last two harvests the values for peas declined, and those for mayweed rose as the peas senesced. The relative yield totals (RYT) for the same three parameters were more consistent than the RCC values, and declined, steadily over time. For the dry year of 1986, the RYT ranged from approximately 0.90 initially to 0.77 at the final harvest for all the measured parameters. By comparison, 1988 was a fairly normal year, and the RYT values ranged from about 1.20 initially to 0.90 at the end. Pod weights increased up through the last harvest for both years, and the 3:1 pea:mayweed treatment (108 pea plants/square meter) yielded the highest pod weights.

[1]Washington State University and USDA-ARS, Pullman, WA

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## EFFECT OF TEMPERATURE ON UPTAKE OF METRIBUZIN AND ITS ETHYLTHIO ANALOG BY WHEAT, JOINTED GOATGRASS, AND DOWNY BROME

R.A. Buman, D.R. Gealy, and A.G. Ogg, Jr.[1]

Abstract. Downy brome (*Bromus tectorum*) and jointed goatgrass (*Aegilops cylindrica*) are two major winter annual weeds in winter wheat production areas of the United States. Only two herbicides, metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} and its ethylthio analog

[1]Washington State University and USDA-ARS, Pullman, WA

(SMY 1500 or ethyl metribuzin) {4-amino-6-(1,1-dimethylethyl)-3-(ethylthio)-1,2,4-triazin-5(4*H*)-one}, applied postemergence, will control downy brome selectively in winter wheat. Ethyl metribuzin is the only herbicide that will control jointed goatgrass selectively in winter wheat. However, the activity of both these as-triazines against downy brome and jointed goatgrass has been inconsistent. The purpose of this study was to determine if temperature variation affects the uptake of these herbicides and contributes to inconsistent control. Experiments were conducted in environmentally controlled growth chambers using 19-day-old plants of downy brome, jointed goatgrass, and winter wheat grown in hydroponics. A sub-lethal dose of $^{14}$C-labeled metribuzin or ethyl metribuzin ($3 \times 10^{-8}$ *M*) was added to the nutrient solution in each pot. Plants of each species were exposed at temperatures of 10, 15, 20, and 25 C to labeled herbicide for 48 hours followed by a 48-hr exposure to nonlabeled herbicide. Radioactive herbicide in roots and shoots were quantified using an oxidizer and scintillation spectrophotometer. Absorption of both herbicides by all three species increased with increasing temperature. The absorption and distribution of ethyl metribuzin and metribuzin by downy brome and jointed goatgrass on a per gram dry weight basis were similar. Absorption of ethyl metribuzin on a per gram dry weight basis was similar for three species, Absorption of metribuzin was lower for winter wheat than for the other two species. The distribution of absorbed metribuzin was also similar in all three species. However, proportionately less of the absorbed ethyl metribuzin was detected in shoots than in roots of wheat than in the other species. The molar concentrations of herbicide solutions absorbed by winter wheat and jointed goatgrass were similar to those of the initial hydroponic solution at 10 and 15 C, but declined at 20 and 25 C. Molar concentrations of herbicide solutions absorbed by downy brome, were 80% of the initial concentration of the hydroponic solution at 10 and 15 C but declined at 20 and 25 C.

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## RESPONSE OF PHOTOSYNTHESIS AND GROWTH OF JOINTED GOATGRASS AND WHEAT TO PHOTOSYNTHETIC HERBICIDES AND TEMPERATURE

D.R. Gealy and R.A. Buman[1]

Abstract. Ethyl metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(ethylthio)-1,2,4-triazin-5(4*H*)-one}, the ethylthio analog of metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one}, has sometimes controlled jointed goatgrass (*Aegilops cylindrica*) in wheat fields without injuring wheat, but control has been inconsistent. Experiments were conducted in hydroponics in temperature-controlled growth rooms to determine the relative sensitivity of whole plants of wheat and jointed goatgrass to metribuzin and ethyl metribuzin. Wheat ('Daws') and jointed goatgrass plants growing at either 10, 20, or 30 C were exposed to four concentrations of metribuzin ($0.25 \times 10^{-7}$ to $8.0 \times 10^{-7}$ *M*) and ethyl metribuzin ($2.5 \times 10^{-7}$ to $40 \times 10^{-7}$ *M*). Net photosynthesis and transpiration rates were monitored periodically for 10 days and plants were then harvested. Both herbicides reduced net photosynthesis earlier at 30 C than at cooler temperatures. The same trend was true for transpiration, but the onset

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of inhibition was delayed and the extent of inhibition was less than for net photosynthesis. Averaged overall temperatures, growth of jointed goatgrass and wheat was about 2 and 5 times more sensitive, respectively, to metribuzin than to ethyl metribuzin. This difference is consistent with the greater selectivity of ethyl metribuzin between wheat and jointed goatgrass observed in the field. Averaged over both species and herbicides, the concentration of herbicide needed to reduce net photosynthesis, and growth by 50% at 10 C was about five times greater than at 30 C. The enhanced herbicide activity at higher temperatures was probably a result of increased herbicide uptake into plants and increased activity at the site of action. Inhibition of photosynthesis and transpiration was closely correlated to growth reduction.

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## LONG-TERM TEBUTHIURON CONTENT OF SIDEOATS (*Bouteloua curtipendula*) AND BLUE GRAMA (*B. gracilis*)

Thomas N. Johnsen, Jr. and Howard L. Morton[1]

Abstract. Tebuthiuron {*N*-[5-(1,1-dimethylethyl)-1,3,4,thiadiazol-2-yl]-*N*,*N*'-dimethylurea} is a persistent, soil applied herbicide widely used to control brush and weeds. It is not known how long tebuthiuron and its metabolites can be detected in perennial forage grasses. Blue grama [*Bouteloua gracilis* (H.B.K.) Lag.] and sideoats grama [*B. curtipendula* (Michx.) Torr.] samples were collected from pinyon-juniper rangelands in northern Arizona that had been treated 2 to 11 years previously with pelleted tebuthiuron. Application rates ranged from 0.9 to 6.7 kg ai/ha. Tebuthiuron and its metabolites in the grass samples were assayed using gas chromatography with flame photometric detection. Tebuthiuron was detected in blue grama and sideoats grama 10 years after application. The highest amounts of tebuthiuron found were 2.8 µg/g in blue grama and 3.6 µg/g in sideoats grama, 3 and 9 years after treatment, respectively. Tebuthiuron was detected in all samples collected less than 6 years after application. Tebuthiuron metabolites were measured in all the samples, including sideoats and blue grama collected 10 and 11 years after application, respectively. Tebuthiuron:metabolites ratios varied widely, but tebuthiuron was always present in lower amounts than the metabolites. The highest total amount of tebuthiuron and its metabolites measured was 24.5 µg/g in blue grama and 23.5 µg/g in sideoats grama, after application of 6.7 and 4.5 kg ai/ha, respectively. None of the other samples exceeded 20 µg/g of tebuthiuron and its metabolites in plants.

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# TEBUTHIURON ACCUMULATION AND METABOLISM BY WAIT-A-MINUTE-BUSH AND ENGELMANN PRICKLYPEAR CACTUS

Howard L. Morton, Richard D. Martin, and Thomas N. Johnsen, Jr.[1]

Abstract. Plant susceptibility to tebuthiuron {*N*-[5-(1,1-dimethylethyl)-1,3,4,thiadiazol-2-yl]-*N*,*N*'-dimethylurea}, a soil-applied herbicide, is variable. We compared wait-a-minute-bush (***Mimosa biuncifera*** Benth.), a very susceptible plant, and Engelmann pricklypear (***Opuntia engelmannii*** Salm-Dyck), a very resistant plant, to determine if resistance and susceptibility were due to differences in metabolism. Individuals of each species were grown in 2000 g of sandy loam soil (65% sand, 20% silt, and 15% clay) in a greenhouse. Wait-a-minute-bush was grown from seed, and Engelmann pricklypear was grown from vegetative cuttings. Wait-a-minute-bush was grown to the 20-leaf stage, and Engelmann pricklypear was grown until the roots fully occupied the potting medium. Because of tebuthiuron susceptibility differences, wait-a-minute-bush and Engelmann pricklypear received 1 and 10 µg of tebuthiuron/g of soil, respectively, in 100 ml of water poured on the soil surface.

One day after application, wait-a-minute-bush accumulated tebuthiuron at concentrations of 14, 9, and 16 µg/g in roots, stems, and leaves, respectively, but Engelmann pricklypear accumulated 63 and 3 µg/g in roots and cladophylls (stems), respectively. While wait-a-minute-bush metabolized no tebuthiuron in its roots and stems and less than 5% in its leaves, Engelmann pricklypear metabolized over half of the tebuthiuron in its roots and cladophylls. During the one week after treatment, both wait-a-minute-bush and Engelmann pricklypear continued absorbing tebuthiuron: reaching concentrations of 22, 26, and 198 µg/g in wait-a-minute-bush roots, stems, and leaves, and 96 and 12 µg/g in Engelmann pricklypear roots and cladophylls, respectively. Thus, wait-a-minute-bush accumulated tebuthiuron primarily in its leaves, but Engelmann pricklypear accumulated tebuthiuron primarily in its roots. Wait-a-minute-bush metabolized only about 10% of the tebuthiuron in its tissues, but Engelmann pricklypear metabolized about 50%. In summary, wait-a-minute-bush did not rapidly metabolize tebuthiuron, but Engelmann pricklypear did. This differential metabolism may explain the relative susceptibility of these plant species to tebuthiuron.

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# INDUCTION OF CHLOROACETAMIDE HERBICIDE METABOLISM BY ANTIDOTES

E. Patrick Fuerst[1], J.W. Gronwald[2], C.V. Eberlein[3], J.V. Dean[3], P.R. Viger[3], and G.L. Lamoureux[4]

Abstract. The antidotes CGA-92194, cyometrinil {(*Z*)- [(cyanomethoxy)imino] benzeneacetonitrile}, flurazole {phenylmethyl-2-chloro-4-(trifluoromethyl)-5-thiazolecarboxylate}, naphthalic anhydride, and dichlormid {2,2-dichloro-*N*,*N*-di-2-propenylacetamide} provided varying degrees of protection from metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide} injury in sorghum. The degree of protection was highly correlated with the rate of metolachlor metabolism, and with the decrease in concentration of parent metolachlor in sorghum shoots. Two dichloroacetamide antidotes, CGA-154281 and BAS-154-138, accelerated the metabolism of metolachlor and metazachlor, respectively, in corn. BAS 145-138 decreased the concentration of parent metazachlor in all growing tissues of corn seedlings. The greatest decrease occurred in the developing leaves, which are the presumed primary anatomical target of chloroacetamide herbicides. In each instance, increased metabolism rate was correlated with increased glutathione S-transferase activity. Several isozymes of glutathione S-transferase were induced by antidotes in both corn and sorghum. Observations are consistent with the hypothesis that antidotal activity is due to enhanced herbicide detoxification, and that glutathione S-transferase is primarily responsible for this detoxification.

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# FACTORS AFFECTING ETHYLENE EVOLUTION FROM ETHEPHON IN RELATION TO WEED SCIENCE GERMINATION

M.M.F. Abdallah, A.S. El-Beltagy, M.A. Maksoud, and M.A. Hall[1]

Abstract. Ethephon {(2-chloroethyl)phosphonic acid} treatment breaks seed dormancy and increases germination percentage of purslane (*Portulaca oleracea* L.) and corn spurry (*Spergula arvensis* L.) especially at higher concentrations (250-500 ppm). Exogenous ethylene evolution from ethephon during weed seed germination was studied. The results indicated that ethylene evolution in the gasphase around the seeds increased at low ethephon concentration and little or no ethylene evolution was observed at higher ethephon concentrations (250-500 ppm) over a 7-day period. High exogenous levels of ethyelen arising from low ethephon concentrations marginally promote germination. In the absence of seeds, ethylene evolution from ethephon was enhanced only at low concentrations (5-50 ppm) in the presence of Whatman filter paper No. 1 compared with ethephon alone.

[1]Ain Shams University, Cairo-Egypt and University of Wales, Aberystwyth, U.K.

At the lowest ethephon concentrations the pH was also observed to increase in the presence of Whatman filter paper. We propose that a critical factor in breaking dormancy is the uptake of ethephon by the seed, its conversions to ethylene which is pH dependent.

Breaking weed seed dormancy and promoting germination with ethephon may provide an additional strategy to improve the efficacy of chemical methods to control weed species.

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## RESTORATION OF DESERT HABITATS: THE ROLE OF HERBICIDES IN CONTROLLING PERENNIAL WEEDS ON ARIZONA RANGELANDS

John H. Brock and Jesse M. Richardson[1]

Abstract. Three suffrutescent perennial weeds were treated with selected herbicides as an aid to modify rangeland habitats in Arizona. The objective of this research is to control the target species and shift vegetative dominance to a grassland condition which existed before the undesirable perennial weeds increased in density. The target weeds included: burroweed (*Happlopappus tenuisectus* (Greene) Blake ex Benson) on rangelands near Willcox, turpentine weed (*Happlopappus larcifolius* Gray) near Winkelman, and broomsnake weed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby) near Peach Springs, AZ. Herbicide treatments were applied to plots arranged in a randomized complete block design. Herbicides applied as foliar sprays were applied with a handboom delivering 20 gpa, and the spray solution contained 0.05% v/v nonionic surfactant. Pelleted herbicide was applied by hand broadcast. Treatments were initiated in October 1987 on turpentine weed. In the spring of 1988 all 3 species were treated between the dates of mid April and late May. Metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid}, at all rates tested, has provided the greatest degree of control based on these preliminary results. Picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} at the rate of 1.0 kg ai/ha has also produced good control.

[1]School of Agribusiness and Environmental Resources, Arizona State Univ., Tempe, AZ and Dow Chemical Company, City of Industry, CA.

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## BASAL SPRAY TECHNIQUES AND HERBICIDES FOR BRUSH MANAGEMENT IN CENTRAL ARIZONA

John H. Brock and Jesse M. Richardson[1]

Abstract. Selected herbicides were applied by basal treatment at concentrations of 2% ai conventional, and 25% ai by low volume and streamline basal techniques to control undesirable woody plants. All treatments were applied in diesel.

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Treatments were applied in early July 1987 and 1988 at two locations in central Arizona. Three replicates consisting of 10 plants constituted the experimental units. Treatments were evaluated for defoliation near the end of the first growing season and for canopy reduction and mortality approximately 1 yr following application. Velvet mesquite (*Prosopis velutina* (Woot.)) was the target species on the study site near Apache Junction, and catclaw acacia (*Acacia greggii* Gray), whitethorn acacia (*Acacia constricta* Benth.), and velvet mesquite were target species, growing in mixed stands, on the study site near Winkelman. There were no statistical differences in plant control among the 2% conventional and 25% low volume treatments. Streamline treatments consistently gave less control. The most effective herbicide providing control of these leguminous woody plants has been triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid}. Clopyralid {3,6-dichloro-2-pyridinecarboxylic acid}, clopyralid and triclopyr mix (1:1) and picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} mixed with triclopyr (1:1) have also been effective herbicide treatments. Greatest average velvet mesquite mortality was 93% from 2% triclopyr conventional sprays. Catclaw acacia mortality of 100% was observed for the 2% conventional triclopyr and 25% clopyralid low volume treatments. Of the 3 species treated, whitethorn acacia was the most susceptible to the herbicide/basal treatments. Year effects appear to be minimal at the Apache Junction site, while initial defoliation in 1988 seems to be higher on the mixed brush site near Winkelman.

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## GORSE (*Ulex europaeus*) CONTROL WITH HERBICIDES

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### Introduction

Gorse (*Utex europaeus*) is a dense, spiny, evergreen, legume shrub which infests more than 30,000 acres in the southern coastal counties of Oregon. It grows up to 10 feet tall and has spreading branches ending in a sharp spine and bearing stiff spine-like leaves, where adapted gorse increases rapidly, crowding out other vegetation, forming dense thickets that render land almost worthless. The individual plants grow outward, forming a central area of dry, dead vegetation. The oil in the plant combined with the dead dry-matter creates a serious fire hazard.

Propagation is largely by seed. The plants are prolific seed producers, and bursting seed pods scatter seed for several feet. Seed is also carried by animals, machinery, and water. New infestations any distance from existing stands can usually be traced to movement of machinery. The seeds have hard coats and will lie in the soil for years before germinating.

### Control

Cultivation. Cultivation is one of the best methods of controlling gorse in areas accessible with equipment. Methods of cultivation that remove the old gorse crowns and bring them to the surface are the most successful. For well established stands large tractors or graders with blades and rippers are used

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to clear the land and push the gorse into piles for burning. Because gorse usually becomes established on nontillable land and in inaccessible places, such as fence rows, river banks, and rough sites, cultivation is often not possible.

Grazing. Livestock will eat the tender new tips of gorse plants if heavily stocked for a short time. Occasional mowing or herbicide application may be required if plants escape control by the livestock.

Burning. Burning will destroy most of the existing growth and some of the seeds on the soil surface. To be effective, burning must be done under conditions of low humidity. If conditions are unfavorable for a good burn, the area can be sprayed with a desiccant and oil to dry the foliage.

Crowns of gorse plants are usually not killed by cutting or burning top growth. Many crowns can be killed with a herbicide applied prior to burning. An option is to spray the regrowth from crowns after it has reached 12 to 18 inches in height.

## Chemical Control

Several tests were established to compare the effectiveness of various herbicides on established gorse. Two herbicide screening trials and a surfactant trial with Glyphosate {(*N*-(phosphonomethyl)glycine)} will be reported here.

## Herbicide Screening Trial Number 1

An experiment was conducted on well-established gorse plants to evaluate the effectiveness of certain herbicides in preventing regrowth in addition to giving top kill. The research site is 2 miles south of Bandon on the Oregon coast. Gorse was well established in an area that had been a pasture.

On April 16, 1987 herbicide applications were made to single large plants that were treated as plots. The treatments were replicated three times. Herbicides were applied through an adjustable-cone nozzle on a hand-held wand. Herbicides were added to water to make one gallon of spray mix at the desired concentration. One gallon of the spray mix was prepared to treat three plants, but because of difference in plant size the whole gallon was not necessarily used each time. We attempted to apply the spray mix so that the entire plant was uniformly wet. Herbicides tested were picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid}, glyphosate {(*N*-(phosphonomethyl)glycine)}, dicamba {3,6-dichloro-2-methoxybenzoic acid}, triclopyr {[(3,5,6-trichloro-2-pyridinyl) oxy]acetic acid}, triclopyr + 2,4-D {(2,4-dichlorophenoxy)acetic acid}, dicamba + 2,4-D, and 2,4-D LVE.

Evaluation of gorse control was made on July 12, 1987 which was 15 months after treatment. Results can be found on Table No. 1. All of the plants were still brown except one of the plants treated with 2,4-D and one treated with glyphosate. In both of these cases tips of only one or two branches were green. This was probably a result of poor distribution of the spray on the plant. Desiccation of the plant is important to get better results when the field is burned, but it may also be an indication of long-term control. In this test only the two plants mentioned above and another plant treated with 2,4-D were growing new shoots from the crown.

Gorse control in this experiment was better than expected for most of the herbicides used. Conditions were about optimum for maximum herbicide activity except the soil was unusually dry in 1987, and the gorse was in full bloom. It is usually more effective to apply herbicides soon after bloom because the blossoms tend to absorb the herbicide and drop off. The unusually good results are likely an indication of the importance of thorough coverage with the spray.

## Herbicide Screening Trial Number 2

An experiment was established to compare the performance of several herbicides on gorse that had regrown to a height of about 2 feet after being cut by a large "mower" in the previous year. There was a thick and uniform growth of the gorse over the plot area so plots 12 by 25 feet were sprayed rather than individual plants. This experiment was conducted on the Knapp ranch located between the town of Port Orford and the Elk River. This is one of two places where gorse is reported to have been planted before the turn of the century.

On September 1, 1987 herbicides were applied with a hand-held boom fitted with four 8003 flat fan nozzles. A $CO_2$ powered, hand-held plot sprayer was used. Treatments were replicated three times. Because most gorse spraying is done with a handgun, we opted to mix the herbicides at an appropriate concentration rather than spray on an area basis. Herbicides were applied with enough water to create the desired concentration. In an attempt to demonstrate the role of a surfactant, we applied the low rate of each herbicide with, and without, X-77 surfactant at 0.2% by volume. Because metsulfuron is formulated as dispersible granules it was applied on an area basis rather than on a concentration basis. A surfactant was added to metsulfuron at both rates.

Conditions for herbicide activity on gorse were not good. The summer had been extremely dry so the gorse plants had been under moisture stress for several months. Because we used relatively small nozzles, the volume of water was low and coverage was probably not complete.

Evaluation of gorse control was made on March 29 and again on July 12, 1988. As seen on Table No. 3 overall activity was much less than observed with some of the same herbicides in a test conducted earlier under better conditions and reported earlier in this paper. The evaluation made on March 29 was included to demonstrate that initial activity is not necessarily a good indication of final control. For most of the treatments the control was less in July than observed in March. Exceptions were metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid}, and dicamba at the high rate. In July of 1988 only metsulfuron, dicamba, triclopyr, and Crossbow (2,4-D + triclopyr) were giving control of 75% or better. These results were particularly encouraging considering the poor environmental conditions for the test.

## Effect of surfactants on glyphosate activity on gorse

Addition of a surfactant or an oil to a spray mixture is generally considered to improve herbicide entry into gorse plants. Few field experiments have been done specifically to test the effect of surfactants on herbicides applied to gorse. In the experiment reported here glyphosate formulated as Roundup was applied without additional surfactant, with two rates of the surfactant X-77, and with two rates of Surphtac. Surphtac contains 25% surfactant, 25% Monocarbamide Dihydrogen Sulfate as Enquik, and 50% water. The research site and conditions were the same as described in the first experiment in this paper.

On April 16, 1987 applications were made to large single plants that were treated as plots. The treatments were replicated three times. The herbicides were applied through a single adjustable-cone nozzle on a hand-held wand. Sufficient herbicide was added to water to make one gallon of a 1,2, or 4% concentration of Roundup with the appropriate amount of surfactant. We attempted to apply the spray mix so the entire plant was uniformly wet.

Table 1. Herbicide Screening Trial Number 1. Wayne Peters Farm, Bandon, OR, 1987-88

| Herbicide | % Conc | % Gorse Control 1 | 2 | 3 | Avg |
|---|---|---|---|---|---|
| picloram (Tordon 22K) | 1 | 100 | 100 | 100 | 100 |
| picloram (Tordon 22K) | 2 | 100 | 100 | 100 | 100 |
| glyphosate (Roundup) | 2 | 100 | 80 | 100 | 93 |
| glyphosate (Roundup) | 4 | 100 | 100 | 100 | 100 |
| dicamba (Banvel) | 2 | 100 | 100 | 100 | 100 |
| dicamba (Banvel) | 4 | 100 | 100 | 100 | 100 |
| triclopyr (Garlon 4) | 2 | 100 | 100 | 100 | 100 |
| triclopyr (Garlon 4) | 4 | 100 | 100 | 100 | 100 |
| triclopyr + 2,4-D (Crossbow) | 2 | 100 | 100 | 100 | 100 |
| triclopyr + 2,4-D (Crossbow) | 4 | 100 | 100 | 100 | 100 |
| dicamba + 2,4-D (Weedmaster) | 2 | 100 | 100 | 100 | 100 |
| dicamba + 2,4-D (Weedmaster) | 4 | 100 | 100 | 100 | 100 |
| 2,4-D LVE (Esteron Conc. 99) | 2 | 100 | 100 | 100 | 100 |
| 2,4-D LVE (Esteron Conc. 99) | 4 | 100 | 100 | 100 | 100 |

Table 2. Effect of Surfactants on Glyphosate Activity on Gorse. Wayne Peters Farm, Bandon, OR. 1987-88

| Surfactant | % Conc. | % Conc. Roundup | % Gorse Control RI | RII | RIII | Avg. |
|---|---|---|---|---|---|---|
| None | 0 | 1 | 40 | 40 | 50 | 43 |
| | 0 | 2 | 80 | 75 | 80 | 78 |
| | 0 | 4 | 80 | 100 | 100 | 93 |
| X-77 | 1 | 1 | 75 | 80 | 75 | 77 |
| | 1 | 2 | 90 | 95 | 80 | 88 |
| | 1 | 4 | 90 | 85 | 100 | 92 |
| | 2 | 1 | 95 | 50 | 70 | 72 |
| | 2 | 2 | 90 | 90 | 85 | 88 |
| | 2 | 4 | 98 | 100 | 90 | 96 |
| Surphtac | 0.5 | 1 | 95 | 90 | 40 | 75 |
| | 0.5 | 2 | 90 | 85 | 90 | 88 |
| | 0.5 | 4 | 75 | 90 | 90 | 85 |
| | 1 | 1 | 75 | 85 | 80 | 80 |
| | 1 | 2 | 95 | 90 | 75 | 87 |
| | 1 | 4 | 95 | 95 | 100 | 97 |

Table 3. Herbicide Screening Trial Number 2. Knapp Ranch - Curry County - Port Orford, OR

| Herbicide | % Conc. | % Control — Evaluated March 19, 1988 | | | | % Control — Evaluated July 12, 1988 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Avg | 1 | 2 | 3 | Avg |
| picloram (Tordon 22K) | .5 | 20 | 15 | 30 | 23 | 0 | 0 | 2 | 7 |
| picloram + X-77 | .5 | 25 | 50 | 50 | 42 | 0 | 0 | 0 | 0 |
| picloram | 1 | 40 | 40 | 40 | 40 | 0 | 0 | 20 | 7 |
| 2,4-D LVE | 2 | 30 | 35 | 50 | 38 | 40 | 0 | 0 | 13 |
| 2,4-D LVE + X-77 | 2 | 40 | 20 | 20 | 27 | 0 | 0 | 0 | 0 |
| 2,4-D LVE | 4 | 40 | 35 | 50 | 42 | 0 | 0 | 0 | 0 |
| 2,4-D amine | 2 | 30 | 20 | 20 | 23 | 0 | 0 | 0 | 0 |
| 2,4-D amine + X-77 | 2 | 30 | 10 | 15 | 18 | 0 | 0 | 0 | 0 |
| 2,4-D amine | 4 | 45 | - | 60 | 53 | 0 | 0 | 0 | 0 |
| glyphosate (Roundup) | 2 | 70 | 70 | 75 | 72 | 40 | 0 | 30 | 23 |
| glyphosate + X-77 | 2 | 75 | 80 | 80 | 78 | 40 | 40 | 30 | 37 |
| glyphosate | 4 | 80 | 75 | 80 | 78 | 40 | 30 | 50 | 40 |
| dicamba (Banvel) | 1 | 10 | 10 | 10 | 10 | 0 | 20 | 30 | 17 |
| dicamba + X-77 | 1 | 20 | 15 | 20 | 18 | 40 | 30 | 50 | 40 |
| dicamba | 2 | 40 | 30 | 40 | 37 | 80 | 75 | 75 | 77 |
| triclopyr (Garlon 4) | .5 | 60 | 60 | 75 | 65 | 0 | 70 | 40 | 37 |
| triclopyr + X-77 | .5 | 75 | 70 | 70 | 72 | 50 | 50 | 50 | 50 |
| triclopyr | 1 | 80 | 90 | 85 | 85 | 80 | 80 | 75 | 78 |
| Crossbow | 1.5 | 80 | 80 | 50 | 70 | 75 | 50 | 40 | 55 |
| Crossbow + X-77 | 1.5 | 85 | 75 | 85 | 82 | 70 | 60 | 75 | 68 |
| Crossbow | 3 | 95 | 90 | 90 | 92 | 90 | 85 | 95 | 90 |
| Weedmaster | 2 | - | 20 | 20 | 20 | 30 | 0 | 0 | 10 |
| Weedmaster + X-77 | 2 | 30 | 20 | 40 | 30 | 20 | 20 | 20 | 20 |
| Weedmaster | 4 | 60 | 30 | 15 | 35 | 30 | 30 | 20 | 27 |
| clopyralid (Stinger) | .75 | 15 | 10 | 10 | 12 | 20 | 0 | 0 | 7 |
| clopyralid + X-77 | .75 | 20 | 15 | 10 | 15 | 30 | 20 | 25 | 25 |
| clopyralid | 1.5 | 40 | 15 | 20 | 25 | 40 | 20 | 30 | 30 |
| metsulfuron + X-77 (Escort) | 1 oz/A | 20 | 10 | 20 | 17 | 95 | 90 | 90 | 92 |
| metsulfuron + X-77 | 2 oz/A | 55 | 40 | 25 | 40 | 80 | 80 | 90 | 83 |

Evaluation of gorse control was made on July 12, 1988 which was 15 months after treatment. Results can be found in Table No. 2. At 1 and 2% concentrations of Roundup there was an obvious improvement in control when either of the surfactants was used. Increased activity was most noticeable at the lowest rate of Roundup, which would be expected. At 1% concentration of Roundup plus additional surfactant, gorse control was equal to control with 2% concentration of Roundup without additional surfactant.

## Summary

Results reported here demonstrate that several herbicides applied under good conditions will give complete control of mature gorse for at least 15 months after treatment. Even under poor environmental conditions for herbicide activity metsulfuron, dicamba, triclopyr, and Crossbow gave at least 75% control. A surfactant added to Roundup increased activity. Short-term use of herbicides should not be expected to give complete control of a gorse problem. The difficulty of achieving complete crown kill and the supply of seeds in the soil dictate a long-term program using appropriate mixtures of control methods.

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# GORSE CONTROL WITH HERBICIDES AND ITS ENHANCEMENT WITH SURFACTANTS

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Abstract. Four field trials were conducted to evaluate herbicides and a polyalkyleneoxide modified polydimethylsiloxane surfactant (Silwet L-77[2]) for the control of gorse (*Ulex europaeus* L.) in Hawaii. The first two trials were evaluated at 10 months after treatment, the others at 9 months after treatment. Triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid} ester without surfactant was effective at 1 and 2 kg ae/ha but triclopyr amine with the surfactant nonylphenoxypolyethoxyethanol (hereafter NI) was not, suggesting that poor triclopyr amine uptake by gorse was limiting efficacy. Metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoicacid} with L-77 (0.25% v/v) was effective at 90 g ai/ha, the lowest rate applied.

In the second trial, metsulfuron at 90 g ai/ha was ineffective with no surfactant, NI, or another polyalkyleneoxide modified polydimethylsiloxane, L-7607 (Silwet L-7607), but effective with L-77. Picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} at 0.5 kg ae/ha was more active with L-77 than with L-7607. Dicamba {3,6-dichloro-2-methoxybenzoic acid} was ineffective regardless of surfactant used.

The third trial established that metsulfuron at 35 g ai/ha with 0.2% v/v L-77 was the lowest effective rate of application for gorse.

The last trial indicated that sulfometuron {2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid} was ineffective on gorse, but that triclopyr amine and picloram, at 0.5 kg ae/ha, were each effective for the control of gorse when applied with L-77.

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It was concluded that metsulfuron and triclopyr amine with L-77 were effective for relatively long-term control. A consistently higher response rating attributable to L-77, though not always statistically significant, suggested that further studies with this surfactant were warranted.

## Introduction

Gorse, a large, spiney, leguminous shrub, infests 6000 ha of pastures and forests around the 1500 m elevation of the slopes of Mauna Kea on the island of Hawaii. A prolific seeder, gorse forms dense stands of spiney thickets that cattle will not penetrate. Some 3000 ha of pastures on Mauna Kea are literally non-productive because of gorse infestations (3). There is an additional 1500 ha on the slopes of Haleakala on Maui that are also infested. Gorse infested areas on Maui have been developed into residential subdivisions, and gorse thereby poses a fire hazard. Gorse has also invaded the Haleakala National Park. Thus, gorse poses a threat to pastures; forests, including native forests; homes; and safety.

An ad hoc public and private interagency committee is coordinating a program to manage the gorse problem. It is recognized that long-term solutions lay in biocontrol and cultural (e.g. grazing management, reforestation) programs. However, there still exists a role for herbicides where rapid suppression is required.

The herbicide of choice for pastures has been picloram. However, the usefulness of this herbicide is limited by recently imposed restrictions on its use in pastures. Its use in residential lands is prohibited.

Balneaves (1) reported that metsulfuron with the surfactant L-77 was effective on gorse in New Zealand. Therefore trials were conducted to evaluate these and other herbicides and the potential of L-77 to increase herbicide efficacy.

## Materials and Methods

These experiments were conducted on the NE slope of Mauna Kea near the 1500 m elevation level. Trials 1 and 2 were installed in August 1986 on a young infestation where the gorse plants stood ca 1 m tall. Trials 3 and 4 were installed in October 1987 on a site that had been manually cleared in February 1987. The gorse here were ca 0.6 m tall.

Herbicide applications were made with a hand-held 4-nozzle boom sprayer pressurized to 1.44 kP with $CO_2$. Flat fan stainless steel nozzles, 8002 in trials 1 and 2, and 8004 in trials 3 and 4, were used to yield volume-rates of 233 and 305 l/ha for each respective set of nozzles.

The plots were 2m by 5m arranged in randomized complete blocks. The treatments imposed are presented in Tables 1, 2, 3, and 4. Trials 1 and 2 were evaluated at 10 months after treatment and trials 3 and 4 were evaluated at 9 months after treatment. Evaluations consisted of visual control ratings using a 0-10 scale with 0 being no effect and 10 being complete kill. The data were transformed by the arcsin function for analyses of variance and retransformed for presentation (5).

## Results and Discussion

Trial 1. Metsulfuron, applied with L-77, was effective at 90 g ai/ha, the lowest rate used which suggested that the optimal rate did not exceed 90 g/ha. (Table 1).

Table 1. Response of gorse to triclopyr and metsulfuron, at 10 months after treatment.

| Herbicide | Rate (per ha) | Response Rating[1] |
| --- | --- | --- |
| Control | 0 | 0[a] |
| Triclopyr amine + 0.5% v/v NI[2] | 0.5kg | 2.2[b] |
| | 1.0kg | 2.3[b] |
| | 2.0kg | 4.5[bc] |
| Triclopyr ester | 0.5 kg | 4.0[b] |
| | 1.0 kg | 6.7[c] |
| | 2.0 kg | 7.9[cd] |
| Metsulfuron + 0.25% v/v L-77[3] | 90 g | 8.6[cd] |
| | 180 g | 9.0[d] |
| | 360 g | 9.9[d] |

1 0-10 visual rating scale; 0 = no effect, 10 = kill; means followed by different letters significantly different at 0.05 level (Duncan's New Multiple Range Test); analysis performed on arcsin transformed data and retransormed for presentation.

2 Nonylphenoxypolyethoxyethanol.

3 Polyalkyleneoxide modified polydimethylsiloxane.

Triclopyr amine, applied with NI, did not produce adequate control of gorse at 2.0 kg ae/ha, the highest rate applied, and there was no significant response to rates of application.

In contrast, gorse did show a response to rates of triclopyr ester applied, a significant increase in response at 1.0 kg ae/ha over 0.5 kg ae/ha and a higher but insignificant increase at 2.0 kg ae/ha over 1.0 kg ae/ha. This contrast between the amine and ester formulations of triclopyr suggests that the effectiveness of triclopyr amine was limited by poor uptake by the gorse plant. Gorse, with its inconspicuous leaves, provides a small foliar area for herbicide deposition. Furthermore, the cuticle on gorse is believed to be relatively dense and inpenetrable by hydrophyllic substances (4). Thus the lipophyllic ester produced the greater response in gorse.

Trial 2. The surfactant L-77 significantly increased the efficacy of metsulfuron in contrast to no surfactant, NI (the conventional standard), and L-7607. (Table 2)

Picloram, the current standard herbicide for gorse control in pastures and non-cropland of Hawaii, was moderately effective with L-77, although the difference in response over the picloram with NI treatment was not significant. It should be noted that the effective rate of picloram on gorse was 1 or 2 kg ae/ha (2). The rather low rate of 0.5 kg ae/ha was employed to avoid masking of the surfactant effect by a potent dose of herbicide.

Dicamba, which has been ineffective in previous trials (2), was included to determine if L-77 might increase its efficacy. However, dicamba was ineffective regardless of surfactant used.

Table 2. Effect of surfactants on gorse response to herbicide, at 10 months after treatment.

| Herbicide | Rate | Surfactant | Response Rating[1] |
|---|---|---|---|
| Control | 0 | 0 | 0.7[a] |
| Picloram | 0.5 kg a.e./ha | 0 | 1.5[a] |
| | | NI[2] | 4.0[bc] |
| | | L-77[3] | 6.6[cd] |
| | | L-7607[3] | 1.9[ab] |
| Metsulfuron | 90 g a.i./ha | 0 | 2.0[ab] |
| | | NI | 4.3[bc] |
| | | L-77 | 8.7[d] |
| | | L-7607 | 5.7[c] |
| Dicamba | 2 kg a.e./ha | 0 | 1.3[a] |
| | | NI | 0.7[a] |
| | | L-77 | 2.6[ab] |
| | | L 7607 | 0.9[a] |

[1] 0-10 visual rating scale; 0= no effect, 10 = kill; means followed by different letters significantly different at 0.05 level (Duncan's New Multiple Range Test); analysis conducted on data transformed by arcsin function and retransformed for presentation.

[2] Nonylphenoxypolyethoxyethanol; 0.5% v/v.

[3] Polyalkyleneoxide modified polydimethylsiloxane; 0.25% v/v.

Trial 3. Metsulfuron at 35 g ai/ha applied with 0.25% v/v L-77 was the lowest effective rate of application (Table 3). The criticalness of an effective surfactant was illustrated by the lack of further response beyond 35 g ai/ha and the poor response of 90 g ai/ha with no surfactant, NI, and L-7607 (Table 2).

Table 3. Response of gorse to rates of metsulfuron[1], at 9 months after treatment.

| Rate (g a.i./ha) | Response Rating[2] |
|---|---|
| 0 | 0.1[a] |
| 17.5 | 6.3[b] |
| 35 | 8.3[c] |
| 70 | 7.9[bc] |
| 105 | 8.9[c] |

[1] With 0.2% v/v L-77 (polyalkyleneoxide modified polydimethylsiloxane).

[2] 0-10 visual rating scale; 0 = no effect, 10 = kill; means followed by different letters differ significantly at 0.05 level (Duncan's New Multiple Range Test); analysis performed on arcsin transformed data and retransformed for presentation.

Trial 4. This trial was conducted to determine the lowest efficacious concentration of L-77 necessary for gorse control with several herbicides (Table 4). Although sulfometuron was ineffective, there was a response to 0.2% v/v L-77 over the no surfactant treatment. Metsulfuron and picloram were more effective with L-77 than without, and though there was a trend to increasing response with L-77 between 0.1% and 0.2%, the response was not statistically significant. Likewise, there was a trend with triclopyr ester towards increasing response with increasing concentration of L-77 that was not statistically significant. However, the difference in response between no surfactant and 0.2% L-77 treatments was significant. Triclopyr amine, which had previously provided poor control of gorse (Table 1), produced marked response in gorse with increasing L-77 concentration. Of note here, the rate of triclopyr amine, along with that of triclopyr ester and picloram, were intended to be sub-lethal in order to demonstrate the effect of the surfactant. Yet, triclopyr amine at 500 g ai/ha with 0.2% v/v L-77 provided excellent control of gorse.

Table 4. Effect of L-77[1] on the response of gorse to herbicides at 9 months after treatment.

| Herbicide | Rate (g/ha) | L-77 (% v/v) | Response Rating[2] |
|---|---|---|---|
| Control | 0 | 0 | 0.7[a] |
| Metsulfuron | 70[3] | 0 | 2.3[ab] |
| | | 0.1 | 6.4[cde] |
| | | 0.2 | 7.8[def] |
| Sulfometuron | 420[3] | 0 | 0.7[a] |
| | | 0.1 | 2.3[ab] |
| | | 0.2 | 3.6[bc] |
| Picloram | 500[4] | 0 | 3.3[bc] |
| | | 0.1 | 7.5[def] |
| | | 0.2 | 8.4[ef] |
| Triclopyr Amine | 500[4] | 0 | 1.9[ab] |
| | | 0.1 | 6.2[cde] |
| | | 0.2 | 9.1[f] |
| Triclopyr Ester | 500[4] | 0 | 5.3[cd] |
| | | 0.1 | 6.0[cde] |
| | | 0.2 | 7.3d[ef] |

1 Polyalkyleneoxide modified polydimethylsiloxane.

2 0-10 visual rating scale; 0= no effect, 10 = kill; means followed by different letters are significantly different at the 0.05 level (Duncan's New Multiple Range Test); analysis performed on arcsin transformed data and retransformed for presentation.

3 a.i./ha

4 a.e./ha

## Conclusion

The surfactant L-77 clearly increased the activity of metsulfuron and triclopyr amine and made lower than usual rates of triclopyr amine very effective. Consistent though non-significant responses suggest that L-77 may also increase the efficacy of other herbicides as well.

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# THE EFFECTS OF TRICLOPYR AND 3,6-DICHLOROPICOLINIC ACID ON GORSE

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Abstract. Triclopyr {(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid} and 3,6-dichloropicolinic acid (clopyralid) were applied broadcast to gorse seedlings (*Ulex europaeus* L.). Rates of triclopyr were: 0.28, 0.57, 1.12, 2.24 and 4.48 kg ae/ha. Rates of clopyralid were: 0.14, 0.28, 0.57, and 1.12 kg ae/ha. All applications made at 280.6 L/ha had a crop oil concentrate added at 1.5% v/v. Treatments were applied at Jughandle State Park in Mendocino County, CA on May 6, 1987 with a $CO_2$ backpack sprayer at 131 kPa using a boom with 3 XR 8004 flat fan nozzles. Temperatures were 18-20C during application.

Triclopyr at 1.12, 2.24 and 4.48 kg ae/ha controlled gorse seedlings (90, 94, and 97%, respectively) at 6 months after treatment. At the same evaluation time, clopyralid plots were not significantly different than the untreated plots at the 0.14, 0.28 and 0.57 kg ae/ha rates. The highest rate of clopyralid, 1.12 kg ae/ha, gave 46% seedling control.

Another trial with these 2 materials was established on gorse bushes (about 1 m tall and 1-2 m wide) at the same time using an individual plant treatment (spray-to-wet). Triclopyr and clopyralid rates were: 0.5, 1.0, and 2.0% v/v solutions in water with 0.5% crop oil concentrate. Treatments were applied the same day under the same conditions. A $CO_2$ backpack sprayer was used with a wand and a single XR 8004 nozzle.

All treatments controlled the gorse better than 90% at 6 months after treatment. Triclopyr controlled the gorse at 98, 100 and 100% with the rate of 0.5, 1.0 and 2.0%, respectively. Clopyralid gave 92, 100, and 100% gorse control at rates of 0.5, 1.0, and 2.0% respectively.

Both triclopyr and clopyralid have activity on gorse. Triclopyr provides more consistent control across various application techniques. Clopyralid provided good control of gorse when applied with individual plant treatments.

## Introduction

Gorse (*Ulex europaeus* L.) is a perennial native to England and southern Europe. It has been introduced into other regions as hedges for livestock. The plant reproduces by seeds, which are dispersed by the force created when the seed pods open, and by animals and water. The plants are very competitive and cause a reduction in desirable grass species in range or pastures. The plants are considered a fire hazard because of the high oil content in the foliage. Leaves are spiny with a waxy cuticle, decreasing penetration of herbicides and making control more difficult. Mechanical control is not effective because of the plant's resprouting ability. Gorse is classified as a noxious weed in Hawaii, California, Washington, and Oregon. This paper will review results of 2 trials on gorse control established in California.

## Materials and Methods

Two field studies were established on May 6, 1987 in Jughandle State Park, just north of Mendocino, California. The gorse was in the early post-bloom stage. Conditions at the time of treatment were similar: (1) temperature was 18-20C, (2) wind speed was 0-5 kmph, and (3) the sky was clear.

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The products used were triclopyr butoxy ethyl ester (0.5 kg ae/L) as GARLON 4 and clopyralid monoethanolamine salt (0.4 kg ae/L) as STINGER. Visual estimates of percent control were made at 8 weeks and 6 months after application.

## Broadcast Application Study

The broadcast application study was conducted in a 1.2 ha gorse infestation. A controlled burn operation was done on the site in 1985. Seedlings (about 10-15 cm) were dense, and some of the old stems were resprouting.

Plots were set out in a randomized complete block design with 4 replications of each treatment. Individual plots were 1.5 by 6 m. Applications were made at 131 kPa with a $CO_2$ backpack sprayer using a 1.5 m boom and 3 XR 8004 nozzles. Spray volume applied 280.6 L/ha.

Rates of clopyralid were 0.14, 0.28, 0.57, and 1.12 kg ae/ha. Rates of triclopyr were 0.28, 0.57, 1.12, 2.24, 4.48 kg ae/ha. All treatments included a crop oil concentrate at 1.5% v/v.

## Individual Plant Application Study

The individual plant application study was conducted in another part of the park in a gorse infestation with discreet bushes or clumps of bushes, about 1-1.5 m in height. This area had not been burned in 1985.

Plots consisted of individual bushes or clumps of bushes. Each treatment was replicated 3 times. Applications were made to the foliage and stems applied to the point of runoff at 131 kPa with a $CO_2$ backpack sprayer using a single wand and a XR 8004 nozzle. Triclopyr and clopyralid rates were: 0.5, 1.0 and 2.0% v/v solutions in water with 0.5% crop oil concentrate.

# Results and Discussion

## Broadcast Application Study

Triclopyr at 1.12, 2.24, and 4.48 kg ae/ha provided 91.5, 92.5, and 100% control, respectively, of gorse seedlings and resprouts when rated at 8 weeks after application (Table 1). Lower rates of triclopyr (0.28 and 0.57 kg ae/ha) were not as effective (26.3 and 59.3% gorse control). Treatment effects had not changed significantly 6 months after application. The highest triclopyr ester rates still gave excellent control of the seedlings and resprouts (90, 94.5, and 97.5%).

Broadcast applications of clopyralid at 0.14, 0.28, and 0.57 kg ae/ha did not result in control of gorse seedlings. Even the highest rate (1.12 kg ae/ha) provided only 37.5% control. While the control ratings did increase for most of the clopyralid treatments, results did not significantly improve at 6 months after application.

## Individual Plant Application Study

Triclopyr rates of 1 and 2% gave excellent control of the gorse bushes when rated eight weeks after application (Table 2). The lowest rate of 0.5% gave about 70% control of the stems. All of the treatments were significantly different from the control, and none was significantly different from the others.

The 2% rate of clopyralid gave 90% control of the plant stems. Rates of 0.5 and 1% treatments gave 58.3 and 63.3% control, respectively. Volumes applied for directed spray applications will vary from 50-150 gpa or more. At 100 gpa

TABLE 1 : SEEDLING GORSE CONTROL WITH TRICLOPYR AND CLOPYRALID

BROADCAST APPLICATION STUDY

| TREATMENT | RATE (kg ae/ha) | AVERAGE % CONTROL 8 WAT* | 6 MAT** |
|---|---|---|---|
| clopyralid | 0.14 | 10.0 de | 13.0 d |
| clopyralid | 0.28 | 10.8 de | 9.3 d |
| clopyralid | 0.57 | 15.0 de | 16.3 d |
| clopyralid | 1.12 | 37.5 c | 46.3 bc |
| triclopyr | 0.28 | 26.3 cd | 37.5 c |
| triclopyr | 0.57 | 59.3 b | 61.3 b |
| triclopyr | 1.12 | 91.5 a | 90.0 a |
| triclopyr | 2.24 | 92.5 a | 94.5 a |
| triclopyr | 4.48 | 100 a | 97.5 a |
| untreated control | ---- | 0 e | 3.0 d |

Averages with the same letter are not significantly different at 0.05 using Duncan´s New Multiple Range T-test.

* WAT = weeks after treatment
** MAT = months after treatment

**TABLE 2: GORSE CONTROL WITH TRICLOPYR AND CLOPYRALID**

**INDIVIDUAL PLANT APPLICATION STUDY**

| TREATMENT | RATE (% v/v) | AVERAGE % STEM CONTROL 8 WAT* | 6 MAT** |
|---|---|---|---|
| clopyralid | 0.5 | 58.3 a | 91.7 a |
| clopyralid | 1.0 | 63.3 a | 100 a |
| clopyralid | 2.0 | 90.0 a | 100 a |
| triclopyr | 0.5 | 69.7 a | 98.3 a |
| triclopyr | 1.0 | 98.3 a | 100 a |
| triclopyr | 2.0 | 100 a | 100 a |
| untreated control | --- | 0.3 b | 0 b |

Averages with the same letter are not significantly different at 0.05 using Duncan's New Multiple Range T-test.

* WAT = weeks after treatment
** MAT = months after treatment

volume the rates of clopyralid would have been 1.68-6.72 kg ae/ha. The highest broadcast rate used was 1.12 kg ae/ha. Activity on the gorse was greater at this rate than at the lower broadcast rates, so increasing broadcast rates may have increased activity as seen in the individual plant applications.

Six months after application all rates of both materials gave excellent control (91.7 to 100%) of the gorse bushes. Field use of GARLON 4 on gorse in California State Parks and on private timber lands at 1-2% spray solution has shown consistent control.

## Conclusions

Triclopyr can be used to control gorse seedlings when broadcast at rates of 1.12-4.48 kg ae/ha and to control gorse bushes at 0.5%-2% spray solution. Gorse can also be controlled with directed spray applications of 0.5-2% spray solutions of clopyralid. Broadcast applications of clopyralid did not give acceptable control of gorse seedlings at any application rate.

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# A SATELLITE REMOTE SENSING TECHNIQUE TO PREDICT FUTURE DISTRIBUTION OF DYERS WOAD (*Isatis tinctoria*) ON THE CACHE NATIONAL FOREST

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Abstract. Dyers woad (*Isatis tinctoria* L. #ISATI), although traditionally considered an agricultural and rangeland weed, has recently appeared on the rugged Logan District of the Cache National Forest in northern Utah. This invader is rapidly naturalizing on a wide variety of forest environments. The exact District acreage infested by dyers woad is not known but is estimated to be approximately 500 hectares. Forest resource managers are concerned about this weed invasion and desire to know what additional forest lands might be susceptible to infestation.

Satellite remotely sensed data are currently used in land resource management studies by many agencies throughout the world. In this study researchers at Utah State University used spectral data from Landsat-5 Thematic Mapper (TM) to model and map the potential distribution of dyers woad on 149,021 hectares within the Cache National Forest. Satellite data were incorporated into a Geographic Information System (GIS) to associate dyers woad with spectrally homogeneous land cover types. Imaging and GIS analysis were performed using Earth Resources Data Analysis Systems (ERDAS).

During May and June of 1988, field crews identified 1,741 forest sites infested by dyers woad. These sites were plotted on USGS 7.5 minute quadrangle maps, and location points were computer digitized into a GIS database format. Using a brightness/greenness transformation, six channels (3 visible, 1 infrared and 2 mid-infrared) of Landsat-5 TM data were transformed into three spectral components (brightness, greenness, and wetness). Using an unsupervised clustering algorithm, the transformed data were classified into 60 spectrally homogeneous land cover types.

Ground control points (GCP) were used to geographically register the dyers woad location map to the spectral land cover classification map. A GIS was then

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used to correlate dyers woad locations with spectral cover classes. The GIS information layers were resampled to a 30m$^2$ pixel size to match with satellite TM pixel size.

Potential for eventual dyers woad invasion into uninfested areas was determined in two ways. In the first, all classes registering at least one current dyers woad occurrence were tabulated and designated as "vulnerable" to some degree of invasion. In the second, percent of the study area occupied by each of the 60 spectral classes was determined and used to calculate the number of dyers woad occurrences expected (based on a completely random distribution) within each spectral class. A Chi-square goodness-of-fit test was used to evaluate for significant differences between "expected" and "observed" occurrences overall and within individual classes. Spectral classes exhibiting a significantly greater than expected number of dyers woad occurrences ($P = 0.005$) were classified as land cover types "highly susceptible" to invasion.

Dyers woad is an exotic weed known for its adaptability to a wide variety of plant communities, elevation diversity, and environmental conditions. Speculation that the plant could successfully inhabit most of the land cover types on the Cache National Forest is supported by findings in this study. Dyers woad was observed in 55 out of 60 spectral classes. These 55 classes represent 98.8% of the total hectares within the study area. The findings also indicate that 16.6% (24,802 hectares) of the study area is "highly suited" to dyers woad, including much of the land within the Mt. Naomi Wilderness area.

The use of satellite data with GIS allows for a synoptic view of study areas and ease in deriving acreage estimates. The improved ability to output scaled maps will allow land managers to investigate predicted areas of dyers woad invasion in the field with greater efficiency and accuracy. Detection of critical sites susceptible to invasion, such as wilderness areas or lands occupied by threatened and endangered plant species, will be possible. Weed control Environmental Assessment (EA) and Environmental Impact Statement (EIS) documents will be significantly improved.

It is believed the use of this technique is a substantial improvement over existing methods and will greatly improve land management planning for the control of noxious weeds.

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## SPOTTED KNAPWEED CONTROL IN PASTURE

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Abstract. Spotted knapweed (*Centaurea maculosa* Lam.) is rapidly spreading in northern Idaho. The objective of this experiment was to determine the effects of metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid}, DPX-L5300 {methyl 2-[[[[*N*-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoate}, clopyralid {3,6-dichloro-2-pyridinecarboxylic acid}, chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide}, sulfometuron {2-[[[[(4,6-dimethyl-2-pyrimidinyl)carbonyl]amino]sulfonyl]benzoic acid}, and picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} on established spotted knapweed in pasture. The experiment was established at Farragut State Park, east of Athol, ID on June 9, 1986.

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Results of the first year (1986) indicated metsulfuron, DPX-L5300, chlorsulfuron, and sulfometuron slightly suppressed the biomass of spotted knapweed. Clopyralid and picloram at all rates reduced the spotted knapweed biomass by 95-100% during growth of the first year after application ($p = 0.0001$). Less than 5% of the plants treated with metsulfuron, DPX-L5300, sulfometuron, clopyralid, and picloram produced seeds the first year.

Evaluations of second year (1987) showed 95% control of spotted knapweed with all rates of clopyralid and picloram. Metsulfuron, DPX-L5300, chlorsulfuron, or sulfometuron did not reduce spotted knapweed biomass or seed production in the second year.

Evaluations in the summer of the third year (1988) indicated that all clopyralid and picloram treatments continued to control over 95% of the spotted knapweed. After three years, results suggest picloram and clopyralid will control spotted knapweed growth and seed production for more than two years.

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## METHODS OF CONTROLLING DOWNY BROMEGRASS IN BURNED-OVER AREAS DURING ESTABLISHMENT OF PERENNIAL RANGE GRASSES

W.H. Horton and K.H. Asay[1]

Abstract. Four methods of seedbed preparation and seeding were evaluated to establish nine perennial wheatgrasses during a three-year period on two burned-over downy bromegrass (*Bromus tectorum* L.) dominated areas in Skull Valley, Utah. Precipitation at the two sites ranged from 20 to 30 cm annually. All seedings were made in the late fall (7 October 1983) using the following treatments: 1) mechanical seedbed preparation with a spring tooth harrow, followed by minimum-till drill; 2) treatment with a 1.2 liters/ha (1 pt/A) glyphosate {*N*-(phosphonomethyl)glycine} followed by minimum-till drill; 3) deep-furrow drill, which simulated a rangeland drill; and 4) minimum-till drill with no prior seedbed preparation. Competition from downy bromegrass was the major factor limiting establishment of perennial grasses. When heavy late summer precipitation led to excellent germination of downy bromegrass seedlings prior to treatment, spring-tooth harrowing followed by minimum-till drilling was most effective. In this case, the fire in mid July eliminated more than half of the downy bromegrass seed source. Weed competition was reduced further by mechanical cultivation of seedlings prior to seeding of the perennial grasses. Seeding with a minimum-till drill after herbicide application also was effective. Minimum-till drilling and deep furrow drilling with no prior weed control were least successful. Of the ten grasses evaluated, two crested wheatgrasses, I-28 Synthetic and Hycrest, had the greatest establishment vigor and essentially eliminated the downy bromegrass competition after two years.

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Table 1. Visual ratings of stand establishment of nine perennial grasses using four methods of seeding on a downy bromegrass range foothill site in western Utah (Site 1).

| | Visual rating by seeding treatment and year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | 1 | | 2 | | 3 | | 4 | | Mean | |
| Years | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 |
| Cultivars | | | | | | | | | | |
| | % | | | | | | | | | |
| I-28 CWG | 92 | 88 | 80 | 77 | 37 | 35 | 8 | 1 | 54 | 50 |
| Nordan CWG | 35 | 30 | 27 | 27 | 18 | 18 | 2 | 1 | 30 | 19 |
| Hycrest CWG | 90 | 92 | 80 | 73 | 37 | 33 | 5 | 1 | 53 | 50 |
| Alkar TWG | 38 | 28 | 27 | 23 | 25 | 20 | 5 | 1 | 24 | 18 |
| Boz-Sel RWR | 8 | 7 | 1 | 4 | 40 | 1 | 5 | 0 | 4 | 3 |
| Vinall RWR | 5 | 5 | 2 | 2 | 1 | 1 | 0 | 0 | 2 | 2 |
| Mandan PWG | 32 | 33 | 22 | 18 | 2 | 0 | 1 | 0 | 14 | 13 |
| Luna PWG | 73 | 68 | 50 | 47 | 30 | 22 | 4 | 1 | 39 | 34 |
| RS-2 Hybrid | 10 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 |
| Mean | 43 | 39 | 32 | 30 | 17 | 14 | 3 | 0 | 24 | 21 |
| $LSD_{(0.05)}$ | 6 | 8 | 12 | 14 | 13 | 11 | ns | ns | 5 | 4 |

Table 2. Herbage yields of 9 perennial grasses established with four methods of seeding on a downy bromegrass range foothill site in western Utah (Site 1).

| | Grass standing crop by seeding treatment and year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | 1 | | 2 | | 3 | | 4 | | Mean | |
| Years | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 |
| Cultivars | | | | | | | | | | |
| | Kg/ha | | | | | | | | | |
| I-28 CWG | 1600 | 2460 | 1310 | 2010 | 540 | 1090 | 70 | 110 | 880 | 1420 |
| Nordan CWG | 620 | 1480 | 600 | 1220 | 320 | 590 | 30 | 30 | 390 | 830 |
| Hycrest CWG | 1520 | 2500 | 1470 | 2340 | 890 | 1100 | 50 | 70 | 980 | 1520 |
| Alkar TWG | 1640 | 2240 | 1600 | 1800 | 880 | 1190 | 0 | 20 | 100 | 1350 |
| Boz-Sel RWR | 460 | 490 | 80 | 260 | 100 | 0 | 0 | 0 | 160 | 190 |
| Vinall RWR | 100 | 300 | 30 | 50 | 0 | 0 | 0 | 0 | 30 | 90 |
| Mandan PWG | 810 | 1340 | 420 | 920 | 0 | 0 | 0 | 0 | 310 | 560 |
| Luna PWG | 1340 | 2210 | 800 | 1370 | 370 | 460 | 0 | 90 | 630 | 1030 |
| RS-2 Hybrid | 50 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 30 |
| Mean | 900 | 1460 | 700 | 1110 | 340 | 490 | 20 | 50 | 490 | 780 |
| $LSD_{(0.05)}$ | 260 | 510 | 450 | 570 | 290 | 470 | NS | NS | 140 | 170 |

Table 3. Visual ratings of stand establishment of 10 perennial grasses using four methods[1] of seeding on a downy bromegrass range exclosure (Site 2) in western Utah.

| Treatments | 1 | | 2 | | 3 | | 4 | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| Years | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 |
| Cultivars | % | | | | | | | | | |
| I-28 CWG | 95 | 92 | 68 | 60 | 17 | 5 | 2 | 0 | 46 | 39 |
| Nordan CWG | 57 | 45 | 22 | 17 | 5 | 0 | 0 | 0 | 21 | 15 |
| Hycrest CWG | 92 | 88 | 47 | 40 | 12 | 3 | 1 | 1 | 38 | 33 |
| Alkar TWG | 57 | 43 | 30 | 27 | 3 | 2 | 2 | 1 | 23 | 18 |
| Boz-Sel RWR | 25 | 20 | 3 | 1 | 2 | 0 | 1 | 0 | 8 | 5 |
| Vinall RWR | 25 | 15 | 2 | 1 | 2 | 0 | 0 | 0 | 7 | 4 |
| Mandan PWG | 37 | 25 | 1 | 0 | 1 | 0 | 0 | 0 | 10 | 6 |
| Luna PWG | 77 | 67 | 2 | 1 | 8 | 1 | 0 | 0 | 22 | 17 |
| RS-2 Hybrid | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Paiute OG | 57 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 25 | 0 |
| Mean | 53 | 40 | 22 | 15 | 5 | 1 | 1 | 0 | 20 | 14 |
| $LSD_{(0.05)}$ | 15 | 12 | 10 | 5 | 4 | 3 | 1 | ns | 5 | 7 |

Table 4. Herbage yields of 10 perennial grasses established with four methods of seeding on a downy bromegrass range exclosure (Site 2) in western Utah.

| Treatments | 1 | | 2 | | 3 | | 4 | | Mean | |
|---|---|---|---|---|---|---|---|---|---|---|
| Years | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 | 1984 | 1986 |
| Cultivars | Kg/ha | | | | | | | | | |
| I-28 CWG | 2150 | 2510 | 1690 | 2020 | 200 | 110 | 170 | 0 | 1010 | 1160 |
| Nordan CWG | 1390 | 1610 | 640 | 600 | 30 | 0 | 0 | 0 | 510 | 550 |
| Hycrest CWG | 1910 | 2190 | 1530 | 1460 | 210 | 80 | 0 | 0 | 910 | 930 |
| Alkar TWG | 1460 | 1530 | 1200 | 1570 | 60 | 30 | 0 | 0 | 680 | 780 |
| Boz-Sel RWR | 1150 | 720 | 0 | 0 | 0 | 0 | 0 | 0 | 290 | 180 |
| Vinall RWR | 480 | 380 | 0 | 0 | 0 | 0 | 0 | 0 | 120 | 100 |
| Mandan PWG | 1290 | 900 | 0 | 0 | 0 | 0 | 0 | 0 | 320 | 230 |
| Luna PWG | 1930 | 1920 | 0 | 0 | 0 | 0 | 0 | 0 | 480 | 480 |
| RS-2 Hybrid | 35 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 8 |
| Paiute OG | 30 | 0 | 250 | 0 | 0 | 0 | 0 | 0 | 70 | 0 |
| Mean | 1180 | 1180 | 530 | 570 | 50 | 22 | 2 | 0 | 440 | 440 |
| $LSD_{(0.05)}$ | 350 | 380 | 230 | 290 | 120 | 7 | NS | NS | 130 | 220 |

# MODELING JAPANESE BROME POPULATION DYNAMICS

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## Introduction

Japanese brome (*Bromus japonicus*) is an introduced, annual grass which has become a common component of many mixed prairie communities of the northern Great Plains. It is most abundant on fine-textured soils with a good litter cover.

Few attempts have been made at modeling the population dynamics of annual grasses in grasslands. Mortimer (1976) presented a flow diagram of the population dynamics of annual bluegrass (*Poa annua*) in a grassland. He indicated only half the seeds produced entered the seed bank and about half of those never germinated. The chance of a seed in the surface seed bank producing a seedling and surviving to adulthood were both very low. All transitions in his model were represented as constants and no environmental parameters were considered. Detection of causal mechanism can be improved when environmental measurements and demography are used together (Mack and Pyke 1984). In less predictable environments, the transition between life stages cannot be adequately represented with constants.

Livestock have generally reduced litter accumulations in the northern mixed-prairie, but managed natural areas and parks without domestic livestock often have higher litter accumulations than adjacent areas containing domestic animals. Fire is often excluded from these same parks and natural areas. Excluding fire (and/or domestic livestock) from these grassland communities has resulted in greater litter accumulations. Kirsch and Kruse (1972) hypothesized that reduced fire frequencies--and the resulting higher litter accumulations--following settlement of the northern great Plains aided the establishment and successful spread of Japanese brome. This study was undertaken to examine those relationships.

The objectives of this study were to quantify the relative importance of precipitation and litter accumulations and to develop a dynamic, determinate model of Japanese brome population dynamics as affected by fire. The approach was to examine the influence of precipitation and litter accumulations on Japanese brome recruitment, mature tiller densities, seed production, and seed banks. Japanese brome population dynamics on plots from a previous study (Whisenant and Bulsiewicz 1986) were studied for an additional three years to obtain data under a wider range of environmental conditions. To more accurately represent population dynamics in a changing environment, difference equations were used instead of constants.

## Materials and Methods

The study site was located in Badlands National Park in west-central South Dakota. The area studied was never cultivated and has not been grazed by domestic livestock in at least 25 years. In this apparently undisturbed area, Japanese brome established and maintained tiller densities averaging 2500 $m^{-2}$ in good stands of native, perennial grasses ($\approx$400 tillers $m^{-2}$) (Whisenant and

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Bulsiewicz 1985). Western wheatgrass (*Agropyron smithii*) was the dominant perennial species and Japanese brome was the codominant on the Larvie silty clay (fine, montmorillonitic, mesic vertic Camborthid) site.

Three 5- by 5-m plots were burned on 20 April 1983, three were burned on 16 April 1984, and three remained unburned. The plots were arranged in a randomized complete block design. All the fuel on these plots consisted of either living or dead herbaceous foliage (fine-fuel). Fine-fuel and litter differed in that fine-fuel consisted of both living and dead material and litter contained only dead material. Fine-fuel weight and the fine-fuel water content were determined before each burn by clipping five 0.10-$m^{-2}$ quadrats from each plot, drying at 60 C for 48 hours and weighing. Surface litter was determined before burning, immediately after burning and each April for the duration of the study. During each fire, ambient temperature and relative humidity were measured with a sling psychrometer, and wind speed was measured with a hand-held wind meter.

Average Japanese brome tiller densities were estimated on 10, 7 and 12 April and 25, 13 and 18 July of 1985, 1986 and 1987, respectively. Tiller densities were collected from five placements of a 0.10-$m^2$ quadrat on a permanently marked diagonal across each plot. As a result, density determinations at different dates were made on the same spots. In some cases, when several seeds within an intact spikelet germinated, it was difficult to discern individual plants without destructive sampling. However, most tillers were obviously individual plants, and tiller density was used as an approximation of plant density.

Japanese brome seed production per $m^2$ was determined by counting fully developed seed per tiller in each of five 0.10-$m^2$ quadrats per plot. Preliminary sampling found few viable seed below three cm depth in the mineral soil. Therefore, seed banks were determined each July by collecting the surface litter and the top three cm of soil in three 0.10 $m^2$ quadrats from each plot. Seeds held in the erect inflorescence are unlikely to germinate during the first autumn (Baskin and Baskin 1981) and were not counted as part of the seed bank. Soil samples were stored in plastic bags with no chilling or stratification treatments applied. The soil samples were spread in plastic greenhouse trays to a depth of 1 cm within 45 days of collection. The trays were placed in a greenhouse, watered daily, and the soil stirred every ten days. Cumulative germination percentages of Japanese brome were determined over a 52-day period.

Litter accumulations were determined in April of each year by collecting, drying, and weighing the litter from ten 0.10-$m^2$ quadrats in each plot. Monthly precipitation totals recorded about 5 km from the study site were provided by the U.S. National Park Service. Litter (g $m^{-2}$) and monthly precipitation (mm) were used as independent variables in developing regression equations with April tiller density as the dependent variable. Japanese brome tiller density in July and spring-summer precipitation amounts were used as independent variables to predict Japanese brome seed production ($m^{-2}$).

Response surface analyses using linear, quadratic, and interaction terms for surface litter accumulations and October plus November precipitation were fit to April density using means for each plot-year combination (n=45). The population dynamics model is represented by rectangular "stocks", round "converters", and tubes which represent the flow of materials to or from stocks (Fig. 1). Arrows indicate the direction of flow and "valves" (inline converters) control the flow rates. Each iteration represents one year, and calculations are made with the 4th-order Runge-Kutta computation method.

## Results and Discussion

Japanese brome seed germinated in October and November, but little aboveground growth occurred until March. Burning occurred when Japanese brome seedlings were 3 to 5 cm in height. Fires on 20 April 1983 were conducted at 22 C and 40% relative humidity, with 211 g $m^{-2}$ (18% fuel water) and winds of 6 to 9 km $hr^{-1}$. Fires on 16 April 1984 were conducted at 14 C and 43% relative humidity, with 276 g $m^{-2}$ (23% fuel water) and winds of 5 to 13 km $hr^{-1}$. The amount of litter consumed by fire was similar in both years; $95 \pm 4\%$ in 1983 and $92 \pm 6\%$ in 1984. Total precipitation from October 1984 to July 1985 was only about 61% of the long-term mean. The 1983 and 1984 growing seasons were preceded by above-average October and November precipitation.

Density. Japanese brome density in April was a function of surface litter accumulations and autumn precipitation. The resulting linear regression equation was: $\underline{Y} = (\beta_1)16.3 + (\beta_1)1.70$ ($r^2 = 0.897$) where $\underline{Y}$ is density (seedlings $m^{-2}$ in April); $\beta_1$ is the total precipitation (mm) the previous October and November and $\beta_2$ is the amount of litter on the soil surface (g $m^{-2}$). A plot of predicted densities versus externally studentized residuals from the regression indicated no apparent patterns, and the Pearson product-moment correlation between predicted density and externally studentized residuals was 0.208. Nonlinear models resulted in lower correlation coefficients, and distinct patterns were evident in plots of predicted densities versus the externally studentized residuals. As a result, this interactive relationship between density, litter, and precipitation was considered linear.

Tiller densities in April and July were used as an estimate of recruitment and mature plant density, respectively. April seedling density in 1983 (prior to burning) ranged from 2299 to 2738 seedlings $m^{-2}$ (Table 1). By April 1984, density on plots burned in 1983 was similar to density on the unburned plots. Density in 1985 was reduced on plots burned in 1984 compared to unburned plots or those burned in 1983. The amount of litter on the soil surface became more important to seedling density in 1985 when precipitation was low (Table 1).

Mature tiller densities were reduced to 39 and 1% of April density by burning in 1983 and 1984, respectively (Table 1). Individual tiller size increased as density decreased, resulting in larger Japanese brome tillers on the burned areas (data not shown).

Environmental conditions affecting seedling density are precipitation from the previous October and November and the amount of litter on the soil surface. Litter becomes more important when precipitation is low and less important when precipitation is high. Seed production varies with the number of mature plants and the April through July precipitation (Apr Jul Precip.).

Japanese brome seed dormancy is lost during summer, allowing seeds to germinate if favorable temperature and soil moisture conditions occur in the autumn (Baskin and Baskin 1981). Autumn germination also allows vernalization and/or photoperiod requirements to be met (Baskin and Baskin 1981). Low winter temperatures prevent germination and induce dormancy in a large portion of Japanese brome seed. These dormancy and germination characteristics combine to insure that most Japanese brome seedlings emerge in autumn. Thus, recruitment is relatively insensitive to the amount of winter precipitation. The response of Japanese brome in this study confirmed this pattern of autumn germination. Precipitation in October and November was most important, yet precipitation in September and/or December had little impact on April densities. This indicates a temperature function may also have been involved.

Litter Accumulations. Following fire, litter accumulations in the northern, mixed prairie stabilize after six to seven years in the absence of domestic livestock (Dix 1960, Abouguendia and Whitman 1979). Fire-free periods of less than six years reduce total litter accumulations, thus reducing Japanese brome densities, particularly when autumn precipitation is low. Litter accumulations might be expected to play a more important role in Japanese brome population dynamics in more xeric areas.

Seed production. Seed production was reduced for at least three growing seasons following spring burning (Table 1). Seed production during a dry year (1985) was greatest on the untreated plots and lowest on recently burned plots. In 1986, seed production was reduced on plots burned in 1984, but was no different on plots burned in 1983 and untreated plots (Table 1). Seed production was greater on plots with higher litter accumulations.

Japanese brome grown under low intraspecific densities produced more seeds per tiller than those growing under high densities. Regression equations were used to quantify this relationship between density, precipitation, and seed production per tiller. Monthly precipitation and July density were used as independent variables with seed production per tiller as the dependent variable. April through July precipitation and mature tiller density were found to be significant predictors of seed production per tiller. The resulting regression equation was: $\underline{Y} = \beta_1(-0.005) + \beta_2(0.148)$ ($r^2 = 0.874$), where $\underline{Y}$ is seed production per tiller; $\beta_1$ is July density ($m^{-2}$) and $\beta_2$ is April-July precipitation (mm).

Seed banks. The litter seed bank was reduced for the first growing season after burning, but usually recovered by the end of the second growing season (Table 1). In 1987, litter seed banks were still lower on previously burned plots compared to litter seed banks of untreated plots. The litter seed bank was usually lower than seed production for a particular year, because of the sampling dates and possibly seed predation. In July, the current seed crop was still in the inflorescence and was not represented in the litter seed bank. Many Japanese brome seed fail to germinate during the year in which they are produced because they are held in the erect inflorescence until winter (Baskin and Baskin 1981). Many of the seeds germinating each autumn are from the seed crop produced 1.5 years earlier. As a result, the seed bank measured in this study was a good approximation of seed available for germination that autumn.

The soil seed bank was not affected during the first two years after burning in 1983 (Whisenant and Bulsiewicz 1986). Reduced seed production in 1985 lowered seed in the surface 3 cm of soil, with the greatest reductions occurring on the more recently burned plots (Table 1).

Japanese Brome Population Model. The Japanese brome seed bank in the litter is simulated as seed production minus seeds lost to various causes (rodents, disease, and other aboveground losses). Litter accumulation reflects the amount of litter received from Japanese brome and 'other species'. Mature Japanese brome density is converted to litter weight through a function (Gm per IndivBrja) which reduces the weight of individual plants as density increases. 'Other Litter' adds litter from all other species. This component increases with decreasing Japanese brome and increasing April through July precipitation. The 'Spring Grazing' function reduces litter input based on a relative grazing assessment (0.1-1.0 scale), where 0 is no grazing and 1.0 is 100% grazing. Litter loss is through the 'Litter Decomp' function which increases with increasing accumulations (DecompFactor). Litter may also be consumed with a fire simulation component.

The model was developed using data collected between 1983 and 1986. Validation of the model was achieved by using the 1987 data from plots which had been burned at various intervals in the past. This provided a test with several different litter amounts. Additional validation of the grazing component was accomplished by collecting density data on nearby plots (out of the National Park Service boundaries) which had been grazed yearly for many years. The model accounted for at least 75% of the year-to-year variability in litter accumulations, density, and seed bank dynamics.

Simulated litter accumulations reached an equilibrium after six to eight years when median precipitation values were used. Burning every five years reduced peak litter accumulations from 372 to 300 g $m^{-2}$. Burning every three years reduced peak litter accumulations to 248 g $m^{-2}$, but that fire frequency is too great for practical application. Simulating spring grazing (50% intensity), reduced peak litter accumulations to 190 g $m^{-2}$. The combination of grazing and burning at five-year intervals reduced peak litter accumulations from 372 to 128 g $m^{-2}$. Figure 2 illustrates the effects of grazing and fire on litter accumulations.

Burning every five years reduced peak seedling densities from 3307 to 2780 $m^{-2}$ over a 40-year simulation. Simulating spring grazing (50% intensity) reduced peak seedling densities to 2036 $m^{-2}$. The combination of burning at five-year intervals, and grazing reduced peak seedling densities to 1655 $m^{-2}$. Figure 3 illustrates the effects of grazing and fire on seedling and mature plant densities. The current model does not limit germination based on seed banks. This works well for established populations, but restricts the application of the model. Later versions of this model should remove this restriction.

Simulated seed production peaked at about 35,000 $m^{-2}$, without fire or gazing. With a five-year burning interval seed production peaked at 29,200 $m^{-2}$. Simulating spring grazing (50% intensity) reduced peak seed production to 28,200 $m^{-2}$. The combination of burning at five year intervals and grazing reduced peak seed production to 20,500 $m^{-2}$. With lower plant densities, seed production per plant is higher, but decreases dramatically at higher densities.

Burning at five-year intervals reduced simulated peak litter seed bank densities from 19,000 to 15,875 $m^{-2}$ over a 40-year simulation. Simulating spring grazing (50% intensity) reduced peak litter seed bank densities to 14,200 $m^{-2}$. The combination of burning at five-year intervals and grazing reduced peak litter seed bank densities to 12,519 $m^{-2}$. Burning every five years reduced peak soil seed bank densities from 13,000 to 8500 $m^{-2}$ over a 40-year simulation. Simulating spring grazing (50% intensity) reduced peak soil seed bank densities to 13,200 $m^{-2}$. The combination of burning at five-year intervals and grazing reduced peak soil seed bank densities to 10,400 $m^{-2}$. Figure 4 illustrates the effects of grazing and fire on peak litter and soil seed bank densities.

Sensitivity analysis of the effects of October and November precipitation, Spring Grazing intensity, and April through July precipitation was used to indicate which of those factors had the greatest impact on Japanese brome populations. The sensitivity analysis was performed using the following formula:

$$\frac{(\Delta output/output)}{(\Delta parameter/parameter)}$$

This analysis indicated a 10% change in the parameters resulted in a sensitivity value of 1.2, 0.99, and 0.28 for grazing intensity, fall precipitation, and spring precipitation, respectively. This illustrates the strong influence of litter accumulations on Japanese brome populations. Grazing reduces the amount of litter on the soil, thus reducing Japanese brome populations.

This model simulates Japanese brome population dynamics reasonably well. Management applications of this model include evaluating the long-term effects of different prescribed burning frequencies or grazing intensities on Japanese brome populations.

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Table 1. Japanese brome population dynamics in Badlands National Park, South Dakota[1].

| | Unburned | | Burned April 1983 | | Burned April 1984 | |
|---|---|---|---|---|---|---|
| | (m$^{-2}$) | | | | | |
| Seedling density; April 1983 | 2738 | ± 214 | 2299 | ± 111 | 2516 | ± 235 |
| Mature plants; July 1983 | 2360 | ± 226 | 908 | ± 306 | 2118 | ± 171 |
| Seed production; 1983 | 73,160 | ±8050 | 1620 | ± 394 | 67,815 | ±2586 |
| Seedling density; April 1984 | 2287 | ± 125 | 2417 | ± 212 | 2381 | ± 136 |
| Mature plants; July 1984 | 2017 | ± 284 | 2028 | ± 194 | 23 | ± 5 |
| Seed production; 1984 | 94,212 | ±1629 | 46,644 | ±8246 | 368 | ± 83 |
| Litter seed bank; July 1984 | 12,460 | ±2589 | 11,775 | ±2227 | 700 | ± 97 |
| Surface soil seed bank; July 1984 | 11,852 | ±1904 | 10,760 | ± 758 | 11,512 | ±1496 |
| Seedling density; April 1985 | 578 | ± 183 | 554 | ± 58 | 72 | ± 8 |
| Mature plants; July 1985 | 306 | ± 31 | 213 | ± 46 | 14 | ± 4 |
| Seed production; 1985 | 1410 | ± 247 | 785 | ± 81 | 375 | ± 75 |
| Litter seed bank; July 1985 | 187 | ± 17 | 112 | ± 46 | 18 | ± 3 |
| Surface soil seed bank; July 1985 | 7859 | ± 753 | 6923 | ± 392 | 5754 | ± 460 |
| Seedling density; April 1986 | 990 | ± 128 | 523 | ± 48 | 65 | ± 6 |
| Mature plants; July 1986 | 466 | ± 113 | 347 | ± 134 | 112 | ± 15 |
| Seed production; 1986 | 31,584 | ±6930 | 29,911 | ±5692 | 12,208 | ±1243 |
| Litter seed bank; July 1986 | 6712 | ± 798 | 263 | ± 41 | 89 | ± 36 |
| Surface soil seed bank; July 1986 | 4587 | ± 901 | 3712 | ± 389 | 2251 | ± 230 |
| Seedling density; April 1987 | 2114 | ± 255 | 1847 | ± 267 | 1710 | ± 257 |
| Mature plants; July 1987 | 1758 | ± 300 | 1640 | ± 153 | 1675 | ± 358 |
| Seed production; 1987 | 30,416 | ±3999 | 27,897 | ±1120 | 38,157 | ±5959 |
| Litter seed bank; July 1987 | 7914 | ± 451 | 869 | ± 203 | 475 | ± 146 |
| Surface soil seed bank; July 1987 | 6810 | ± 779 | 2861 | ± 136 | 2551 | ±1294 |

[1]Data from 1983 and 1984 are taken from Whisenant and Bulsiewicz (1985).

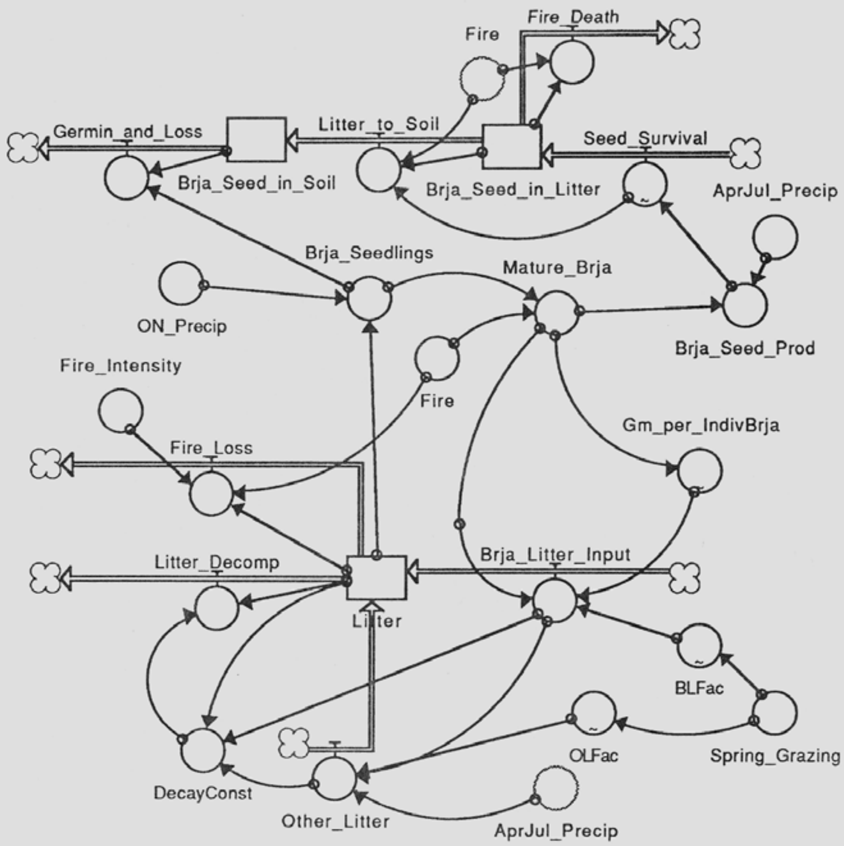


Fig. 1. Diagram of Japanese brome population model.

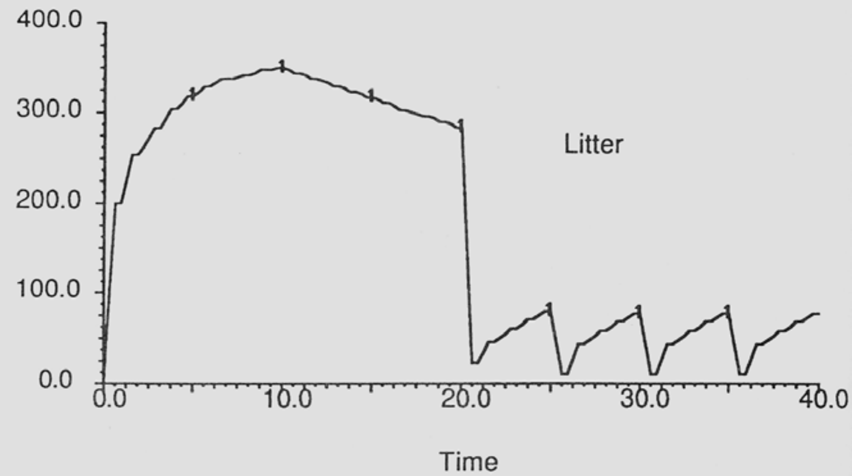


Fig. 2. Simulated litter accumulations. Years 1 – 10 were without fire or grazing; years 11 – 20 included grazing 50% of the production and; years 21 through 40 included both grazing and a 5 year burning frequency.

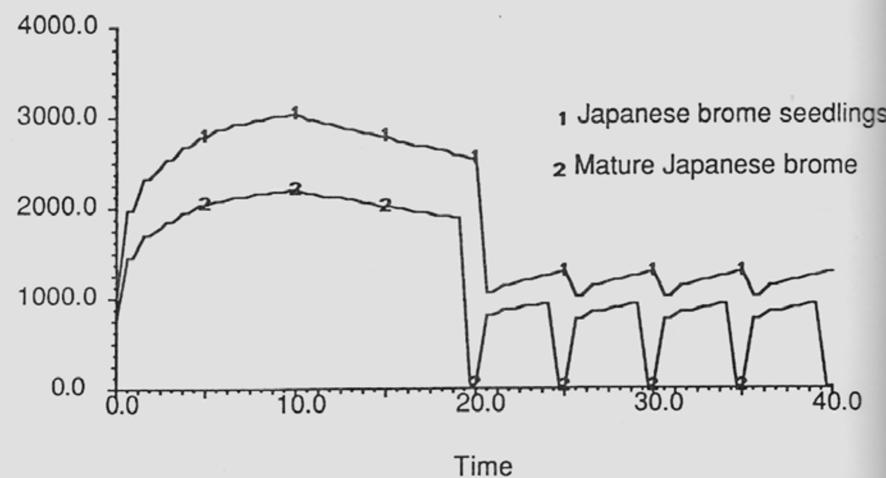


Fig. 3. Simulated densities of Japanese brome seedlings and mature plants. Years 1 – 10 were without fire or grazing; years 11 – 20 included grazing 50% of the production and; years 21 through 40 included both grazing and a 5 year burning frequency.

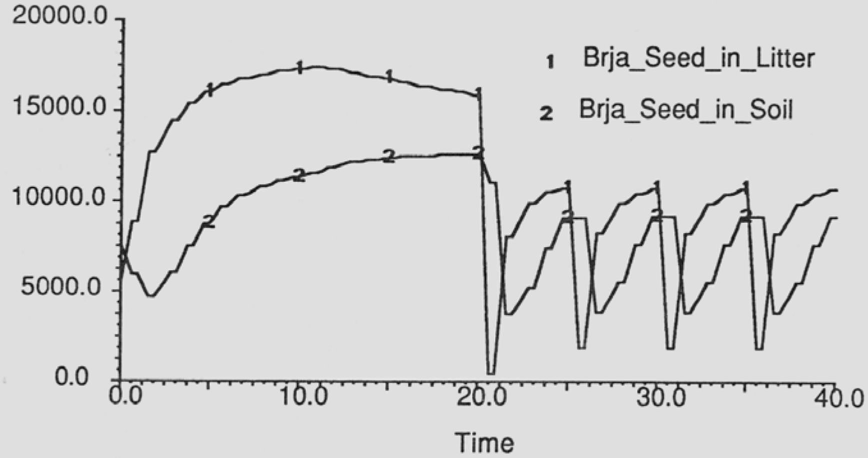


Fig. 4. Simulated Japanese brome seed-banks in the litter and surface soil. Years 1 – 10 were without fire or grazing; years 11 – 20 included grazing 50% of the production and; years 21 through 40 included both grazing and a 5 year burning frequency.

# FLAMING AND DINOSEB TREATMENT EFFECTS ON DODDER SEED SURVIVAL

S.B. Orloff, D.W. Cudney, and J.S. Reints[1]

Abstract. Flaming is commonly used to control attached dodder (*Cuscuta* spp.) in alfalfa. An abundance of dodder seed is often present, particularly in the latter part of the growing season. Experiments were conducted in the high desert of Southern California for three consecutive years to measure the effects of flaming and a contact herbicide on dodder seed survival. The treatments were a single "light" burn (to simulate a broadscale field treatment), a "double" burn (a light burn followed by another light burn two days later), a "heavy" burn (to simulate a concentrated spot treatment), a contact herbicide application (dinoseb), and a contact herbicide application followed by a light burn. A 0.2 $m^2$ sample was removed from each treatment. The sampling depth was one cm and included both soil and plant debris. The sample was then placed on top of flats containing a planting mix and kept moist in a greenhouse. Dodder emergence was then monitored for three weeks. All flaming treatments greatly reduced dodder emergence (98.9%, 99.7%, and 99.6% reduction in emergence for the single, double, and heavy burn treatments, respectively). Dinoseb (2-(1-methylpropyl)-4,6-dinitrophenol) and dinoseb followed by flaming also significantly reduced emergence (95.9 and 99.0%, respectively). A reduction in dodder emergence was also noted when dodder seed was oventreated to simulate field flaming. The results of these trials indicate that it would be advisable for alfalfa producers to flame dodder-infested areas at the end of the growing season, particularly if dodder seed was observed. This would reduce dodder emergence the following spring.

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# DODDER CONTROL IN NEWLY SEEDED ALFALFA

J.H. Dawson[1]

Abstract. Uncontrolled dodder (*Cuscuta* spp.) can kill alfalfa seedlings. Three methods of protecting newly seeded alfalfa from dodder have been developed.

a. Planting at a time when alfalfa can escape injury from dodder.
b. Application of a selective systemic herbicide to the alfalfa foliage after the dodder is attached and well established as a parasite.
c. Application to the soil of herbicides that kill dodder seedlings before they can attach themselves to the alfalfa.

In Washington, alfalfa is commonly seeded in early spring (March to May) or late summer (August and September). Research conducted in 1967 and 1968 (Weed Science 19:222-225. 1971) indicated that dodder severely injured and killed alfalfa seeded before 15 August in dodder-seeded soil. In contrast, alfalfa

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seeded 15 August or later escaped devastation by dodder. Abundant dodder became attached to alfalfa seeded 15 August or 2 September, but cool weather of the autumn suppressed the dodder before it injured the alfalfa measurably. Abundant dodder emerged with alfalfa seeded 15 September, but none became attached. Winter temperatures killed the alfalfa foliage and all attached dodder.

Low rates of glyphosate {*N*-(phosphonomethyl)glycine} and SC-0224 (trimethylsulfonium carboxymethylaminomethyl-phosphonate) (75 to 150 g ae/ha) applied to alfalfa foliage after dodder is parasitically attached, could control dodder selectively. The herbicides injure dodder by direct contact and by translocation from the alfalfa foliage to the parasite. In research conducted in 1983 to 1987, glyphosate at 75 and 150 g/ha was applied to spring-seeded alfalfa one, two, or three times on several different dates. Both rates of glyphosate suppressed dodder severely at each date of application. However, one treatment with glyphosate never protected alfalfa satisfactorily, regardless of rate or date of application. In contrast, alfalfa was protected when glyphosate was applied twice at 3-week intervals, when dodder shoots were 10 to 40 cm long, and before the dodder had suppressed the alfalfa noticeably.

Three dinitroanaline herbicides, pendimethalin {*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine} at 2.2 kg/ha, prodiamine {2,4-dinitro-$N^3$,$N^3$,-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine} at 2.2 kg/ha, and trifluralin {2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine} at 4.5 kg/ha, control dodder selectively in established alfalfa when applied to the soil before dodder seedlings emerge. Research was conducted in 1988 to determine the tolerance of newly seeded alfalfa to these treatments. Each herbicide (at the above rate) was applied at five growth stages in dodder-free alfalfa at each of three seeding dates, viz., 26 April, 9 June, and 19 August.

All three herbicides killed most of the alfalfa when applied pre-planting. Alfalfa was suppressed very little by prodiamine at 2.2 kg/ha applied when two or more trifoliolate leaves were well developed. Pendimethalin at 2.2 kg/ha injured alfalfa the most. Alfalfa was always severely suppressed and some plants died if pendimethalin was applied when the first trifoliolate leaf was not yet fully grown. When 2, 4, or 6 trifoliolate leaves were fully developed when pendimethalin was applied, the alfalfa was initially suppressed but recovered and later grew normally. Trifluralin at 4.5 kg/ha injured seedlings less severely than did pendimethalin at 2.2 kg/ha. Trifluralin did not kill any seedlings at the 1-trifoliolate stage and suppressed seedlings less at the 2-, 4-, and 6-trifoliolate stage than did pendimethalin.

Because alfalfa germinates at lower temperatures than dodder does, alfalfa could be seeded in early spring, emerge, and reach the 2-trifoliolate stage before dodder seedlings had become attached to it. Thus, prodiamine at 2.2 kg/hga could be used to control dodder in newly seeded alfalfa. It is probable that dodder would have become attached to alfalfa and be beyond control by dinitroanaline herbicides before trifluralin at 4.5 lb/A or pendimethalin at 2.2 lb/A could be applied without suppressing the alfalfa severely.

# SURVEY OF WEEDS IN CONSERVATION AND CONVENTIONALLY TILLED GRAIN FIELDS IN MONTANA

J.E. Nelson, B. Mullin, D. Wichman, and K. Schweitzer[1]

Abstract. A weed survey was conducted to determine weed spectrum and population changes that occur under conservation tillage. One hundred-eighty dryland cereal grain fields--90 adjacent conservation and conventional fields--were surveyed in eighteen counties during June and July of 1987 and 1988. Conservation farming practices were defined as any residue management program which provides for at least 30 percent of the soil surface to be covered by residue at all times. Survey methods were patterned after weed surveys conducted by Agricultural Canada and North Dakota State University. Weedy plants were counted in twenty 0.25 square meter quadrants in the selected field. Surface residue was measured at 10 of the 20 weed count locations by laying a yard stick at an angle across rows and determining the frequency with which residue intersects the one-inch increments. The number of residue intersection counts is divided by 36 to arrive at a percent of surface covered by residue. A field history form was completed by the farmer which compiled a four-year history of production information. Survey data was compiled and analyzed as described in the Agricultural Canada and North Dakota State University weed surveys. Sixty-nine winter wheat, 52 spring wheat and 59 barley fields were surveyed. Cropping systems ranged from alternate crop-fallow to continuous cropping for both classes. The average number of years conservation tillage was practiced during the four-year history survey period was 0.6 years for conventional and 2.8 years for conservation fields. Fourteen cropping systems were used in conventional fields with an average of 2.4 crops per four years and 16 systems were used in conservation fields with an average of 2.9 crops per four years. Soil surface residue cover averaged 14% and 43% and ranged from 0 to 29% and 30 to 74% in conventional and conservation fields, respectively. Weed pressures were low relative to similar Canada and North Dakota surveys. Thirty-five weed species were found in conventional fields and 37 were found in conservation fields, respectively. Twenty-eight weed species were common to both production systems. Three weed species ranked in the top-five and nine weed species in the top-ten weeds in both production systems by weed index, a composite value calculated from weed frequency, field uniformity and weed density measurements. Field bindweed (*Convolvulus arvensis* L.) ranked sixth and twelfth and Canada thistle [*Cirsium arvense* (L.) Scop.] ranked sixteenth and twenty-first in conventional and conservation fields, respectively. These results indicate that conservation farming practices have little effect on the kinds and numbers of annual weeds in cereal grains. The field history information collected for this survey indicates that Montana farmers practice flexible conservation farming in which tillage practices, crop rotation, and herbicide use may be altered annually to maximize agronomic and economic productivity. Annual farming practice changes or adjustments in herbicide selection may be sufficient to halt annual weed population changes. The predominate use of sweep tillage equipment which undercuts and redistributes root, crown, and stem parts across the field, may be responsible for the greater frequency of Canada thistle and field bindweed in conventional tillage fields.

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Table 1. Top Ten Weeds In Conventional and Conservation Tilled Fields Based On Weed Index Values.

| Rtg. | Conventional | Conservation |
|---|---|---|
| 1 | Russian thistle (SASKR) | kochia (KCHSC) |
| 2 | wild oat (AVEFA) | Russian thistle (SASKR) |
| 3 | wild buckwheat (POLCO) | downy brome (BROTE) |
| 4 | downy brome (BROTE) | wild oat (AVEFA) |
| 5 | field pennycress (THLAR) | green foxtail (SETVI) |
| 6 | field bindweed (CONAR) | volunteer grain |
| 7 | kochia (KCHSC) | wild buckwheat (POLCO) |
| 8 | tansymustard/flixweed (DESPI/DESSO) | field pennycress (THLAR) |
| 9 | redroot pigweed (AMARE) | tansymustard/flixweed (DESPI/DESSO) |
| 10 | green foxtail (SETVI) | redroot pigweed (AMARE) |

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## EFFECT OF FOLIAR NITROGEN ON BROADLEAF WEED CONTROL IN WHEAT

S.D. Wright, H.M. Kempen, W.J. Steele, and J.A. Voth[1]

Abstract. Several herbicides were evaluated at different rates for weed control in irrigated wheat. In addition these herbicides were evaluated in combination with urea-ammonium nitrate fertilizer to determine the effect on weed control and wheat injury.

In February of 1987, plots were established at two locations within California: Porterville and Shafter. In 1988 one plot was conducted near Bakersfield. Herbicides were applied to Yecora Rojo wheat during the tillering stage (6- to 8- inches tall). The urea-ammonium nitrate solution was applied at a rate of 8.0 gallons or 28 pounds per acre.

Weeds that were evaluated included shepherd's purse (*Capsella bursa-pastoris* L.), common chickweed (*Stellaria media* L.), london rocket (*Sisymbrium irio* L.), common groundsel (*Senecio vulgaris* L.), annual yellow sweetclover (*Melilotus indica* L.), annual sowthistle (*Senchus oleraceus* L.), and burning nettle (*Urtica urens* L.).

1987 Results. Chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide} at 0.75, 0.15, and .075 oz ai/a plus foliar fertilizer gave good control of all weeds present at that site. Chlorsulfuron caused a slight yellowing to the wheat except in the treatment with foliar nitrogen. Methyl {3-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl aminocarbonyl] aminosulfonyl]-2-thiophenecarboxylate} gave good control of all weeds at the 0.06, 0.125, 0.125 oz ai/a plus foliar nitrogen, and 0.25 oz ai/a at the Porterville site. At the Shafter site control was only fair at the 0.06 and 0.125 oz ai/a plus foliar nitrogen for annual sowthistle and sweetclover. Treatments without foliar nitrogen exhibited a slight yellowing.

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Methyl {3-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl aminocarbonyl]amino-sulfonyl]-2-thiophenecarboxylate} plus methyl {methylamino]carbonyl]amino] sulfonyl]benzoate} gave good control of all weeds at the 0.06, 0.125, and 0.25 oz ai/a. The 0.06 oz ai/a plus foliar nitrogen reduced weed control in all weed species. Treatments without foliar nitrogen exhibited a slight yellowing.

MCPA {(4-chloro-2-methylphenoxy)acetic acid} and 2,4-D amine {2,4-dichlorophenoxy)acetic acid} gave good control of shepherd's purse and london rocket at 0.25 and 0.50 lb ai/a. The 0.25 lb ai/a plus foliar nitrogen gave similar weed control at the 0.25 lb rate without the addition of nitrogen, however wheat injury was evident for about two weeks. Dicamba {3,6-dichloro-o-anisic acid} plus MCPA gave good control of shepherd's purse, london rocket, chickweed, and groundsel at 0.125 + 0.25, 0.25 + 0.50, and 0.125 + 0.25 lb ai/a plus foliar nitrogen. The treatment with foliar nitrogen showed considerably less shortening and flattening than in dicamba treatments without the foliar nitrogen.

Bromoxynil {3,5-dibromo-4-hydroxybenzonitrile} gave good control of shepherd's purse, london rocket, and groundsel at 0.25, 0.50, and 0.25 lb ai/a plus foliar nitrogen. Bromoxynil plus foliar nitrogen gave the greatest injury of any treatment, however injury was temporary.

<u>1988 Results</u>. Unfortunately in this field, wheat was water stressed and deficient in nitrogen. The addition of foliar nitrogen to herbicide treatments enhanced the control of shepherd's purse and burning nettle. Wheat growing where treatments containing the urea-ammonium nitrate fertilizer were applied, was taller and greener. Therefore these treatments probably had an advantage in terms of weed control because of greater herbicide uptake and crop competition. Crop injury was negligible for herbicide treatments.

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## THE LRB BIOASSAY SERVICE. A PROGRAM TO PREDICT ROTATIONAL CROP OPTIONS FOLLOWING USE OF CHLORSULFURON, METSULFURON, OR FINESSE HERBICIDE

D.C. Burkhart, C.J. Peter, H.J. Strek, N.D. McKinley, and J.L. Saladini[1]

<u>Abstract</u>. A pilot program was initiated in the fall of 1987 to commercially use the LRB Bioassay to predict crop rotational options following use of chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]benzenesulfonamide}, metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid} and (chlorsulfuron + metsulfuron) herbicide in North Dakota, Montana, Idaho, Washington, and Oregon. Local chemical dealers and distributors were selected and trained to sample grower fields, submit samples for analysis and report LRB Bioassay results to the grower. Between October 1987 and May 1988, crop rotation recommendations were made for 56 grower fields from LRB Bioassay results of over 500 samples. When sulfonylurea treated fields were recropped with species ranging from very sensitive to tolerant, no injury was observed when LRB Bioassay recommendations were followed.

[1]E.I. DuPont de Nemours & Co., Inc. Wilmington, DE

# EVALUATION OF FOUR SULFONYLUREA HERBICIDES FOR BROADLEAF WEED CONTROL IN WINRIDGE WINTER WHEAT

V.R. Stewart and Todd K. Keener[1]

Abstract. A post-emergence herbicide study was established in winter wheat to evaluate the efficacy of DPX-M6316 {methyl 3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylate}, DPX-L5300 {methyl 2-[[[[*N*-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoate}, DPX-R9674 (2:1 ratio of DPX-M6316 + DPX-L5300), metsulfuron{2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid}, and bromoxynil + MCPA {3,5-dibromo-4-hydroxybenzonitrile} + {(4-chloro-2-methylphenoxy)acetic acid}. The variety Winridge was seeded in the fall of 1987 at 70 lbs/a. Plots 10 x 20 feet were established in the stand of winter wheat the spring of 1988 and were replicated three times in a randomized complete block design. Herbicides were applied using a tractor mounted research-sprayer with 8002 nozzles at 32 psi applying 24.85 gpa. At the time of application there was a very high population of henbit (*Lamium amplexicauli*) and light to moderate populations of tansymustard *Descurainia pinnata*); cone catchfly (*Silene conoidea*); and field pennycress (*Thlaspi arvense*). Broadleaf weed control ratings were made May 10, 1988 and June 10, 1988. A 48 square-foot area was harvested with a Hege plot combine to determine yields.

No significant differences were found among treatments for yield, test weight, and height of the winter wheat. However, we did have a yield range of 56.79 bu/a to 70.65 bu/a. The untreated check had the lowest yield and was shorter than the herbicide treatments. The test weight for the untreated check was the highest in the study. The sulfonylurea compounds gave excellent control of tansymustard, henbit, cone catchfly and fanweed. The bromoxynil plus MCPA treatment was weak on henbit and gave only 88% control of the cone catchfly. These data would indicate a high level of crop safety for these compounds on winter wheat. The high population of henbit was not a tremendously competitive factor at this location. The data does show that we can effectively control henbit with the sulfonylurea herbicides (Tables 1 and 2).

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Table 1. Weed Control data from the evaluation of sulfonylurea herbicides in Winridge winter wheat conducted at Kalispell, MT. ( 1988).

Date planted: September 20, 1987 Date harvested: July 27, 1988

| Treatment | Form | Rate AI/A | Percent Broadleaf Control 1/ ------- 5/10/88 ------- DESPI | LAMAM | SILCD | THLAR | - 6/10/88 - DESPI | SILCO |
|---|---|---|---|---|---|---|---|---|
| DPX - M6316 + Surf | 75% | .125 oz | 100 | 87 | 100 | 100 | 98 | 98 |
| DPX - M6316 + Surf | 75% | .25 oz | 100 | 94 | 100 | 100 | 97 | 98 |
| DPX - M6316 + Surf | 75% | .375 oz | 100 | 96 | 100 | 100 | 100 | 100 |
| DPX-R9674 + Surf | 75% | .25 oz | 98 | 97 | 100 | 100 | 100 | 100 |
| DPX-R9674 + Surf | 75% | .375 oz | 98 | 100 | 100 | 100 | 100 | 100 |
| DPX-L5300 + Surf | 75% | .125 oz | 100 | 100 | 100 | 100 | 100 | 100 |
| DPX-L5300 + Surf | 75% | .25 oz | 100 | 100 | 100 | 100 | 100 | 100 |
| Metsulfuron + Surf | 60% | .06 oz | 100 | 100 | 100 | 100 | 100 | 100 |
| Bromox + MCPA | 4 lb | .375 lb | 100 | 58 | 88 | 100 | 93 | 98 |
| Check | ---- | ---- | 0 | 0 | 0 | 0 | 0 | 0 |
| | | $\bar{X}$ | 89.6 | 83.3 | 88.8 | 90.0 | 88.8 | 89.5 |
| | | L.S.D. | 2.11 | 10.3 | 6.83 | .000 | 7.20 | 2.85 |
| | | C.V. | .793 | 4.26 | 2.59 | .000 | 2.73 | 1.07 |
| | | P-VALUE | .000 | .000 | .000 | .000 | .000 | .000 |

Plots 10' X 20', 3 reps, 24.85 gpa , 32 PSI
Surfactant .25% v/v, 90% active, non-ionic
1/ DESPI = Tansey mustard (Descurainia pinnata)
LAMAM = Henbit (Lamium amplexicauli)
SILCD = Cone catchfly ( Silene conoidea )
THLAR = Field pennycress (Thlaspi arvense)

Crop and weed stages at applications:

Wheat: 2-3 leaf, tillering
Field pennycress: 6-10 leaves, 1-2" dia.
Henbit: 10-15 leaves, 1-2" dia.
Cone catchfly: 6-8 leaves 1 1/2" dia.
Tansey mustard: 8-12 leaves

Table 2. Agronomic data from the evaluation of sulfonylurea herbicides in Winridge winter wheat conducted at Kalispell, MT.

Planted: September 20, 1987 Harvested: July 27, 1988

| Treatment | Form | Rate AI/A | Height (") | Yield Bu/A | Test Wt lb/Bu |
|---|---|---|---|---|---|
| DPX - M6316 + Surf | 75% | .125 oz | 45.16 | 65.77 | 61.37 |
| DPX - M6316 + Surf | 75% | .25 oz | 44.88 | 60.46 | 60.37 |
| DPX - M6316 + Surf | 75% | .375 oz | 44.61 | 64.25 | 61.30 |
| DPX-R9674 + Surf | 75% | .25 oz | 46.47 | 70.65 | 61.63 |
| DPX-R9674 + Surf | 75% | .375 oz | 45.39 | 67.55 | 61.43 |
| DPX-L5300 + Surf | 75% | .125 oz | 45.55 | 67.88 | 61.40 |
| DPX-L5300 + Surf | 75% | .25 oz | 43.43 | 65.27 | 60.70 |
| Metsulfuron + Surf | 60% | .06 oz | 44.61 | 68.18 | 61.50 |
| Bromoxonyl + MCPA | 4 lb | .375 lb | 46.18 | 57.19 | 61.00 |
| Check | ---- | ---- | 41.73 | 56.79 | 62.60 |
| | | $\bar{X}$ | 44.80 | 64.42 | 61.33 |
| | | L.S.D. | 2.645 | 11.85 | 1.358 |
| | | C.V. | 1.987 | 6.195 | .7455 |
| | | P-VALUE | .0516 | .2474 | .1590 |

Plots 10' X 20', 3 reps, 24.85 gpa, 32 PSI
Surfactant .25% v/v, 90% active, non-ionic
Crop: Winter wheat
Previous crop: Fallow
Type of planter: Press drill
Seeding depth: 1 1/2 inches Seeding rate: 70 lbs/A

Application data:

Date: 3/22/87 Air temp: 48 F Soil temp: 45 F Rel. Hum. 29%
Wind: 0 Cloud cover: partly cloudy
Soil: Topsoil - good moisture subsoil - good moisture

# DPX-R9674--A NEW SHORT RESIDUAL HERBICIDE

Gilbert Cook, Bill Kral, Steve Hull, and Ron Yoder[1]

DPX-R9674 (DPX-L5300 {methyl 2-[[[[N-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]benzoate} acid}) + DPX M6316 is a new cereal broadleaf weed killer from DuPont for use in irrigated and annual cropping areas. Like DPX-M6316 {methyl 3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]-amino]sulfonyl]-2-thiopehencarboxylic acid} is a short residual cereal herbicide with excellent crop safety that has been tested extensively in the Pacific Northwest for over five years. DPX-R9674 controls a broader spectrum of weeds than DPX-M6316 and is an excellent tankmix partner with all of the currently registered broadleaf cereal herbicides. Tankmixes broaden the weed spectrum. In addition, such tankmixes are a way of combating and delaying the developing of a resistant weed population. DPX-R9674 is another new tool for use in wheat and barley for controlling tough weed broadleaf weeds in the Pacific Northwest.

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[1]E.I. DuPont de Nemours & Co., Spokane, WA

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# LATE POST APPLICATION TIMING OF BENSULFURON METHYL IN CALIFORNIA'S WATER-SEEDED RICE

J.L. Pacheco and D.S. Jarrett[1]

Abstract. Bensulfuron methyl (formerly DPX-F5384) {methyl 2-[[[[[(4,6-dimethoxyprimidin-2-yl)amino]carbonyl]-amino]sulfonyl]methyl]benzoate} is a new sulfonylurea herbicide from DuPont that provides outstanding broadleaf and sedge weed control in water-seeded rice (*Oryza sativa* L.). Bensulfuron methyl 60DF (60% dry flowable spray formulation) is expected to receive a full federal registration for use in the United States, including California in time for the 1989 use season. This compound when applied at 1.0 oz ai/ac (70 g ai/ha) to standing paddy water that is held for a minimum of five days, when weeds are at a preemergence to early postemergence stage, and when rice is in the 1-3 leaf stage has performed effectively on essentially all important annual broadleaf weeds and sedges infesting California rice paddies. These weeds include California arrowhead (*Sagittaria montevidensis* Cham. & Schlecht.), ducksalad (*Heteranthera limosa* (Sw.) Willd.), disc waterhyssop/roundleaf waterhyssop (*Bacopa rotundifolia* (Michx.)Wettst.), eisen waterhyssop (*Bacopa eisenii* (Kell.)Penn.), purple ammannia (*Ammannia coccinea* Rottb.), redstem (*Ammannia auriculata* Willd.), narrowleaf waterplantain/seedling (*Alisma gramineum* J.C. Gmel.), southern naiad (*Najas quadalupensis* (Spreng.)Magnus), blunt spikerush (*Eleocharis obtusa* (Willd.)Schultes), roughseed bulrush (*Scirpus mucronatus* L.) and smallflower umbrellaplant (*Cyperus difformis* L.).

We know that the optimum time to apply bensulfuron methyl is when weeds are submersed in paddy water and are either preemergent or very small in the early postemergent stage of growth. There may be times, however, when it is best

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[1]E.I. DuPont de Nemours & Co., Inc. Wilmington, DE

that growers not apply a herbicide where seedling rice is stressed or under poor growing conditions due to adverse weather, pest or disease damage, nutrient deficiencies, inferior rooting or stand establishment, or where a previously usedgrass herbicide has caused rice injury. In addition, there may be situations where growers or applicators may not be able to treat fields at the proper time due to extended periods of wind and concern of off-target drift. For reasons such as these, we felt it was important to better define the application window and benefits bensulfuron methyl might be able to offer rice growers if used as a late post application treatment.

In 1988, two experiments were conducted to determine whether bensulfuron methyl could be applied safely and effectively as a late postemergence application to weeds and rice 26 to 46 days after seeding. At each location, one or both of the currently used herbicides MCPA {(4-chloro-2-methylphenoxy)-acetic} acid and/or bentazon {3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide} were used as comparison standards at 1.0 lb ai/ac (1,121 g ai/ha). Bentazon treatments included crop oil concentrate. Bensulfuron methyl 60DF was used at rates of 0.5 - 2.0 oz ai/ac (35-140 g ai/ha) in conjunction with a crop oil concentrate at 1.0 qt pr/ac (2.3 l/ha). Spray volume was 20 gallons per acre (187.0 l/ha). In these particular tests, paddy water was removed from individual plots prior to herbicide applications in order to achieve maximum exposure of the target weeds. Water was reintroduced 24-48 hours after application, much the same way currently used late post herbicides are used today in California rice production.

At all rates tested, and at all late post application timings (26 to 46 days after seeding), bensulfuron methyl clearly provided more effective control of both economically important sedge weeds, roughseed bulrush and smallflower umbrellaplant than MCPA. At the 1.0 oz ai/ac rate, bensulfuron methyl significantly outperformed bentazon on smallflower umbrellaplant at all timings, and provided as good or better roughseed bulrush control. At rates of 1.0 oz ai/ac and above, bensulfuron methyl provided greater than 96% control of California's most important economic broadleaf weed, purple ammannia. No significant rice injury or yield reduction was observed or found from any of the bensulfuron methyl application rates and/or timings (Tables 1-7).

It should be noted that while late post applications of bensulfuron methyl 60DF would provide flexibility and/or options for rice producers in California to obtain effective sedge weed control 25 to 45 days after seeding, it does not have the broadspectrum weed control (broadleaf weeds and sedge) benefits and water management advantages, of the early optimumly timed and recommended 1-3 leaf stage rice applications.

Table 1. Broadleaf and sedge weed control with Bensulfuron methyl applied early postemergence (8 DAS/2 LSR) or (18 DAS/1 TILLER RICE) and sequentially to Molinate (8 DAS/2 LSR) in water-seeded rice CV. S-101, at Pleasant Grove, Sutter County, California in 1988.

| Treatment | Rate* ozai/ac | Timing DAS** | Percent weed control*** CYPDI | AMMCO | HETLI | ALSGR |
|---|---|---|---|---|---|---|
| Bensulfuron methyl | 0.5 | 8 | 99.5 | 91.3 | 93.8 | 92.0 |
| Bensulfuron methyl | 1.0 | 8 | 100.0 | 99.3 | 98.8 | 99.8 |
| Bensulfuron methyl | 2.0 | 8 | 100.0 | 99.5 | 98.8 | 99.5 |
| Bensulfuron methyl | 0.5 | 18 | 83.8 | 27.5 | 30.0 | 67.5 |
| Bensulfuron methyl | 1.0 | 18 | 98.3 | 45.0 | 48.8 | 93.8 |
| Bensulfuron methyl | 2.0 | 18 | 100.0 | 72.5 | 40.0 | 90.0 |
| Untreated | ---- | ---- | 0.0 | 0.0 | 0.0 | 0.0 |

* all treatments applied to 3-4" deep maintained paddy water
** Days After Seeding
*** weed control ratings taken at 70 DAS (Days After Seeding)

CYPDI = Cyperus difformis (Smallflower umbrellaplant)
AMMCO = Ammannia coccinea (Purple ammannia)
HETLI = Heteranthera limosa (Ducksalad)
ALSGR = Alisma gramineum (Narrowleaf waterplantain)

Table 2. Broadleaf and sedge weed control with Bensulfuron methyl applied late postemergence (26 DAS) and and sequentially to Molinate (8 DAS/2 LSR) in water-seeded rice CV. S-101, at Pleasant Grove, Sutter County, California in 1988.

| Treatment | Rate* ozai/ac | % Crop Injury | Percent weed control** CYPDI | AMMCO | HETLI | ALSGR |
|---|---|---|---|---|---|---|
| Bensulfuron methyl | 0.5 | 1.3 | 100.0 | 71.3 | 35.0 | 97.5 |
| Bensulfuron methyl | 1.0 | 1.3 | 100.0 | 96.0 | 55.0 | 99.8 |
| Bensulfuron methyl | 2.0 | 0.0 | 100.0 | 98.8 | 78.8 | 98.8 |
| Bentazon | 16.0 | 0.0 | 56.3 | 36.3 | 81.3 | 100.0 |
| Untreated | ---- | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* all treatments included crop oil concentrate (1 qt/ac)
** weed control ratings taken 40 DAT (Days After Treatment)

CYPDI = Cyperus difformis (Smallflower umbrellaplant)
AMMCO = Ammannia coccinea (Purple ammannia)
HETLI = Heteranthera limosa (Ducksalad)
ALSGR = Alisma gramineum (Narrowleaf waterplantain)

Table 3. Broadleaf and sedge weed control with Bensulfuron methyl applied late postemergence (35 DAS) and and sequentially to Molinate (8 DAS/2 LSR) in water-seeded rice CV. S-101, at Pleasant Grove, Sutter County, California in 1988.

| Treatment | Rate* ozai/ac | % Crop Injury | Percent weed control** CYPDI | AMMCO | HETLI | ALSGR |
|---|---|---|---|---|---|---|
| Bensulfuron methyl | 0.5 | 1.3 | 92.5 | 98.8 | 63.8 | 80.0 |
| Bensulfuron methyl | 1.0 | 1.3 | 100.0 | 100.0 | 75.0 | 86.3 |
| Bensulfuron methyl | 2.0 | 1.3 | 97.5 | 98.8 | 92.5 | 91.3 |
| Bentazon | 16.0 | 0.0 | 70.0 | 87.5 | 80.0 | 99.5 |
| Untreated | ---- | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* all treatments included crop oil concentrate (1 qt/ac)
** weed control ratings taken 30 DAT (Days After Treatment)

CYPDI = Cyperus difformis (Smallflower umbrellaplant)
AMMCO = Ammannia coccinea (Purple ammannia)
HETLI = Heteranthera limosa (Ducksalad)
ALSGR = Alisma gramineum (Narrowleaf waterplantain)

Table 4. Broadleaf and sedge weed control with Bensulfuron methyl applied early or late postemergence to weeds and sequentially to Molinate (11 DAS) in water-seeded rice CV. M-201, at Maxwell, Colusa County, CA. in 1988.

| Treatment | Rate* ozai/ac | Timing DAS** | Percent weed control*** SCPMU | CYPDI | AMMCO | HETLI |
|---|---|---|---|---|---|---|
| Bensulfuron methyl | 1.0 | 8 | 100.0 | 100.0 | 100.0 | 100.0 |
| Bensulfuron methyl | 0.5 | 26 | 99.5 | 100.0 | 98.8 | 76.3 |
| Bensulfuron methyl | 1.0 | 26 | 100.0 | 100.0 | 100.0 | 95.0 |
| Bensulfuron methyl | 2.0 | 26 | 100.0 | 100.0 | 100.0 | 96.8 |
| Bensulfuron methyl | 0.5 | 35 | 97.5 | 100.0 | 100.0 | 88.8 |
| Bensulfuron methyl | 1.0 | 35 | 98.8 | 100.0 | 100.0 | 96.3 |
| Bensulfuron methyl | 2.0 | 35 | 100.0 | 100.0 | 100.0 | 98.8 |
| Bensulfuron methyl | 0.5 | 46 | 88.8 | 90.0 | 95.0 | 85.0 |
| Bensulfuron methyl | 1.0 | 46 | 91.3 | 92.5 | 95.0 | 91.3 |
| Bensulfuron methyl | 2.0 | 46 | 93.8 | 93.8 | 93.8 | 88.8 |
| Untreated | ---- | ---- | 0.0 | 0.0 | 0.0 | 0.0 |

* all treatments included crop oil concentrate (1 qt/ac) except the early timing (8 DAS) of bensulfuron methyl.
** Days After Seeding
*** weed control ratings taken at 76 DAS (Days After Seeding)

SCPMU = Scirpus mucronatus (Roughseed bulrush)
CYPDI = Cyperus difformis (Smallflower umbrellaplant)
AMMCO = Ammannia coccinea (Purple ammannia)
HETLI = Heteranthera limosa (Ducksalad)

Table 5. Broadleaf and sedge weed control with herbicides applied late postemergence to weeds (26 DAS) and sequentially to Molinate (11 DAS/2 LSR) in water-seeded rice CV. M-201, at Maxwell, Colusa County, CA. in 1988.

| Treatment | Rate* ozai/ac | % Crop Injury | Percent weed control** SCPMU | CYPDI | AMMCO | HETLI |
|---|---|---|---|---|---|---|
| Bensulfuron methyl | 0.5 | 0.0 | 99.5 | 100.0 | 98.8 | 76.3 |
| Bensulfuron methyl | 1.0 | 0.0 | 100.0 | 100.0 | 100.0 | 95.0 |
| Bensulfuron methyl | 2.0 | 2.5 | 100.0 | 100.0 | 100.0 | 96.8 |
| Bentazon | 16.0 | 0.0 | 77.0 | 90.0 | 93.5 | 92.5 |
| MCPA | 16.0 | 0.0 | 7.5 | 15.0 | 97.5 | 61.3 |
| Untreated | ---- | ---- | 0.0 | 0.0 | 0.0 | 0.0 |

* all treatments included crop oil concentrate except MCPA
** weed control ratings taken at 50 DAT (Days After Treatment)

SCPMU = Scirpus mucronatus (Roughseed bulrush)
CYPDI = Cyperus difformis (Smallflower umbrellaplant)
AMMCO = Ammannia coccinea (Purple ammannia)
HETLI = Heteranthera limosa (Ducksalad)

Table 6. Broadleaf and sedge weed control with herbicides applied late postemergence to weeds (35 DAS) and sequentially to Molinate (11 DAS/2 LSR) in water-seeded rice CV. M-201, at Maxwell, Colusa County, CA. in 1988.

| Treatment | Rate* ozai/ac | % Crop Injury | Percent weed control** SCPMU | CYPDI | AMMCO | HETLI |
|---|---|---|---|---|---|---|
| Bensulfuron methyl | 0.5 | 0.0 | 97.5 | 100.0 | 100.0 | 88.8 |
| Bensulfuron methyl | 1.0 | 0.0 | 98.8 | 100.0 | 100.0 | 96.3 |
| Bensulfuron methyl | 2.0 | 0.0 | 100.0 | 100.0 | 100.0 | 98.8 |
| Bentazon | 16.0 | 0.0 | 99.5 | 95.5 | 100.0 | 100.0 |
| MCPA | 16.0 | 0.0 | 30.0 | 47.5 | 100.0 | 100.0 |
| Untreated | ---- | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* all treatments included crop oil concentrate except MCPA
** weed control ratings taken at 40 DAT (Days After Treatment)

SCPMU = Scirpus mucronatus (Roughseed bulrush)
CYPDI = Cyperus difformis (Smallflower umbrellaplant)
AMMCO = Ammannia coccinea (Purple ammannia)
HETLI = Heteranthera limosa (Ducksalad)

Table 7. Broadleaf and sedge weed control with herbicides applied late postemergence to weeds (46 DAS) and sequentially to Molinate (11 DAS/2 LSR) in water-seeded rice CV. M-201, at Maxwell, Colusa County, CA. in 1988.

| Treatment | Rate* ozai/ac | % Crop Injury | Percent weed control** SCPMU | CYPDI | AMMCO | HETLI |
|---|---|---|---|---|---|---|
| Bensulfuron methyl | 0.5 | 0.0 | 88.8 | 90.0 | 95.0 | 85.0 |
| Bensulfuron methyl | 1.0 | 0.0 | 91.3 | 92.5 | 95.0 | 91.3 |
| Bensulfuron methyl | 2.0 | 0.0 | 93.8 | 93.8 | 93.8 | 88.8 |
| Bentazon | 16.0 | 0.0 | 91.0 | 83.8 | 100.0 | 100.0 |
| MCPA | 16.0 | 10.0 | 32.5 | 37.5 | 100.0 | 100.0 |
| Untreated | ---- | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* all treatments included crop oil concentrate except MCPA
** weed control ratings taken at 30 DAT (Days After Treatment)

SCPMU = Scirpus mucronatus (Roughseed bulrush)
CYPDI = Cyperus difformis (Smallflower umbrellaplant)
AMMCO = Ammannia coccinea (Purple ammannia)
HETLI = Heteranthera limosa (Ducksalad)

# COTTON RESPONSE TO EPTC AND BUTYLATE AS INFLUENCED BY METHOD OF APPLICATION AND DEPTH OF SOIL INCORPORATION

J.P. Chernicky, E.S. Heathman, and K.C. Hamilton[1]

Abstract. Cotton (*Gossypium hirsutum*) tolerance to EPTC {S-ethyl dipropylcarbamothioate} and butylate {*S*-ethyl bis (2-methylpropyl)carbamothioate} was shown in a two-year field study to be influenced by application method and depth of field study to be influenced by application method and depth of soil incorporation. Cotton emergence was not significantly reduced when butylate (2.2 and 3.4 kg/ha) and EPTC (1.1 kg/ha) were applied preplant to flat ground and soil incorporated by a rototiller at two depth (5 cm or 10- to 15-cm depth). However, after the first postemergence, irrigation cotton stands were significantly reduced when either herbicide was applied preplant and incorporated deep when compared against a tankmix of trifluralin {2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)-benzenamine} 0.84 kg/ha and prometryn {*N,N'*-bis(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine} 1.8 kg/ha). Cotton was more tolerant of EPTC and butylate when they were applied preplant and incorporated shallow (5 cm) or when either herbicide was broadcast over mulched beds just after a preplant irrigation. Early season stand reductions resulting from preplant application of either EPTC or butylate incorporated deep resulted in a significantly lower yield of seed cotton.

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# GROWTH AND INTERACTION OF JOHNSONGRASS WITH COTTON

P.E. Keeley and R.J. Thullen

Abstract. Several weed-free and weed-competition periods were established and maintained in cotton to evaluate their influence on cotton yield and reproduction of johnsongrass (*Sorghum halepense* L.). When johnsongrass was sprayed with fluazifop {(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid} in field plots 3, 6, 9, and 12 weeks after cotton emergence, only plots sprayed at 3 weeks yielded as much cotton as weed-free plots. Johnsongrass permitted to compete for 6, 9, 12, and 25 weeks reduced yields 20, 60, 80 and 90%, respectively. When johnsongrass was transplanted into weed-free plots of 3, 6, 9, and 12 weeks after cotton emergence, a weed-free period of 9 weeks was required to protect cotton yields. Cotton in plots weed-free for 3 and 6 weeks yielded 81 and 89% respectively, as much seed cotton as weed-free controls. Although johnsongrass produced only 20 to 40% as many seed and rhizomes in delayed-treatment plots as weedy-control plots, delaying control of johnsongrass for 9 to 12 weeks permitted johnsongrass to reproduce. Although seed and rhizome production were negligible in plots weed-free for 9 to 12 weeks, some seed and/or rhizome were produced in these plots. Cotton grades were reduced in plots weed-free for 3 to 6 weeks, and in plots where johnsongrass competed for 9 to 25 weeks.

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# EVALUATION OF HERBICIDES FOR WEED CONTROL IN FEIJOA ORCHARDS

Bill B. Fischer[1]

Abstract. Feijoa (*Feijoa sallowiana*), varieties Mammoth and Triumph, exhibited excellent tolerance to diuron, isoxaben, napropamide, norflurazon, oryzalin, oxyfluorfen, and prodiamine. Terbutryn, terbuthilazine, and simazine caused chlorosis and defoliation in greenhouse studies on rooted cuttings, and simazine caused chlorotic symptoms in a field trial. The combination of oryzalin, oxyfluorfen plus diuron or simazine provided the most effective and longest residual weed control. However, no combination gave seasonal control under the frequent irrigation with micro-sprinklers used in the orchard. Following each weed control evaluation, the surviving weeds were sprayed with glufosinate or glyphosate. This enabled the evaluation of the residual activities of the herbicides on a broad spectrum of winter and summer annual weeds. Additional index words: vegetation management, pineapple guava, weed control under low volume emitters.

## Introduction

There is increasing interest in the commercial production of feijoa. At present there are 480 ha planted in California by approximately 150 growers. In New Zealand there are 350 ha under cultivation. Feijoa, also referred to as pineapple guava, matures late in autumn over a prolonged period of time. The fruit does not ripen well in storage, and it is somewhat difficult to recognize mature fruit on the trees. Therefore, the fruit is often allowed to fall as it matures and is picked up daily by hand from the orchard floor. A device is being developed by Mr. McCrill in California (1) to catch the mature fruit in a net wheeled under the tree as the trunk is hit with a rubber bumper. Regardless of the method of harvest, it is desirable to have the area under the shrubs relatively free of vegetation to facilitate this type of harvesting.

No references could be found regarding the use of herbicides in feijoa orchards. In a greenhouse study, conducted by the author in New Zealand (2) in 1985-86, the tolerance of feijoa seedlings and rooted cuttings to several herbicides was demonstrated. In that study the triazine herbicides: terbutryn {N-(1,1,-dimethylethyl)-*N'*-ethyl-6-(methylthio)-1,3,5-triazine-2,4-diamine}, terbuthylazine, and especially simazine {6-chloro-*N,N'*-diethyl-1,3,5-triazine-2,4-diamine} were observed in exhibit the least selectivity. They caused chlorosis and some degree of defoliation. A summary of the greenhouse evaluations is presented in Table 1.

[1]University of California Cooperative Extension, Fresno, CA

TABLE 1: EFFECT OF SOME SOIL-APPLIED HERBICIDES ON YOUNG FEIJOA PLANTS

Herbicides applied: November 22

| Herbicide | kg ai/ha | PHYTOTOXICITY RATING* 12 Feb | 21 Mar | 31 Mar | VIGOR RATING % 20 Mar | 31 Mar |
|---|---|---|---|---|---|---|
| fluorochloridone | 2.2 | 0 | 0 | 0 | 100 | 100 |
| | 4.4 | 0 | 0 | 0 | 100 | 100 |
| | 8.9 | 0 | 0 | 0 | 100 | 100 |
| isoxaben | 2.2 | 0 | 0 | 0 | 100 | 100 |
| | 4.4 | 0 | 0 | 0 | 90 | 87 |
| | 8.9 | 0.2 | 1.2 | 0 | 87 | 85 |
| oxyfluorfen | 2.2 | 0 | 0 | 0 | 100 | 100 |
| | 4.4 | 0 | 0 | 0 | 100 | 100 |
| | 8.9 | 0.5 | 0 | 0 | 92 | 100 |
| terbutryn | 2.2 | 0.7 | 2.2 | 2.7 | 95 | 95 |
| | 4.4 | 1.0 | 3.5 | 4.0 | 87 | 77 |
| | 8.9 | 3.5 | 6.7 | 7.7 | 55 | 37 |
| terbuthylazine | 2.2 | 0.5 | 1.0 | 2.2 | 85 | 90 |
| | 4.4 | 3.5 | 5.5 | 4.7 | 72 | 60 |
| | 8.9 | 3.2 | 4.5 | 5.0 | 67 | 67 |
| simazine | 2.2 | 4.7 | 5.0 | 4.7 | 55 | 62 |
| | 4.4 | 5.2 | 7.0 | 7.5 | 40 | 47 |
| | 8.9 | 5.7 | 7.0 | 8.0 | 40 | 32 |
| diuron | 2.2 | 0 | 0 | 0 | 100 | 100 |
| | 4.4 | 0 | 1.2 | 1.2 | 95 | 100 |
| | 8.9 | 0.7 | 3.5 | 4.2 | 90 | 95 |
| oryzalin | 4.4 | 0 | 0 | 0 | 100 | 100 |
| | 8.9 | 0 | 0 | 0 | 100 | 100 |
| napropamide | 4.4 | 0 | 0 | 0 | 100 | 100 |
| | 8.9 | 0 | 0 | 0 | 100 | 100 |
| untreated | --- | 0 | 0 | 0 | 100 | 100 |

*Phytotoxicity rating based on a 0 to 10 scale; 0 = no effect, 10 = death

In February, 1985, a trial was also established in a commercial orchard in which numerous combinations of herbicides were applied. The herbicides for this study were selected from those that were evaluated in trials conducted in deciduous and citrus orchards.

## Materials and Methods

A trial was established in an orchard planted May, 1984, with young feijoa plants, varieties Mammoth and Triump, on Atwater loamy sand soil and organic matter content less than 1%. The plants were trained to single trunk and spaced 2.43 by 2.43 meters. At the same time, low volume micro-sprinklers were installed as a method of irrigation. One sprinkler was placed between every other tree. The herbicide evaluation trial was established February 2, 1985. Individual plots were 4.87 by 1.82 m, replicated three times.

The herbicides were applied with a $CO_2$ constant pressure sprayer in 460 cc of water per plot. The plots were retreated with the same herbicides December 4, 1985, February 16, 1987, and January 19, 1988. Weed control evaluations and observations for phytotoxicity were made several times each year after the establishment of the trial. Following each weed control evaluation, the weeds present in each plot, including the untreated, were sprayed with glyphosate or glufosinate. This enabled the evaluation of not only the efficacy of the herbicides on the numerous winter and summer annual weed species, but their residual activities as well.

The selection of herbicides for evaluation was based on the results obtained in numerous trials conducted by the author in deciduous and subtropical fruit orchards and in grape and kiwifruit vineyards under varied methods of irrigation. Because of the broad spectrum of annual weeds, monocots and dictos, found infesting orchards and vineyards in central California, only combinations of herbicides were evaluated in this study.

## Results and Discussion

The herbicides used and the rates of application are given in Tables II and III. These tables summarize the results; space limitations do not permit the presentation of all the evaluations. Therefore, only those made on selected dates during 1987 and 1988 are given.

TABLE II - EFFECT OF PREEMERGENCE APPLIED HERBICIDES ON WEED CONTROL IN ESTABLISHED FEIJOA

06, 44, 425, 135, 10, 85-1

LOCATION: Temperance, 1/4 mi. N of McKinley, West Side of road
SOIL TYPE: Atwater loamy sand
VARIETY: Mammouth Triumph
HERBICIDES APPLIED: 2/5, 12/4/85; 2/16/86

IRRIGATION: Microsprinkler
PLOT SIZE: 1.82 x 4.87 m
PLANTED: May, 1984
EVALUATED: 3/9, 6/8, 7/15, 10/8/87

| | | WEED CONTROL EVALUATIONS* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 3/9/87 | | 6/8/87 | | 7/15/87 | | 10/8/87 | |
| HERBICIDE | Kg ai/ha | % Weed Control | Weeds** Present | % Weed Control | Weeds** Present | % Weed Control | Weeds** Present | % Weed Control | Weeds** Present |
| A oryzalin<br>terbutryn | 4.4<br>2.2 | 88 | A,G,J,K,<br>M,P | 99 | N | 80 | D,E,W | 83 | B,E,L,M<br>U,W |
| B oryzalin<br>isoxaben | 2.2<br>0.28 | 78 | A,H,K,M,<br>P,X | 98 | W | 92 | D,E,U,W | 75 | B,D,E,L<br>U,W |
| C oryzalin<br>isoxaben | 4.4<br>0.55 | 73 | E,G,M,P,<br>R | 98 | W | 90 | D,E,U,W, | 88 | D,U,W |
| D prodiamine<br>terbutryn | 4.4<br>2.2 | 93 | A,K,M | 90 | D,U,W | 98 | D,W | 90 | D,L,M,U<br>W |
| E norflurazon<br>terbutryn | 2.2<br>2.2 | 83 | E,K,M | 75 | D,U,W | 47 | D,W | 47 | B,D,L,M<br>W |
| F oryzalin<br>simazine | 4.4<br>1.1 | 85 | G,K,T,X | 99 | W | 82 | D,E,W | 73 | D,L,M,W |
| G oryzalin<br>oxyfluorfen<br>simazine | 2.2<br>2.2<br>1.1 | 94 | M | 99 | W | 83 | U,W | 85 | D,W |
| H oxyfluorfen<br>napropamide<br>diuron | 2.2<br>2.2<br>1.1 | 93 | K,M | 96 | D,W | 77 | D,W | 73 | B,D,L,M<br>W |
| J oxyfluorfen<br>simazine | 2.2<br>1.1 | 81 | A,E,K,M,X | 20 | D,U,W | 44 | D,W | 25 | B,D,L,U<br>W |
| K napropamide<br>diuron<br>oxyfluorfen | 4.4<br>1.1<br>1.1 | 88 | A,K,M | 78 | A,D | 75 | D,E,L,W | 70 | B,L,W |
| L Untreated | — | 0 | A,E,K,M<br>P | 0 | D,E,S,U<br>W | 17 | D,E,W | 0 | B,D,E,L<br>M,U,W |

*NOTE: All treatments sprayed with 1% Roundup after each evaluation

**WEEDS PRESENT: A=POANN, B=ERADI, D=DIGSA, E=GNAPV, G=ARYGL, H=STEME, J=AMAAL, K=ERIDI, L=ERADI, M=HPPVU, P=SENVU, R=LUDPV, S=TRBTE, T=CLNCM, U=SONOL, W=EPHMA X=BROIN

**TABLE III - EFFECT OF PREEMERGENCE APPLIED HERBICIDES ON WEED CONTROL IN ESTABLISHED FEIJOA**

06, 44, 425, 135, 10, 85-1

LOCATION: Temperance, 1/4 mi. N of McKinley, West Side of road
SOIL TYPE: Atwater loamy sand
VARIETY: Mammouth Triumph
HERBICIDES APPLIED: 2/5, 12/4/85; 2/16/86; 1/19/88

IRRIGATION: Microsprinkler
PLOT SIZE: 1.82 x 4.87 m
PLANTED: May, 1984
EVALUATED: 5/9, 8/4, 9.23/88

| | | WEED CONTROL EVALUATIONS* | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5/9/88 | | 8/4/88 | | 9/23/88 | |
| HERBICIDE | Kg ai/ha | % Weed Control | Weeds** Present | % Weed Control | Weeds** Present | % Weed Control | Weeds** Present |
| A oryzalin<br>terbutryn | 4.4<br>2.2 | 99 | N | 95 | U,W | 67 | E,F,J,M,Q,U,V,W |
| B oryzalin<br>isoxaben | 2.2<br>0.28 | 97 | R,Y | 65 | A,E,F,L,U, | 57 | D,E,F,I,M,P,Q,U,W,W |
| C oryzalin<br>isoxaben | 4.4<br>0.55 | 99 | U | 95 | N,W | 63 | E,H,I,M,P,U,V,W |
| D prodiamine<br>terbutryn | 4.4<br>2.2 | 95 | D,E,K,U | 99 | U,W | 66 | E,M,N,P,Q,U,V,W |
| E norflurazon<br>terbutryn | 2.2<br>2.2 | 99 | U,K,M | 59 | A,E,U,W | 50 | A,D,E,F,M,N,P,R,U,V,W |
| F oryzalin<br>simazine | 4.4<br>1.1 | 99 | | 80 | D,E,U,V | 48 | E,F,K.L.M,U,V,W |
| G oryzalin<br>oxyfluorfen<br>simazine | 2.2<br>2.2<br>1.1 | 100 | | 68 | D,W | 57 | F,M,U,V,W |
| H oxyfluorfen<br>napropamide<br>diuron | 2.2<br>2.2<br>1.1 | 100 | | 66 | A,D,U,W | 60 | E,F,L,M,N,P,U,V,W |
| J oxyfluorfen<br>simazine | 2.2<br>1.1 | 79 | C,D,M | 43 | A,D,K,U,W | 30 | F,G,K,L,M,N,P,U,V,W |
| K napropamide<br>diuron<br>oxyfluorfen | 4.4<br>1.1<br>1.1 | 99 | C,D,M | 43 | A,D,K,U,W | 30 | F,G,K,L,M,P,U,V,W |
| L Untreated | — | 0 | D,E,I,J<br>K,M,R,U<br>Y | 0 | D,F,R,T<br>U,W | 0 | D,E,F,H,J,L,M,N,O,R,U,V,W |

*NOTE: All treatments sprayed with 1% Roundup after each evaluation

**WEEDS PRESENT: A=POANN, C=ECHCG D=DIGSA, E=GNAPV, F=ERGBR, G=ARYGL, H=STEME, K=ERIDI, I=EROCI, J=AMAAL, K=ERIDI, L=ERADI, M=HPPVU, N=SOLNI, O=URTDI, W=EPHMA P=SENVU, Q=LACSE, R=LUDPV, U=SONOL, V=CAPBP, W=EPHMA, Y=EPIPE

No combination of soil applied herbicides provided 100% seasonal weed control. Each year, as the season progressed, the effectiveness of control decreased in all treatments. The most commonly occurring weed in late season was spotted spurge (*Euphorbia maculata*). Failure to obtain seasonal weed control with any of the combinations of herbicides can be attributed to the frequency of irrigation. The orchard was irrigated three times a week, each time for 2-1/2 to 3 hours, delivering approximately 135 liters of water per day. This frequent irrigation undoubtedly favored rapid microbiological and chemical degradation (hydrolysis) of the herbicides.

In recently conducted studies, the influence of different methods of irrigation on the residual activity of herbicides was clearly demonstrated (3).

The application of soil persistent herbicides will not provide seasonal control of weeds in orchards irrigated frequently with low volume sprinklers. However, a mid-summer treatment with soil persistent herbicides or repeated applications of foliar applied contact or translocated herbicides can be used to keep the areas of the orchard's floor free of unwanted vegetation.

Slight symptoms of venial and intervenial chlorosis were observed only on four shrubs in the trial in late 1987 and in 1988. The symptoms were evident only on a few older leaves. They could not be attributed to any of the herbicide treatments and were assumed to be a nutritional problem.

## Conclusions

The safe and effective use of herbicides for the control of the unwanted vegetation in feijoa orchards was clearly demonstrated. Herbicides such as oxyfluorfen {2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene}, napropamide {*N*,*N*-diethyl-2-(1-naphthalenyloxy)propanamide}, oryzalin {4-(dipropylamino)-3,5-dinitrobenzenesulfonamide}, simazine, diuron {*N*'-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea}, and norflurazon {4-chloro-5-(methylamino)-2-(3-(trifluoromethyl)phenyl)-3)2*H*)-pyridazinone} labeled for use in orchards and vineyards, could be safely used in feijoa. The selection of herbicides has to be governed by the weed infestation and the irrigation method used.

In orchards frequently irrigated with low volume emitters, multiple applications of soil persistent herbicides will need to be applied, or sequential treatments with foliar applied herbicides will be required to maintain the area under the shrubs free of vegetation.

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# ORCHARD FLOOR VEGETATION MANAGEMENT: EFFECTS UPON CONSUMPTIVE WATER USE AND SOIL CHARACTERISTICS

T.L. Prichard, W.K. Asai, L.C. Hendricks, and E.E. Sieckert[1]

Abstract. The effects of orchard floor vegetation management on consumptive water use and soil characteristics were evaluated for a three-year period. Two almond orchards of differing maturities and soil types were observed. Four replicates of five treatments including residual herbicide, resident vegetation, Salina Strawberry clover, chemical mowing, and bromegrass were evaluated. Treatments were evaluated by soil-water disappearance over each irrigation cycle to a depth of 10 feet with neutron probe. Near the surface soil, samples were collected and moisture determined by a gravimetric technique. Soil compaction was indirectly measured using a totalizing cone penetrometer. Soil-water holding

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capacity was measured as well as water infiltration rate. Both orchards, although representing different soil types and maturities, experienced similar trends in water use by treatment. Significant differences in consumptive water use between treatments were found in both orchards. Residual herbicide, brome, or chemically mowed treatments consumed, on the average, 20.5 percent less water than clover or resident vegetation in the mature orchard. Treatment differential was magnified in the younger orchard, suggesting that the impact of treatment is greatest in young orchards. The differential declines with orchard maturity. A significant increase in surface soil compaction and a decrease in water infiltration rate were detected for the residual herbicide treatment in both orchards. No measurable differences were found to exist in soil-water holding capacity.

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## EFFECTS OF REPEAT ANNUAL APPLICATIONS OF PREEMERGENCE HERBICIDES ON SOUR CHERRY ORCHARD WEED CONTROL

J. LaMar Anderson[1]

### Introduction

Utah's fruit industry is located primarily along the foothills of the Wasatch Mountains upon what was formerly the shoreline of prehistoric Lake Bonneville. Soils are often non-uniform and gravelly or have gravel outcroppings. When orchards located on gravelly sites are treated with full label rates of residual, preemergence herbicides, trees often show foliar symptoms of herbicide injury.

The sour cherry (*Prunus cerasus*) industry in Utah is essentially a monoculture. Only one cultivar, 'Montmorency', is grown commercially. Nearly all mature trees in commercial orchards are harvested mechanically over a two- to three-week period. The fruit is pitted within 24 hours after harvest and frozen for use by the fruit processing industry. Tall weeds in the tree row interfere with mechanical harvesting so growers control vegetation within the tree row chemically. If random sour cherry trees in an orchard treated with simazine {6-chloro-*N,N'*-diethyl-1,3,5-triazine-2,4-diamine}, for example, show a marginal chlorosis, this symptom is coupled with a delay in fruit maturity and the tree difficult to harvest mechanically or even unharvestable within the period that the processing plants are operational.

This study was conducted to investigate the efficacy of less-than-label-limit rates of preemergence herbicides or herbicide combinations in a sour cherry orchard.

### Materials and Methods

Ten preemergence herbicides were applied, singly and in combination (Table 1), in an 8-year-old 'Montmorency' sour cherry orchard in South Willard, Utah in October, 1984. The soil was a Dagor loam (fine-loamy, mixed, Mesic cumulic haploxeralls) with a pH of 5.5 (not typical of Utah orchards). The orchard was furrow irrigated by the cooperator "as needed." Napropamide {N,N-diethyl-2-(1-

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[1]Utah State University, Logan, UT

naphthalenyloxy)propanamide}, oryzalin {4-(dipropylamino)-3,5-dinitrobenzenesulfonamide} and oxyfluorfen {2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene} were applied at their label rates; others were generally applied at 1/2 the maximum label rate (or suggested rate in the case of unlabeled chemicals) alone and further reduced when applied in combination. Plots treated in 1984 received the same treatments in October, 1985; October, 1986; and again in March, 1988. The orchard had been clean-cultivated for 6 years prior to the initiation of this study. Plots, 2x18 m containing 3 trees, were laid out along the tree rows and were replicated 4 times. Area between the tree rows continued to be kept vegetation-free by cultivation. Treatments were applied with a $CO_2$ backpack sprayer equipped with 8002 nozzles and calibrated to deliver 330 L/ha at 40 psi. An exception was dichlobenil {2,6-dichlorobenzonitrile} which was applied in granular form with a hand spreader.

## Results and Discussion

During the four years of this study, cherry foliage was observed annually for foliar symptoms of phytotoxicity and tree trunks were measured to determine annual trunk diameter increase. No foliar symptoms of phytotoxicity were observed and trunk diameter differences were generally nonsignificant. After three years of treatment, trees in untreated plots and in treated plots with heavy weed populations had smaller trunk diameter increases than trees in plots with good weed control. However, after the fourth year trunk diameter increases were nonsignificant. Furthermore, no treatment adversely affected the maturity or the mechanical harvestability of cherry fruit.

Tolerant weed populations tended to increase in treated plots (Table 2). Simazine alone did not control kochia (*Kochia scoparia*). As a result, the population density increased and after 4 years, simazine plots contained nearly a solid stand of kochia. Kochia also increased in the terbacil {5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1*H*,3*H*)-pyrimidinedione} and terbutryn {*N*-(1,1-dimethylethyl)-*N'*-ethyl-6-(methylthio)-1,3,5-triazine-2,4-diamine} plots. Russian thistle (*Salsola iberica*) was the predominant weed in norflurazon {4-chloro-5-(methylamino)-2-[3-(trifluoromethyl)phenyl]-3(2*H*)-pyridazinone} plots which also contained blue mustard (*Chorispora tenella*) and prickly lettuce (*Lactuca serriola*). Napropamide failed to control the mustards (*Capsella bursa-pastoris*, *Chorispora tenella*, *Descurainia pinnata* and *Sisymbrium altissium*) and gave incomplete control of dandelion (*Taraxacum officinale*) and kochia. Oxyfluorfen did not control grasses at less than the 2 lb/A rate, and annual grass populations, especially *Bromus tectorum*, tended to increase. Oxyfluorfen was effective when used in combination with herbicides that provided additional grass control.

Herbicide combinations generally provided better weed control than component herbicides applied alone (Table 1). Combinations containing oryzalin (at its full label rate) were especially effective in this study. Based on this and other studies it appears that herbicide combinations of oryzalin or oxyfluorfen with sub-label-limit rates of the more persistent herbicides can provide adequate control of annual weeds in the tree row of sour cherries without affecting fruit maturity or quality. Established perennial weeds would need supplemental treatment with a foliar active herbicide.

Northern Utah received less than normal precipitation during the winter of 1987-88 and the soil profile was quite dry at the beginning of the 1988 growing season. Trees in plots in which large weed populations competed for water showed signs of moisture stress. Leaves of trees in simazine plots with dense kochia populations were especially stressed.

Table 1. Tart Cherry Weed Control
Willard, Utah, 1988

| Treatment | Rate (lb/A) | Ave. Rating[1] |
|---|---|---|
| Diuron | 2 | 9.6 fg |
| Norflurazon | 2 | 6.6 cd |
| Simazine | 2 | 3.3 ab |
| Fluorochloridone | 2 | 9.4 efg |
| Oryzalin | 2 | 9.5 fg |
| Napropamide | 4 | 6.6 cd |
| Terbacil | 1 | 4.4 bc |
| Dichlobenil | 2 | 9.4 efg |
| Terbutryn | 2 | 5.4 bc |
| Oxyfluorfen | 2 | 8.3 defg |
| Oxyfluorfen + simazine | 1 + 1 | 7.6 def |
| Oryzalin + simazine | 2 + 1 | 10.0 g |
| Oxyfluorfen + napropamide | 1 + 4 | 9.3 efg |
| Simazine + napropamide | 1 + 4 | 8.3 defg |
| Oryzalin + diuron | 2 + 1 | 9.8 g |
| Oryzalin + norflurazon | 2 + 1 | 9.5 fg |
| Oryzalin + terbutryn | 2 + 1 | 9.6 fg |
| Napropamide + fluorochloridone | 4 + 1 | 10 g |
| Fluorochloridone + simazine | 1 + 1 | 9.8 g |
| Fluorochloridone + norflurazon | 1 + 1 | 9.5 fg |
| Fluorochloridone + oxyfluorfen | 1 + 1 | 9.8 g |
| Oryzalin + fluorochloridone | 2 + 1 | 9.8 g |
| Norflurazon + simazine | 1 + 1 | 9.4 efg |
| Oryzalin + terbacil | 2 + 1 | 9.9 g |
| Fluorochloridone + terbutryn | 1 + 1 | 8.5 defg |
| Dichlobenil + simazine | 1 + 1 | 8.9 efg |
| Dichlobenil + oryzalin | 1 + 2 | 9.9 g |
| Napropamide + diuron | 1 + 1 | 9.5 fg |
| Oryzalin + oxyfluorfen | 2 + 1 | 9.9 g |
| Untreated | ----- | 1.8 a |

[1]Rated 0-10; 10=100% weed control; ratings followed by a common letter are not significantly different (.05 level) according to Student-Newman-Keuls test.

Table 2. Changes in Tart Cherry Weed Control Ratings Following Repeat Applications of Preemergence Herbicides.

| Annual Treatment | Weed Control Rating[1] 5/86 | 10/86 | 9/87 | 9/88 | Problem Weeds |
|---|---|---|---|---|---|
| Dichlobenil 2 lb | 9.5 | 8.8 | 9.1 | 9.4 | some kochia |
| Diuron 2 lb | 9.8 | 9.5 | 8.9 | 9.6 | dandelion |
| Napropamide 4 lb | 8.7 | 6.2 | 6.3 | 6.6 | mustards |
| Norflurazon 2 lb | 9.5 | 9.0 | 7.0 | 6.6 | Russian thistle |
| Oryzalin 2 lb | 9.3 | 9.2 | 9.1 | 9.5 | mustards |
| Simazine 2 lb | 8.3 | 5.0 | 4.1 | 3.3 | kochia |
| Terbacil 1 lb | 8.6 | 4.2 | 4.3 | 4.4 | kochia |

[1]Rated 0-10; 10=100% weed control.

# WATER USE OF NON-IRRIGATED SAUVIGNON BLANC AND ZINFANDEL WINE GRAPES AS INFLUENCED BY TILL AND NO-TILL VINEYARD FLOOR VEGETATION MANAGEMENT SYSTEMS

D. S. Farnham[1], Edwin E. Sieckert[2], Terry L. Prichard[1], Robert E. Roberts[1], and James A. Wolpert[1]

Trials were established in non-irrigated Sauvignon blanc and Zinfandel vineyards near Plymouth, California to compare chemical mowing no-till management of resident winter weed vegetation using low rates of glyphosate {*N*-(phosphono-methyl)glycine} herbicide with conventional discing.

Soil moisture extraction was measured with a neutron probe. Growth, maturity, and development of Sauvignon blanc wine grapes were evaluated for three growing seasons (1986, 1987, and 1988). Sauvignon blanc wine grape yields from vines in the two weed management treatments did not significantly differ in the three growing seasons. No significant differences were found in daily or seasonal water use in either the Sauvignon blanc or Zinfandel vineyard in 1987. Daily water use of no-till Zinfandel was significantly higher in 1988 at days during the period May 23 through June 6 represented by Julian date 150. This occurred after a spring rain when vegetation on the surface outgrew the chemical mowing treatment and used the available water. After day 158 no significant differences were found. The differences between till and no-till early in the season resulted in a significant difference in total water use by season's end. The 1987 data demonstrates it is possible to manage no-till to equal the till treatment; however, management of no-till vegetation regrowth with either mowing or glyphosate is critical if rains occur in late spring.

## Procedures Used

Four-year-old Sauvignon blanc grapevines trained to bilateral cordons and grafted on St. George rootstock and seven-year-old ungrafted head trained Zinfandel vines were grown under normal Amador County vineyard vegetation management practices (disced twice in the spring) to eliminate winter weed growth until the trial was established. Supplemental water was applied by drip irrigation during vineyard establishment but not during the trial period.

Sauvignon Blanc: Four-row blocks of Sauvignon blanc vines were replicated three times for the two vegetation management practices evaluated. Each four-row block contained 100 Sauvignon blanc vines planted on 2.44 x 3.05 meters spacing. Vegetation management treatments evaluated at both vineyards were (1) conventional discing (twice) and (2) no-till chemical mowing with glyphosate 0.31 kg/ha in 112 l/ha. The herbicide was applied each year in the second to fourth week in January when winter weeds were approximately one-inch tall.

Zinfandel: Seven-year-old ungrafted head trained Zinfandel vines grown on 2.74 x 2.74 meters spacing were divided into four-row blocks each containing 380 vines for (1) conventional discing (twice) and (2) no-till chemical mowing with glyphosate 0.31 kg/ha in 112 l/ha. Each treatment block was replicated three times in the vineyard.

The herbicide was applied each year in the second to fourth week in January when winter weeds were approximately one-inch tall.

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[2]Monsanto Agricultural Company, Roseville, CA

No-Till Chemical Mowing Management: The no-till treatment in both vineyards was followed by one rotary mowing of weeds which escaped or germinated in late spring after the glyphosate treatment.

Two 60-inch neutron probe access wells were installed in each Sauvignon blanc and Zinfandel replication. They were placed in the center of the middles, equal distance from treatment vine rows in both vineyards. Five Sauvingon blanc vines adjacent to the access wells were selected for collection of harvest and yield data in 1987 and 1988. Fruit samples from each treatment replication were also evaluated for brix, pH, and percent TA (total acidity). Pruning weights and shoot counts were obtained prior to treatment and after the 1986 and 1987 growing seasons.

## Results

Consumptive Water Use. Crop water use by each treatment was determined in both vineyards by evaluating changes in soil water content during the season. A neutron probe was used to measure water content from 9 inches to 57 inches of soil depth. Seasonal water use is the sum of the water use periods of a given season.

No significant differences were found in the daily or seasonal water use in the Sauvignon blanc vineyard in 1987 or 1988 (see Figures 1, 2, 3, and 4) and in the Zinfandel vineyard in 1987 (Figures 5 and 7). Late rain in 1988 caused excessive weed growth in the Zinfandel chemically mowed no-till plots. The weeds used water at a higher rate than the disc tilled treatment from May 23 through June 6, represented by Julian date 150 (Figure 6). After day 158, no significant differences were found. The difference in water use between till and no-till early in the season resulted in a significant difference in water use by seasons end (Figure 8).

Impacts on Yield. Yield and fruit quality measurements were not significantly different between treatments in either the 1986, 1987, or 1988 seasons. The vegetation management treatments were imposed, and data was obtained from the test vines in 1986--one year before installation of the neutron probe wells. Zinfandel yields did not significantly differ in 1987. Partial Zinfandel harvest data obtained in 1988 showed a reduction in yield from the no-till vines where weeds had removed water at a higher rate early in the season.

Management Implications. Water use by the Sauvignon blanc vines was not affected by chemical mowing or discing. The vineyard was vigorous with the vine foliage covering most of the soil surface between the rows which shaded the weed regrowth in the chemically mowed treatment. The head-trained Zinfandel covered less soil surface so more weeds grew in the centers. The 1988 Zinfandel cumulative water use data (Figure 8) shows less than 0.4 inch more water was removed by the weeds in the no-till treatment. Prichard et al. in Lodi (1) found a 6% yield reduction occurred in irrigated Sauvignon blanc wine grapes per inch of water withheld below a threshold value. The 0.4 inch reduction in water availability measured in our 1988 Zinfandel trial would be expected to result in a 2.4% yield reduction. Statistically, a 2.4% yield reduction would be very difficult to demonstrate since the variability of yield from vine to vine is high in these vineyards.

The no-till glyphosate chemically mowed vineyard floor strategy offers several advantages over conventional discing. If it's properly managed, they include: frost protection, erosion control, better soil structure, access nearly year round, elimination of plow or disc pans and lighter equipment with less horse power can be economically used.

FIGURE 1

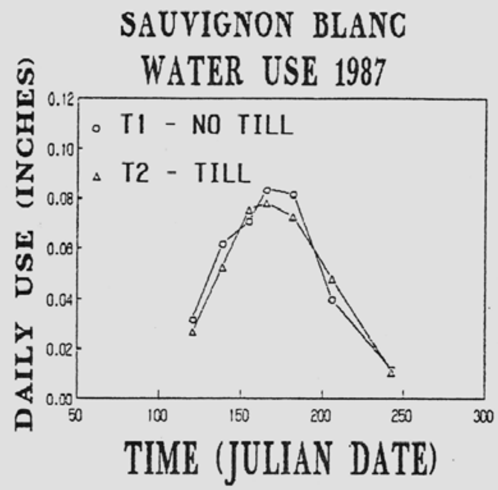



FIGURE 2

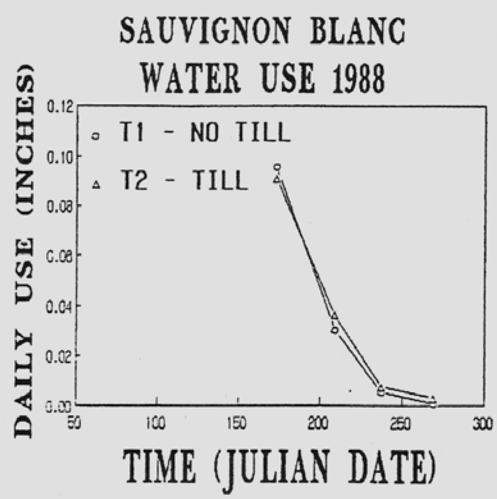


FIGURE 3

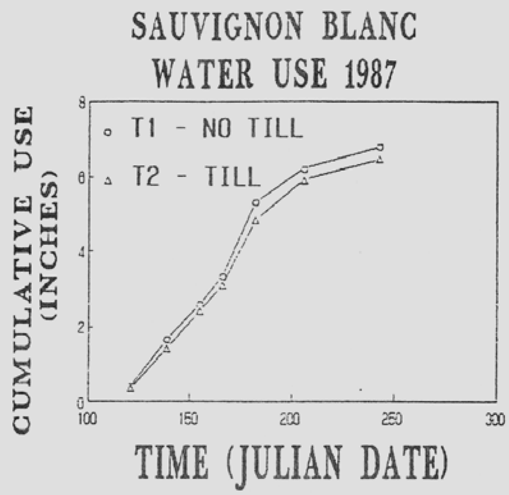



FIGURE 4

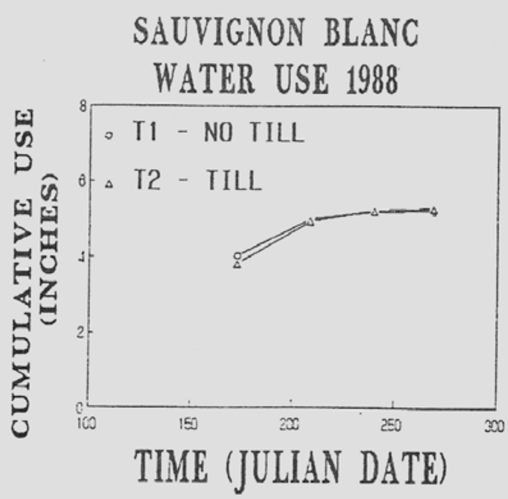


FIGURE 5

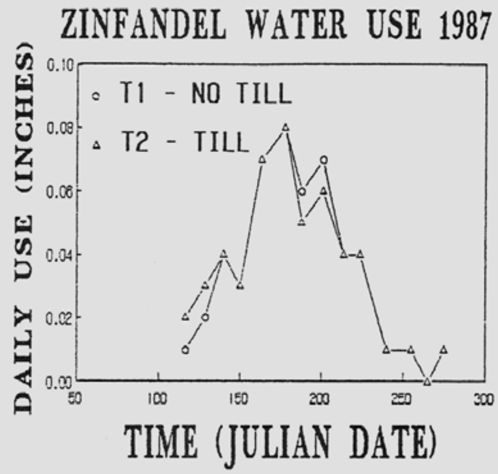



FIGURE 6

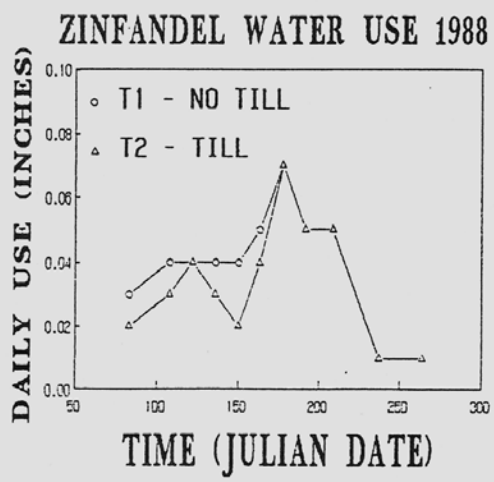


FIGURE 7

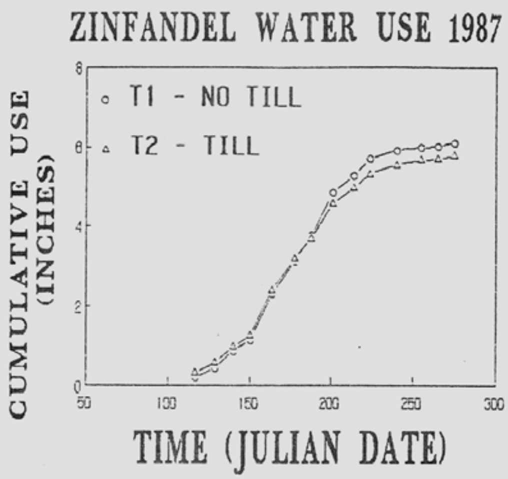
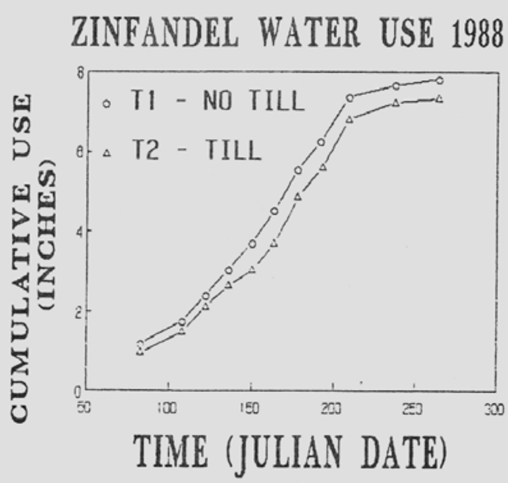



FIGURE 8



Acknowledgement: The authors wish to thank Amador Foothill Winery and Arnese Vineyards, Plymouth, California for their assistance and cooperation with these trials.

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## VEGETATION MANAGEMENT IN NON-IRRIGATED VINEYARDS OF THE SHENANDOAH VALLEY OF CALIFORNIA

Edwin E. Sieckert and Delbert S. Farnham[1]

Abstract. A long-term field study was established to evaluate glyphosate {*N*-(phosphonomethyl)glycine} treatments versus discing for effective weed management in vineyard middles. Vegetation management in the middles is important to provide access for pruners and other pest management operations and to improve frost protection. Currently, growers disc middles two to three times to remove unwanted resident vegetation. Glyphosate at rates of 0.21, 0.31, and 0.42 kg/ha was evaluated for chickweed (*Stellaria media*) and annual bluegrass (*Poa annua*), supressions and control. Glyphosate at 0.31 kg/ha applied in February, suppressed vegetation for 100 days. Glyphosate at 0.42 kg/ha controlled the vegetation but resulted in bare ground at 60 days after application which increases potential for erosion. Sequential glyphosate applications at 0.21 kg/ha in May suppressed emerging summer vegetation. Wet soil did not allow discing until May and several discings were required to adequately incorporate weedy vegetation which was nearly 45 cm tall at that date. Discing also did not provide a smooth surface which is needed to provide maximum frost protection. After three years, resident vegetation shifted in the glyphosate treatment from filaree (*Erodium* sp), bluegrass, and chickweed to filaree and willow herb (*Epilobium paniculatum*). Discing did not cause the resident population to shift. Results of this study indicate that 0.31 kg/ha can effectively be used to manage vegetation in vineyard middles with slight shifts in resident vegetation population. Field observations also indicate that glyphosate rates that suppressed vegetation decreased erosion and provided a firmer soil surface for field access.

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[1]Monsanto Company, Fair Oaks, CA and University of California Cooperative Extension, Jackson, CA.

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## INFLUENCE OF TEMPERATURE ON RESPONSE OF ROUGHSTALK BLUEGRASS TO FENOXAPROP

G.W. Mueller-Warrant[1]

Fenoxaprop {(±)-2-[4-[(6-chloro-2-benzoxazoly)oxy]phenoxy]propanoic acid} was recently registered for control of roughstalk bluegrass (*Poa trivialis*) and wild oats (*Avena fatua*) in perennial ryegrass (*Lolium perenne*) grown for seed in Oregon. Control of roughstalk bluegrass in field trials varied substantially with timing of application and age of the weed, with seedlings being more easily controlled than older, more well-established plants. Sensitivity of perennial

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[1]USDA-ARS, National Forage Seed Prod. Res. Center, Corvallis, OR

ryegrass also varied with date of application during the fall through spring growing season, with greatest injury coming from treatments applied in April. Roughstalk bluegrass control was poor in the fall, satisfactory in late winter, but usually best in early spring. Optimum date of application was around March 1 in 1987, a year with a warmer than normal winter and around April 1 in 1988, a more normal winter. Since weather follows a general warming trend during late winter and early spring, it seemed probable that the temperature near time of treatment was a major factor in the response of these two species to fenoxaprop. However, since temperature influences growth rate of grasses, causing changes in size over time, response to fenoxaprop applied in the field at different dates included confounded effects of differing plant sizes and rates of metabolism. Tests were therefore conducted in growth chambers to more precisely define effects of temperature on the response of roughstalk bluegrass to fenoxaprop.

Roughstalk bluegrass was germinated in a greenhouse under 16 C day/10 C night, 12-hr photoperiod conditions. Seedlings were thinned to a final density of 3 weeds per pot at 25 days after germination, and moved into growth chambers 3 days later. Growth chamber conditions were 12 hr light/12 hr dark photo periods, with a dark period temperature of 2 C in all chambers. Plants were grown in the light period at 5, 8, 11, and 14 C for 22 days prior to herbicide treatment. After herbicide treatment, plants were returned to growth chambers for 36 days before they were harvested for above ground fresh-weight yield. Following this harvest, the plants were allowed to regrow in the greenhouse for 17 days, after which time percent mortality was evaluated based on failure to regrow. The experiment was arranged as a complete factorial with four pre-treatment temperature regimes, four post-treatment temperature regimes, six rates of fenoxaprop (0, 56, 112, 168, 224, and 280 g ai/ha), and six replications within chambers.

Susceptibility of roughstalk bluegrass to fenoxaprop was inversely related to pre-application temperature and directly related to post-application temperature. Since size of the weed at treatment increased with pre-application temperature, the effect of pre-application temperature can be explained as a decrease in susceptibility in larger plants. Reduction in roughstalk bluegrass growth caused by application of any rate of fenoxaprop was proportional to post-treatment temperature within the range tested from 5 to 14 C. Similar conclusions can be drawn from weed mortality evaluations based on failure to regrow after the fresh-weight harvest. Differences in survival disappeared at higher rates due to death of all plants. The growth chamber results suggest that fenoxaprop was most effective when applied to actively growing grass, which agrees with findings by other workers for other grasses.

Similar control from equal rates of fenoxaprop was achieved for pre- and post-treatment temperature combinations of 4/8, 8/11, and 11/14 C. This result seems to indicate that, within this range of temperatures, delaying application for a few weeks during a period of continuously increasing temperature would have little, if any, net effect on performance of fenoxaprop. Larger plants present at later dates of treatment would be proportionately more sensitive due to their faster growth rates under the warmer conditions following treatment. However, if a general warming trend were broken by a period of cooler weather soon after treatment, herbicide performance might decline with delay in application date. Conversely, performance of fenoxaprop applied too early might be impaired by coolness of the weather at that time if an anticipated warming trend failed to materialize.

Table 1. Size of roughstalk bluegrass at various events in the study.

| Event | Days since germination | Plant height | Leaves visible | Tillers visible |
|---|---|---|---|---|
| | | (cm) | (number per plant) | |
| Transfer from greenhouse to growth chambers | 28 | 7.0 | 7.0 | 2.0 |
| Fenoxaprop applied to plants grown at: 5 C | 50 | 10.2 | 13.1 | 4.7 |
| 8 C | 50 | 11.4 | 16.4 | 6.1 |
| 11 C | 50 | 12.7 | 19.8 | 6.4 |
| 14 C | 50 | 17.3 | 22.5 | 7.1 |
| Above ground fresh weight harvest | 86 | Size increased by temperature in the absence of fenoxaprop. | | |
| Mortality rating | 103 | Regrowth size based on relative tolerance to fenoxaprop. | | |

Table 2. Main effects of pre-treatment and post-treatment temperature regimes on selected responses of roughstalk bluegrass to fenoxaprop.

| Daytime temperature | Regrowth in 56 g/ha treatment | GR50% fenoxaprop rate |
|---|---|---|
| | ---------(% kill)--------- | -------(g/ha)-------- |
| 5 C Pre-treatment | 89 | 40 (*4) |
| 8 C " | 79 | 65 (*3) |
| 11 C " | 83 | 126 (*1) |
| 14 C " | 68 | 222 |
| 5 C Post-treatment | 75 | 194 (*1) |
| 8 C " | 75 | 132 (*2) |
| 11 C " | 81 | 75 (*2) |
| 14 C " | 89 | 52 (*3) |

* Number of post- or pre-treatment temperature combinations involved in the calculation of the GR50% rate that were below the linear regression range of 56 to 280 g/ha out of 4 possible values.

# BROADLEAF WEED CONTROL IN COOL-SEASON TURF WITH CLOPYRALID AND TRICLOPYR HERBICIDES

M.M. Mackasey[1]

Abstract. Tank mixtures of triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid} and clopyralid {3,6-dichloro-2-pyridinecarboxylic acid} were evaluated in 1986 and 1987. In 1988, a pre-formulated mixture (XRM-5085) was tested for the first time. XRM-5085 is a new amine formulation of The Dow Chemical Company containing triclopyr and clopyralid in a 3:1 ratio. Mixtures (as tank mixes or in-can) were primarily tested across the cool-season grass zone. Good tolerance of perennial bluegrass (*Poa pratensis*), perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinaceae*) has been observed. Excellent control of white clover (*Trifolium repens*), dandelion (*Taraxacum officinale*), narrowleaf plantain (*Plantase* sp.) and ground ivy (*Glechoma hederacea*) have been reported with rates ranging from 0.375 lb of triclopyr plus 0.125 lb of clopyralid per acre (for clover) up to 0.75 lb plus 0.25 lb per acre of triclopyr and clopyralid, respectively (for dandelion, narrowleaf plantain and ground ivy). The registration package for the formulated product will be submitted to EPA in the latter part of 1988, anticipating registration in mid to late 1989.

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[1]The Dow Chemical Company, Midland, MI

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# QUINCLORAC FOR POSTEMERGENCE CONTROL OF CRABGRASS IN TURF

D.C. Wiley and J.O. Pearson[1]

Abstract. The chemical name of quinclorac is: 3,7-dichloro-8-quinolinecarboxylic acid. It's dermal LD/50 is 2000 mg/kg for rats, and LC/50 is 100 mg/L for fish. The technical active ingredient has demonstrated low toxicity to laboratory animals, birds, fish, aquatic invertebrates and pollinating insects.

Quinclorac is taken into the plant both through the root and the shoot. Mode of action in broadleaf species is the interaction with the auxin regulation. Grass species is unknown.

Tolerant turf grasses found so far are Kentucky bluegrass, annual rye, perennial rye, tall fescue, bermudagrass, zoyzia, and centipede grass (pre.). Non-tolerant turf grasses include red fescue, bentgrass, bahia, St. Augustinegrass and centipedegrass (post).

In 1988, in California, BASF established two postemergence trials on established turf grass. Turf grasses present were Kentucky bluegrass (*Poa pratensis*), perennial ryegrass (*Lolium perenne* L.), annual bluegrass (*Poa annua*), and common bermuda grass (*Cynodon dactylon*). These tests were well watered and had heavy infestations of smooth crabgrass (*Digitaria ischaemum*).

Once crabgrass emerges, it is a very difficult weed to control.

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[1]BASF Corp., Woodland and Roseville, CA

Rates ranging from 0.5 to 2.0 lb ai/acre of quinclorac were applied in a randomized block design. Sequential applications were applied in a few treatments at each test site. Applications were made on 8/15/88 and 9/14/88. See charts below.

CHART 1

PERCENT SMOOTH CRABGRASS CONTROL

WITH QUINCLORAC

| Days after Trt | | lb ai/acre | | | | | Applic. Date |
|---|---|---|---|---|---|---|---|
| | | 0.5 | 0.75 | 1.0 | 1.5 | 2.0 | 8/15/88 |
| 7 | | 77 | 80 | 82 | 87 | 88 | |
| 14 | | 80 | 84 | 86 | 88 | 93 | |
| 21 | | 66 | 79 | 85 | 91 | 93 | |
| 29 | | 48 | 50 | 58 | 84 | 90 | |
| 35 | (**) | -- | -- | -- | 84 | 90 | |
| 42 | | -- | -- | -- | 68 | 82 | |
| 59 | | -- | -- | -- | 78 | 84 | |

(**) Sequential treatment of 0.5 lb ai/acre was made on the lower three rates on 9/14/88. See Chart 2 below.

CHART 2

PERCENT SMOOTH CRABGRASS CONTROL WITH QUINCLORAC
SEQUENTIAL TREATMENTS

| Days after last treatment. | ai/acre | | | Applic. Dates |
|---|---|---|---|---|
| | 0.5+0.5 | 0.75+0.5 | 1.0+0.5 | 1. 8/15/88<br>2. 9/14/88 |
| 5 | 84 | 81 | 76 | |
| 12 | 89 | 92 | 90 | |
| 21 | 94 | 94 | 90 | |
| 29 | 82 | 92 | 92 | |

Quinclorac has been tested under the code number BAS 514 00H and BAS 514 16H. This herbicide was applied using a $CO_2$ pressurized backpack sprayer with 8004 flat fan nozzles, 40 psi, and at 100 gpa of water. A surfactant, BAS 09002S, was used at 0.25% v/v.

Results showed excellent control with all rates tested. Control was maintained for about 30 days with the lower rates tested; then some regrowth occurred. The 1.5 and 2.0 lb ai/acre rates held for longer periods of time. Levels of infestation were reduced drastically after one application with all rates tested. Sequential applications were also showing excellent control when the trials were terminated.

Slight yellowing of annual bluegrass and perennial ryegrass was observed at the 2.0 lb ai/acre rate. After 21 days the yellowing had disappeared. No other phytotoxicity symptoms were noted in these tests.

Further testing for 1989 could include irrigation frequency and amounts, additional rate and timing trials, and continuing turf grass tolerance studies.

## MON 15100 FOR ANNUAL WEED CONTROL IN TURFGRASS

Nelroy E. Jackson[1]

Abstract. MON 15100 {3,5-Pyridinedicarbothioic acid, 2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-*S,S*-dimethyl ester} is a new herbicide being developed for the control of annual grasses and broadleaves in turfgrass and ornamentals. Field trials conducted throughout the U.S. in 1986/88 indicated that MON 15100 at rates of 0.28 to 0.56 kg ai/ha gave 85-100% control of crabgrass (*Digitaria spp.*) when applied preemergence. When applied early postemergence to crabgrass (prior to tillering), MON 15100 at 0.56 kg ai/ha gave 85-100% control.

MON 15100 at 0.56 kg ai/ha also gave control of annual bluegrass preemergence when applied in the fall and postemergence when applied in the spring. Rates of 0.56 to 1.12 kg ai/ha gave excellent control of spotted spurge (*Euphorbia maculata*), woodsorrel (*Oxalis corniculata*) and goosegrass (*Eleusine indica*).

MON 15100 at rates up to 1.12 kg ai/ha also provided excellent safety on most cool and warm season turfgrasses, and allowed overseeding of perennial ryegrass and tall fescuye in the fall after spring applications.

[1]Monsanto Company, Corona, CA

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## BIOLOGY AND COMPETITION OF WILD PROSO MILLET (*Panicum Milaceum*) IN CORN (*Zea Mays*)

P. Westra[1]

Abstract. Field surveys with seed collection over two years showed the existence of 3 biotypes of wild proso millet (PANMI) in Colorado, based on seed color. Field and greenhouse studies confirmed that seed color breeds true for all seed produced by a plant grown from a known seed color. Thus seed color does not appear to be related to seed physiological maturity. Field grown plants were shorter than greenhouse grown plants, but produced more tillers and seed.

Wild proso millet density competition studies in corn over two years showed that at 20 wild proso millet plants per 900 square centimeters, corn yields were reduced approximately 30%. The wild proso millet density and corn yield response appears not to be linear, which may be due to the tillering capability of wild proso millet. Time of planting and time of removal studies showed that 4 to 5 weeks of wild proso millet control were necessary to maximize corn yields.

An additional series study conducted over 2 years showed that one corn plant had the competitive ability of 11 wild proso millet plants. It is possible that wild proso millet effects on corn are more severe under drought conditions, suggesting that optimal irrigation schedules may provide corn with an additional competitive advantage over wild proso millet.

[1]Colorado State University, Ft. Collins, CO

## IMAZETHAPYR - A PROMISING HERBICIDE FOR WEED CONTROL IN DRY BEANS

Stephen D. Miller and Alan W. Dalrymple[1]

Abstract. Imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} controls a wide range of broadleaf and grassy weeds and has shown promise for selective weed control in small and large seeded legume crops. Field experiments were conducted at the Research and Extension Center, Torrington, WY from 1985 to 1988 to evaluate weed control and dry bean (*Phaseolus vulgaris* L.) tolerance with preplant incorporated, preemergence and postemergence applications of imazethapyr alone or in combination with other herbicides. Broadleaf weed control with imazethapyr has been good to excellent (89 to 100%) with preplant incorporated or preemergence applications and fair to good (83 to 90%) with postemergence applications. Grass control with imazethapyr has been variable and influenced by species. Imazethapyr combinations with pendimethalin {*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine}, metolachlor {2-chloro-*N*-(2-ethyl-6-methyl phenyl)-*N*-(2-methoxy-1-methylethyl)acetamide} or cinmethylin {exo-1-methyl-4-(1-methylethyl)-2-[(2-methylphenyl)methoxy]-7-oxabicyclo [2.2.1]heptane} have provided excellent (92 to 100%) broad-spectrum weed control whether applied as a tank mix or sequential treatments. Dry bean tolerance to imazethapyr has been better with preemergence or early postemergence applications than with preplant incorporated applications. Further, imazethapyr combinations with metolachlor or cinmethylin have been safer on dry beans than combinations with pendimethalin regardless if tank mixed or applied sequentially. Dry bean injury with imazethapyr has been in the form of stunting and leaf chlorosis; however, stands have not been reduced significantly with any treatment.

[1]University of Wyoming, Laramie, WY

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## IMAZETHAPYR FOR ANNUAL WEED CONTROL IN EDIBLE BEANS AND PEAS IN THE UNITED STATES

S.J. Carlson and F.R. Taylor[1]

Abstract. Imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid}, which is in the imidazolinone herbicide family, is currently being developed by American Cyanamid Company for weed control in edible beans, snap beans, lima beans, peas, southern peas, and lentils throughout the United States. Depending upon the geographic area, the use rate will vary between 0.032 and 0.063 lb/a and the application timing may be preplant incorporated, preemergence or postemergence. Rotational crops will be wheat at four months after application, barley, field corn, peanuts, and tobacco 9 1/2 months after application, and all other crops 18 months after application. Edible beans and peas may exhibit growth responses such as chlorosis and reduction in plant height early in the growing season, particularly if excessive moisture and hot temperatures occur between the crook and second trifoliate stage of growth. However, these responses are temporary and have not resulted in a decrease of yield. Imazethapyr will control a broad range of important broadleaf weeds and some troublesome grass weeds.

[1]American Cyanamid Co., Princeton, NJ

## EVALUATION OF PRODIAMINE FOR WEED CONTROL IN GUAYULE

M.A. Foster[1], D.W. Ranne[1], and J. Moore[2]

Abstract. Guayule (*Parthenium argentatum*), a rubber-producing shrub native to the Trans Pecos of southwest Texas and northcentral Mexico, is a promising alternative crop for the southwestern United States. Cultivated stands are particularly sensitive to weed competition until the shrubs become established. Currently, there are no herbicides labeled for weed control in guayule. A study was initiated to evaluate postplant applications of prodiamine {$N^3$,$N^3$,-di-*N*-propyl-2,4-dinitro-6-(trifluoromethyl)-m-phenylenediamine} for preemergence weed control in transplanted guayule. Two-month-old guayule seedlings were transplanted into field plots on May 12, 1988 at the Texas Agricultural Experiment Station Research Site near Fort Stockton, Texas. Plots were 3 m wide (4 rows) by 6 m long, and located on a Delnorte very gravelly loam. The study was arranged in a randomized complete block design with four replications. Prodiamine was applied as a broadcast spray immediately after transplanting at rates of 2.2, 3.4, and 4.5 kg ai/ha and incorporated with 1.3 cm of water applied by sprinkler irrigation. Treatments were applied with a backpack sprayer in 187 L of water at 138 kPa pressure. Weed control was determined on July 1, 1988 by counting the number of weeds in each plot. Prostrate pigweed (*Amaranthus blitoides*) was the dominant species present and averaged 25/$m^2$ in unsprayed control plots. Prodiamine at all rates controlled 100% of prostrate pigweed. All other weed species were combined because of uneven distribution and averaged 8/$m^2$ in the controls. Plant density of the associated species was decreased to less than 1/$m^2$ in all treatments. Prodiamine at 2.2, 3.4, and 4.5 kg ai/ha effectively controlled prostrate pigweed with no associated crop injury.

Texas Agricultural Experiment Station, [1]Fort Stockton and [2]Pecos, Texas

## BENTAZON USE POTENTIAL FOR WEED CONTROL IN POTATOES

Lloyd C. Haderlie[1], Stephen L. Love[2], and Robert W. Gunnell[1]

Abstract. Bentazon {3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide} was applied postemergence at 0.75 and 1.0 ai/A to several potato cultivars from 1985 to 1987 and to Russet Burbank cultivar in 1988 at various rates to determine potential for weed control. Russet Burbank was the least tolerant cultivar to bentazon, and at normal bentazon use rates (for other crops) unacceptable injury sometimes occurred. Smaller potato plants (8 to 15 cm tall) were more tolerant than were larger (20 to 30 cm tall) plants. Tuber yield was not reduced when potato plants were smaller. Foliar injury symptoms included chlorosis, leaflet necrosis, and leaflet margin burn. Plants continued to grow, and three weeks after application little foliar injury remained even at the higher rates and larger plants. Experiments in 1988 on only Russet Burbank

[1]AgraServ, Inc., American Falls, ID
[2]University of Idaho, Research & Extension Center, Aberdeen, ID

cultivar used metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} + bentazon combinations at several rates to reduce potato injury (by decreasing the rates of both chemicals) and to the increase weed control spectrum. Hairy nightshade (*Solanum sarachoides*) was one weed of major interest. Results show that such a combination with relatively low rates of each herbicide and the correct crop oil concentration has potential for weed control in Russet Burbank cultivar with acceptable leaf injury.

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## CHEMICAL CONTROL OF WEEDS IN GRAIN LUPINE

Larry W. Mitich, Marsha L. Feyler, and Thomas E. Kearney[1]

### Introduction

Grain lupine is a cool-season legume crop with approximately the same moisture and temperature requirements as wheat. Like all legumes, lupine fixes nitrogen so it does not require fertilization. There is also evidence that wheat benefits from rotation with lupine. If grain lupine can be economically produced in California, it could become an important crop, providing a cool-season alternative to grains and sugarbeets in the Central Valley.

Lupine seed is now being used to replace soybeans in poultry feed and, unlike soybeans, does not require processing other than grinding. Seed, fresh plants, and silage can be used as feed for livestock. Lupine seeds, which resemble baby lima beans, are high in protein (32% to 40%) and high in lycine. These seeds also have value as a food for humans; they are eaten boiled in Europe and roasted like corn-nuts in the Middle East, and immature lupine pods are similar to snap beans. Lupine seed may ultimately be processed like soybeans and garbanzo beans.

Over 1 million acres are planted to lupine each year in Australia; large acreages are also grown in other countries, including the USSR and Poland. Growers in the United States are increasingly interested in lupine, especially in Midwestern areas too cool for soybean production. Several thousand acres were planted in 1988, with yields as high as 3 tons/A, but more commonly 1 to 2 tons/A. The main hindrances to increased plantings in California are (a) insufficient seed supply and (b) lack of registered herbicides for broad spectrum weed control in lupines.

In California, grain lupine is planted in fall and grows slowly during the cool winter months. Weeds frequently emerge before or with the crop, and they have ample opportunity to outcompete lupines during the lengthy seedling stage. From a commercial standpoint, California lupine growers must produce at least 2 tons/A of lupine seed to compete with other agronomic crops; this allows a very slim margin for losses due to weed competition.

Since 1981, 15 research trials have been conducted in grain lupine by weed scientists at the University of California, Davis, and in Yolo and Stanislaus counties. More than 40 herbicides and herbicide combinations have been evaluated for crop tolerance and efficacy in controlling weeds (Table 1). We have focused on herbicides which were already used in soybeans or dry beans, since these chemicals would be the ones most likely suited to lupine physiology.

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[1]University of California, Davis, CA

Table 1. Herbicides tested in grain lupine in California, 1984-1989

| Herbicide | Rates tested (lb ai/A) |
| --- | --- |
| **Preplant incorporated** | |
| benefin | 1.3 |
| dimethazone | 0.75 to 1.5 |
| dimethazone + pendimethalin | 0.75 + 1.5 |
| EPTC | 3.0 |
| metolachlor | 2.0 |
| metolachlor + pendimethalin | 2.0 + 1.5 |
| napropamide | 0.75 to 1.75 |
| pendimethalin | 1.5 |
| prometryn | 1.0 to 2.0 |
| trifluralin | 0.75 to 1.25 |
| **Postplant preemergence** | |
| alachlor | 2.0 to 3.0 |
| atrazine | 0.5 to 1.5 |
| chloramben | 3.0 to 6.0 |
| chloramben + metolachlor | 3.0 + 2.0 |
| chloramben + pendimethalin | 3.0 + 1.5 |
| DCPA | 6.0 to 8.0 |
| desmedipham | 1.0 to 2.0 |
| ethalfluralin | 1.1 to 2.2 |
| linuron | 0.5 to 4.0 |
| linuron + alachlor | 2.0 + 3.0 |
| linuron + metolachlor | (1.0 to 2.0) + (1.0 to 3.0) |
| linuron + pendimethalin | (0.5 to 1.0) + 0.75 |
| metolachlor | 0.5 to 4.0 |
| metolachlor + pendimethalin | (1.0 to 2.0) + (0.75 to 1.5) |
| metribuzin | 0.25 to 0.5 |
| oryzalin | 1.0 to 2.0 |
| oxyfluorfen | 0.3 |
| pendimethalin | 0.75 to 6.0 |
| prometryn | 1.0 to 4.0 |
| propham | 4.0 |
| simazine | 0.75 to 2.0 |
| terbutryn | 1.0 to 4.0 |
| trifluralin | 0.65 to 1.0 |
| **Postemergence** | |
| AC 263,499 | 0.063 to 0.094 |
| acifluorfen | 0.4 to 0.8 |
| bentazon | 1.25 |
| cloproxydim | 0.075 to 0.125 |
| 2,4-DB | 1.0 to 2.0 |
| diclofop | 1.1 to 2.2 |
| fluazifop | 0.24 to 0.6 |
| methazole | 0.5 to 1.5 |
| pronamide | 1.25 |
| sethoxydim | 0.3 to 0.54 |

Our early work with grain lupine helped obtain registration for pendimethalin {*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine} and metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl) acetamide}, separately and in combination for lupine production in California. These are the only two herbicides currently registered for this purpose. Although these herbicides effectively control many problem grasses and some broadleaf weeds, they fail to adequately control mustards - wild mustard (*Sinapis arvensis*), wild radish (*Raphanus raphanistrum*), and black mustard (*Brassica nigra*). These herbicides also fail to control volunteer grains, which may be a significant problem in lupine-grain rotations. We are interested in demonstrating the economic significance of uncontrolled weeds and hastening registration of useful herbicides.

Although the Federal Register of June 1986 placed lupines under the "bean" classification, opening potential use of several dry bean herbicides, many herbicide labels have become more restrictive.

## HERBICIDES FOR GRAIN LUPINE

### Preemergence herbicides

Metolachlor and pendimethalin. As discussed earlier, these registered herbicides do not produce adequate control of mustards or grasses. In California trials they also failed to control filaree. Control of other winter weeds, however, was usually excellent. Metolachlor, for example, is one of few 'safe' herbicides which provide fair control of annual bluegrass (*Poa annua*). In a time-of-application trial (1986-87, UC Davis) comparing preplant incorporated and preemergence applications of several identical herbicide treatments, it was found that metolachlor and pendimethalin applied preplant incorporated produced significantly poorer weed control and somewhat greater crop injury than these treatments applied postplant preemergence.

Linuron. Linuron {*N*'-(3,4-dichlorophenyl)-*N*-methoxy-*N*-methylurea} shows potential for use in grain lupine. Weed control with linuron at 2 lb ai/A was outstanding. Crop tolerance was excellent in most cases; however, linuron at 2 lb ai/A and higher caused injury in one trial conducted on sandy soil with flood irrigation. Linuron gives excellent control of wild mustard and shepherdspurse (*Capsella bursa-pastoris*), and acceptable control of annual bluegrass. Residue samples will be collected from research in progress to help support an IR-4 registration.

In trials conducted in Michigan, a metolachlor-linuron combination has given the best weed control of any herbicide or herbicide combination. California trials also indicate excellent potential for this combination.

Other preemergence herbicides injured lupines and/or produced less than acceptable weed control (Tables 2 and 3).

### Postemergence herbicides

Most postemergence herbicides tested are injurious to lupines and/or ineffective at controlling important weeds. Exceptions include sethoxydim {2-[1-(ethnoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} (up to 0.5 lb ai/A), fluazifop {(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propanoic acid} (up to 0.6 lb ai/A), and cloproxydim {(*E*,*E*)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} (up to 0.125 lb ai/A), which appear safe on lupines and may be useful for controlling grasses, though not annual bluegrass (Tables 2 and 3).

Table 2. Herbicides with potential for use in grain lupine in California (summary of information gained from trials, 1984-1989)

| Material | Rate (lb ai/A) | Percent crop vigor[1] '85 | '86a | '86b | '87a | '87b | '88 | Percent weed control (over all trials)[2] CAPBP | SENVU | CLNCM | MONPE | AMSIN | EROSS | mustd | STEME | POAAN | grass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PREPLANT INCORPORATED** | | | | | | | | | | | | | | | | | |
| metolachlor | 2.0 | | | | | | 73 | 0 | 0 | 43 | 0 | | | | | | |
| metolachlor + pendimethalin | 2.0 + 1.5 | | | | | | 71 | 18 | 25 | 50 | 30 | | | | | | |
| pendimethalin | 1.5 | | | | | | 83 | 23 | 23 | 20 | 20 | | | | | | |
| prometryn | 1.0 | | | | | | 83 | 28 | 28 | 75 | 13 | | | | | | |
| | 2.0 | | | | | | 81 | 40 | 40 | 60 | 30 | | | | | | |
| trifluralin | 0.75 | | | | | | 85 | 3 | 23 | 70 | 28 | | | | | | |
| **POSTPLANT PREEMERGENCE** | | | | | | | | | | | | | | | | | |
| linuron | 0.5 | | | 100 | 94 | 100 | | 97-100 | | 87-100 | 30 | 53 | 82 | 93 | 97 | 90 | 80-82 |
| | 1.0 | | 100 | 98 | 95 | 100 | | 58-100 | | 90-100 | 43-70 | 78 | 97 | 75-100 | 25-97 | 43-95 | 85-100 |
| | 2.0 | 65 | 100 | | 62 | 98 | | 100 | | 100 | 85-95 | 98-100 | | 98-100 | 93 | 81-100 | 89-98 |
| | 4.0 | 71 | | 80 | 32 | 78 | | 100 | | 100 | 100 | 97-100 | 97 | 100 | 100 | 100 | 93-100 |
| linuron + metolachlor | 1.0 + 1.0 | | | 100 | 94 | 95 | | 100 | | 92-100 | 62 | 87 | 100 | 98 | 97 | 95 | 70-95 |
| | 1.0 + 2.0 | | | | 77 | 95 | | 100 | | 100 | 77 | 93 | | 100 | | | 100 |
| | 2.0 + 1.0 | | | | 84 | 87 | | 100 | | 100 | 90 | 97 | | 99 | | | 99 |
| | 2.0 + 2.0 | | | | 60 | 95 | | 100 | | 100 | 92 | 97 | | 100 | | | 100 |
| linuron + pendimethalin | 0.5 + 0.75 | | | | 87 | 95 | | 100 | | 100 | 87 | 100 | | 94 | | | 55 |
| | 1.0 + 0.75 | | | | 85 | 100 | | 100 | | 100 | 87 | 100 | | 100 | | | 95 |
| metolachlor | 1.0 | | | 100 | 97 | 100 | | 0-57 | | 0-10 | 5 | 0 | 37 | 20 | 57 | 87 | 63-67 |
| | 2.0 | 80 | 100 | | 90 | 98 | 78 | 0-100 | 13-60 | 0-60 | 2-63 | 0-100 | | 0-10 | 48 | 80-93 | 75-78 |
| | 3.0 | | | | 80 | 98 | | 0 | | 0 | 40 | | | 15 | | | 75 |
| | 4.0 | 72 | 100 | 83 | | | | 90-100 | | 12-75 | 75 | 99 | 17 | 40 | 80-95 | 87-99 | 42-85 |
| metolachlor + pendimethalin | 1.0 + 0.75 | | | | 85 | 100 | | 100 | | 100 | 87 | 100 | | 50 | | | 58 |
| | 1.0 + 1.5 | | | | 85 | 98 | | 100 | | 98 | 85 | 100 | | 88 | | | 85 |
| | 2.0 + 0.75 | | 97 | | 80 | 95 | | 95-100 | | 90 | 92-98 | 95 | | 58-60 | 98 | 91 | 70 |
| | 2.0 + 1.5 | | | | 76 | 98 | 91 | 95-100 | 28 | 98-100 | 85-93 | 100 | | 78 | | | 90 |
| pendimethalin | 0.75 | | 100 | | 97 | 98 | 80 | 70-100 | 30 | 85-100 | 63-86 | 100 | 51 | 25-73 | 73-90 | 45-64 | 45-80 |
| | 1.5 | | 97 | | 88 | 94 | 90 | 84-100 | 35 | 86-100 | 94-100 | 100 | 47 | 78-100 | 96-98 | 46-69 | 34-91 |
| | 3.0 | | | | 77 | 80 | | 90-100 | | 91-100 | 100 | 100 | 60 | 93 | 100 | 63-82 | 35-64 |
| | 6.0 | | | | 59 | 75 | | 100 | | 100 | 100 | 100 | | 100 | | | 53 |

Table 2 continued

| Material | Rate (lb ai/A) | Percent crop vigor[1] '85 | '86a | '86b | '87a | '87b | '88 | Percent weed control (over all trials)[2] CAPBP | SENVU | CLNCM | MONPE | AMSIN | EROSS | mustd | STEME | POAAN | grass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| terbutryn | 1.0 | | | | 86 | 98 | | 85–100 | | 77–98 | 77 | 63 | 62 | 53 | 92 | 70 | 50–58 |
| | 2.0 | | 100 | | 89 | 85 | | 100 | | 98 | 95–99 | 95 | | 70–80 | 100 | 91 | 83 |
| | 4.0 | | 100 | 53 | | | | 98–99 | | 90 | 100 | | 96 | 100 | 100 | 96–99 | 100 |
| trifluralin | 0.65 | 56 | | | | | | 77 | | 84 | | 74 | | | | 64 | 44 |
| | 1.0 | | 97 | | | | | 35 | | | 43 | | | 30 | 43 | 65 | |
| **POSTEMERGENCE** | | | | | | | | | | | | | | | | | |
| cloproxydim | 0.075 | | | | 95 | 100[3] | | 0 | | 0 | 17 | 0 | | 0 | | | 100 |
| | 0.125 | | | | 94 | 100[3] | 88 | 0–13 | 13 | 0–23 | 13–17 | 0 | | 0 | | | 100 |
| diclofop | 1.1 | 88 | | | | | | 0 | | 0 | | 0 | | | | 0 | 5 |
| | 2.2 | 80 | | | | | | 17 | | 5 | | 0 | | | | 10 | 5 |
| fluazifop | 0.24 | | | | 92 | 100[3] | 76 | 0 | 3 | 0–45 | 0–37 | 0 | | 8 | | | 95 |
| | 0.6 | | | | 94 | 100[3] | 83 | 0 | 0 | 0–53 | 0 | 0 | | 0 | | | 100 |
| methazole | 0.5 | | | | 84 | 95 | | 13 | | 13 | 47 | 15 | | 8 | | | 13 |
| | 1.5 | | | | 60 | 92 | | 25 | | 25 | 55 | 50 | | 65 | | | 50 |
| sethoxydim | 0.3 | 70 | | | | 100[3] | | 2–100 | | 0–100 | 42 | 0–90 | | | | 0–66 | 60–61 |
| | 0.4 | | | | 85 | 100[3] | 83 | 0–5 | 5 | 0–23 | 0–3 | 0 | | 13 | | | 100 |
| | 0.54 | 68 | | | | | | 35 | | 30 | | 50 | | | | 5 | 90 |
| **CHECK** | | 79 | 100 | 98 | 90 | 100 | 100 | | | | | | | | | | |

[1]Suffixes (a, b) are appended for years in which more than one trial was conducted.

[2]Most weed names given are abbreviations presented by the WSSA in its "Composite list of weeds," Weed Sci. v. 32 s. 2, 1984.

**CAPBP** = Capsella bursa-pastoris; **SENVU** = Senecio vulgaris; **CLNCM** = Calandrinia ciliata

**POAAN** = Poa annua; **AMSIN** = Amsinckia intermedia; **STEME** = Stellaria media

**EROSS** (our abbreviation) = Erodium spp.; **MONPE** (our abbreviation) = Montia perfoliata

**mustd** (our abbreviation) = mustard spp., including Raphanus raphanistrum and Sinapis arvensis

**grass** = grass species other than POAAN, including Avena fatua, Bromus spp., and volunteer cereals

[3]Vigor rating discounts injury due to poor root nodulation.

Table 3. Herbicides injurious to grain lupine in California

| Herbicide | Rate (lb ai/A) | Percent crop vigor[1] |
|---|---|---|
| **PREPLANT INCORPORATED** | | |
| dimethazone | 0.75 | 50 |
| | 1.5 | 33 |
| dimethazone + pendimethalin | 0.75 + 1.5 | 50 |
| **PREEMERGENCE** | | |
| atrazine | 0.5 | 30-33 |
| | 1.0 | 20-23 |
| | 1.5 | 14-30 |
| cyanazine | 1.5 | 10-50 |
| | 3.0 | 12-28 |
| metribuzin | 0.25 | 92 |
| | 0.375 | 30-58 |
| | 0.5 | 21 |
| prometryn | 1.0 | 80-90 |
| | 2.0 | 55-70 |
| | 4.0 | 34-43 |
| simazine | 0.75 | No injury rating, but caused stunting and yellowing of lupines. |
| | 1.0 | |
| | 2.0 | |
| **POSTEMERGENCE** | | |
| AC 263-499 | 0.063 | 53 |
| | 0.094 | 48 |
| acifluorfen | 0.4 | 0 |
| | 0.8 | 0 |
| bentazon | 1.25 | 20 |
| 2,4-DB | 1.0 | 0-3 |
| | 2.0 | 3-9 |

[1]Ranges taken from all trials in which chemical was used. Note that percent crop vigor is the opposite of phytotoxicity; 100 = healthy crop, 0 = dead crop.

Sethoxydim and fluazifop are under consideration for registration in grain lupine in California.

## Injurious herbicides

Many herbicides tested caused unacceptable injury to lupines (Table 3). It is interesting to compare susceptibility of grain lupine with that of garbanzos, which lupine plants resemble in behavior; only metolachlor is registered for use in garbanzos.

Simazine {6-chloro-*N*,*N'*-diethyl-1,3,5-triazine-2,4-diamine} is an important herbicide in lupine production in Australia, where the lupine species *Lupinus angustifolius* is the preferred crop. In the U.S. *L.angustifolius* is susceptible to disease, probably *Fusarium*. *L. albus* grows more successfully and accounts for all commercial lupine plantings; however, this species is susceptible to simazine. In California trials, simazine caused yellowing and stunting in lupines. In one case, heavy rain immediately after application resulted in nearly total crop loss. (Coincidentally, linuron, one of the most promising herbicides for California, is not widely used in Australia because it injures *L. angustifolius*.)

# RESEARCH IN PROGRESS

## Current herbicide screening trial

During winter 1988-89, 7 herbicides, in 15 applications, are being evaluated for weed control and crop tolerance in 'Minnesota Ultra' grain lupine at the UC Davis farm. Plots are 10 ft by 40 ft (two 5-ft by 40-ft beds). Seed was coated with an inoculant for lupine and planted 27 October, using a grain drill with 7-inch row spacings. All treatments were applied broadcast with a $CO_2$ backpack sprayer at a spray volume of 15 gpa. Preemergence surface treatments were applied 3 November and sprinkle irrigated 8 November with approximately 1.5 inches of water. Postemergence treatments were applied 9 January 1989, when lupine was 3 to 5 inches tall. Weather at application was cloudy, and temperature was about 50° F. Weeds present during postemergence treatment included annual bluegrass, common groundsel (*Senecio vulgaris*), minerslettuce (*Montia perfoliata*), and shepherdspurse.

In an initial evaluation of preemergence treatments conducted 14 December, it was found that metolachlor (2.5 lb/A), linuron (2.0 lb/A), and combinations of these two herbicides with pendimethalin produced good to excellent control (80% to 100%) of annual bluegrass, common chickweed (*Stellaria media*), and common groundsel; the top ranking treatment in all cases was metolachlor + linuron (2.0 to 2.0 lb/A).

## Need for further research

Future research calls for competition studies in which we will compare yields of grain lupine in plots seeded with set populations of mustard plants, removed at various times during the season or left season-long. In planning for such a study, we face the problem of controlling extraneous weeds without injuring lupines or stunting mustard. We hope to use documentation of the deleterious effects of mustard on lupine seed yields to push for registration of linuron on grain lupine.

# GRASS SEED TOLERANCE TO CLOPYRALID AND CLOPYRALID PLUS PHENOXY COMBINATIONS

Dean R. Gaiser[1]

## Introduction

Turfgrass grown for seed is an important segment of the agricultural economy in the Willamette Valley of Oregon and other areas of the Pacific Northwest. Canada thistle [*Cirsium arvense* (L.) Scop.] is a serious problem for many grass seed growers -- in addition to the competitive nature of the weed, the achenes of Canada thistle are prohibited noxious weed seeds in WA, OR, and ID meaning there is a zero tolerance for them in Certified Seed. Clopyralid {3,6-dichloro-2-pyridinecarboxylic acid} and clopyralid + phenoxy {[2,4-D(2,4-dichlorophenoxyacetic acid} or MCPA {(2-methyl-4-chloro phenoxyacetic acid)]} combinations have been shown to be very effective in controlling Canada thistle in grass seed, but there are questions about crop injury from these herbicides.

The objective of this study was to determine the effect of these herbicides on the viability of seed produced by the treated crop.

## Materials and Methods

Five grass species were of primary interest: annual ryegrass (*Lolium multiflorum*), perennial ryegrass (*Lolium perenne*), fine fescue (*Festuca ruba*), tall fescue (*Festuca arundinacea*), and Kentucky bluegrass (*Poa pratensis*). In the spring of 1988, 12 experiments were initiated in representative grass seed growing regions of the Pacific Northwest. Two sites were selected for each species except bluegrass as shown in Table 1. Four sites were selected for bluegrass to help represent the more variable conditions it is grown under. At each site, weed-free areas were chosen to eliminate competitive effects. The seven herbicide treatments shown in Table 2 were applied in a RCB design with 4 replications. Growth stage at application varied--tillering to jointing (ryegrasses and fescues) and late flag leaf to boot stage (bluegrasses). Two visual evaluations of crop injury were made at roughly 15 and 60 days after treatment. At maturity, enough seed heads were randomly clipped from each plot to make a 0.5 lb composite sample for each treatment at each site. The samples were hand-threshed and tested for percentage germination (400-seed sample) at the Idaho State Seed Laboratory, Boise, ID.

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[1]Dow Chemical Company, Spokane, WA

Table 1. Experiment locations and cultivars tested for broadleaf herbicide tolerance, listed by species.

| SPECIES | LOCATION | CULTIVAR |
|---|---|---|
| perennial ryegrass | Junction City, OR | Rodeo |
| | Salem, OR | Caliente |
| annual ryegrass | Tangent, OR | Gulf |
| | Tangent, OR | Gulf* |
| fine fescue | Jefferson, OR | Wilma |
| | Salem, OR | Enjoy |
| tall fescue | Donald, OR | Bonanza |
| | Rickreal, OR | Mustang |
| Kentucky bluegrass | Latah, WA | Dawn |
| | Latah, WA | Argyle |
| | Nezperce, ID | Newport* |
| | Post Falls, ID | Ram I |

* Seed samples not taken.

Table 2. Herbicide treatments evaluated in grass seed tolerance experiments.

| HERBICIDE | RATE | TRADE NAME |
|---|---|---|
| | (lb ai/a) | |
| clopyralid | Ø.12 | STINGER[1] |
| clopyralid | Ø.25 | STINGER |
| clopyralid + 2,4-D amine | Ø.12 + Ø.62 | CURTAIL[1] |
| clopyralid + 2,4-D amine | Ø.24 + 1.25 | CURTAIL |
| clopyralid + MCPA ester | Ø.13 + Ø.75 | CURTAIL M |
| dicamba + 2,4-D amine | Ø.13 + Ø.52 | BANVEL[2] + 2,4-D |
| bromoxynil | Ø.5Ø | BUCTRIL[3] |

[1] Trademark of the Dow Chemical Company
[2] Banvel (trademark of Sandoz, Ltd.) plus 2,4-D was used as the commercial standard at the Oregon sites (fescues, ryegrasses).
[3] Buctril (trademark of Rhone-Poulenc, Inc.) was used as the commercial standard at the bluegrass sites.

## Results and Discussion

Overall, seed germination was very consistent within the three genera of grasses tested--germination of bluegrass seed was slightly lower than the fescues or ryegrasses due to harvesting too early at two of the three sites that were sampled (see Table 3). Seed viability was not affected by the herbicides in any species.

Table 3. Effect of seven broadleaf herbicides on the viability of seed produced by three genera of treated grasses.

| HERBICIDE | RATE | Lolium | Festuca | Poa |
|---|---|---|---|---|
| | (lb ai/a) | ----- (% | germination) | ------ |
| clopyralid | 0.12 | 95[1] | 93 | 80 |
| clopyralid | 0.25 | 94 | 93 | 84 |
| clopyralid + 2,4-D amine | 0.12 0.62 | 95 | 96 | 87 |
| clopyralid + 2,4-D amine | 0.24 1.25 | 95 | 94 | 82 |
| clopyralid + MCPA ester | 0.13 0.75 | 92 | 94 | 85 |
| dicamba + 2,4-D amine | 0.13 0.52 | 94 | 95 | -- |
| bromoxynil | 0.50 | -- | -- | 85 |
| untreated control | -- | 95 | 94 | 82 |
| C.V. | | 3.14 | 3.48 | 5.71 |
| N | | 3 | 4 | 3 |

[1] There were no significant differences among treatments. Mean separation by DMRT at 5% level.

When present, visual injury caused by the herbicides was generally very minor (5% or less) and decreased over time (see Table 4). Bluegrass (data not shown) exhibited no injury. Annual ryegrass showed the greatest visual injury (8 to 11%), while perennial ryegrass and fine fescue responded similarly (4 to 6%). With all three grasses, the greatest injury was caused by dicamba + 2,4-D amine (0.13 + 0.52 lb ai/acre), clopyralid + 2,4-D amine (0.24 + 1.25 lb ai/acre), and clopyralid + MCPA ester (0.13 + 0.75 lb. ai/acre) (see Table 5). The tall fescue response was highly variable, so the observed injury was not statistically significant, however, it seemed to be the same as perennial ryegrass and fine fescue except it was less sensitive to MCPA.

Although it is not known whether the levels of herbicide injury observed would have translated into decreases in seed yield, it appears that the potential for clopyralid and clopyralid plus phenoxy combinations to injure grass seed crops is no different (and possibly less) than that of other auxin-type herbicide combinations.

Table 4. Percentage injury to two genera of grasses at two intervals after treatment with one of six broadleaf herbicides.

| HERBICIDE | RATE | Lolium | | Festuca | |
|---|---|---|---|---|---|
| | | EARLY[1] | LATE | EARLY | LATE |
| | (lb ai/a) | --------- (% injury[2]) | | | ---------- |
| clopyralid | Ø.12 | Ø.8a | Ø.Øa | Ø.3a | Ø.Øa |
| clopyralid | Ø.25 | 2.8a | Ø.3a | 1.3ab | Ø.Øa |
| clopyralid + 2,4-D amine | Ø.12 Ø.62 | 2.5a | Ø.3a | 2.Øab | Ø.Øa |
| clopyralid + 2,4-D amine | Ø.24 1.25 | 6.3c | 2.Øb | 6.3d | 1.3a |
| clopyralid + MCPA ester | Ø.13 Ø.75 | 5.5b | 1.3ab | 3.Øbc | 1.Øa |
| dicamba + 2,4-D amine | Ø.13 Ø.52 | 8.5c | 4.Øc | 4.7cd | 1.3a |
| untreated control | -- | Ø.Øa | Ø.Øa | Ø.Øa | Ø.Øa |
| C.V. | | 46 | 87 | 54 | 128 |
| N | | 4 | 4 | 3 | 3 |

[1] The early evaluation interval was about 15 days after treatment (DAT) the second evaluation interval was about 6Ø DAT.
[2] Mean separation by DMRT at 5% level.

Table 5. Percentage injury to four species of grass fifteen days after treatment with one of six broadleaf herbicides.

| HERBICIDE | RATE | Lolium | | Festuca | |
|---|---|---|---|---|---|
| | | ANNUAL | PERENNIAL | FINE | TALL |
| | (lb ai/a) | ----------- (% injury[1] | | ) | ----------- |
| clopyralid | Ø.12 | 1.5a | Ø.Øa | Ø.5a | Ø.Øa |
| clopyralid | Ø.25 | 4.5ab | 1.Øa | 2.Øb | Ø.Øa |
| clopyralid + 2,4-D amine | Ø.12 Ø.62 | 4.5ab | Ø.5a | 2.Øb | 1.Øa |
| clopyralid + 2,4-D amine | Ø.24 1.25 | 9.Øbc | 3.5b | 5.5c | 4.Øa |
| clopyralid + MCPA ester | Ø.13 Ø.75 | 7.5bc | 3.5b | 4.5c | Ø.5a |
| dicamba + 2,4-D amine | Ø.13 Ø.52 | 11.Øc | 6.Øc | 4.5c | 3.Øa |
| untreated control | -- | Ø.Øa | Ø.Øa | Ø.Øa | Ø.Øa |
| C.V. | | 4Ø | 38 | 2Ø | 185 |

[1] Mean separation by DMRT at 5% level.

# EFFECT OF CLOPYRALID ON ROTATIONAL CROPS

C. Carson, M. McKone, D. Gaiser, M. Peterson[1]

Abstract. Rotational crop studies were conducted with clopyralid {3,6-dichloro-2-pyridinecarboxylic acid}, at 10 locations during 1988. Locations encompassed geography from the Pacific Northwest across the North Central states.

Clopyralid was applied at 0, 70, 140, 280, 560 g ae/ha to spring wheat at Zadoks 14-31 during the 1987 field season. Crop residues, straw and stubble, were incorporated into the plots in the fall. Sensitive broadleaf crops: soybeans, alfalfa, potatoes, beans, peas, lentils, sunflower, and safflower were planted in the spring of 1988, 10-11 months after clopyralid treatment.

At rates up to 560 g ae/ha no significant effects were seen on yield of soybean, alfalfa, potatoes, beans, sunflower, or safflower. Peas and lentils showed greater sensitivity with significant yield responses at 280 and 560 g ae/ha.

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[1]Dow Chemical Company, Midland, MI

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# TOLERANCE OF ALFALFA, PINTO BEANS, SAFFLOWER, AND SUNFLOWERS TO SOIL RESIDUES OF CLOPYRALID

D.M. Wichman[1], P.K. Fay[2], and E.S. Davis[2]

Abstract. Tolerance of alfalfa, pinto beans, safflower, and sunflower to soil residues of clopyralid {3,6-dichloro-2-pyridinecarboxylic acid} was evaluated in field studies. Clopyralid, at 1, 2, 4, and 8 oz ai/A was applied to spring wheat in the 4-leaf stage. Eleven months after the clopyralid was applied, the test crops were planted. Tolerance was determined by plant numbers, net weight, height, and seed production. Alfalfa, pinto beans, and sunflower seedlings exhibited minor injury from the high clopyralid rates. The clopyralid residues did not have a significant effect on safflower.

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# EFFECTS OF HERBICIDES ON ANNUAL BROADLEAF WEEDS IN PUMPKINS GROWN ON COARSE-TEXTURED SOILS

R.N. Arnold, E.J. Gregory, and D. Smeal[1]

Abstract. The purpose of this study is to evaluate the efficacy of individual and/or herbicide combinations applied preemergence surface for annual broadleaf

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weed control in pumpkins (var. Connecticut Field). Preemergence treatments applied alone or in combination were trifluralin {2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine}, pendimethalin {(*N*-1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine)}, ethalfluralin {(*N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine)}, bensulide {*O,O*-bis(1-methylethyl)*S*-[2-[(phenylsulfonyl)amino]ethyl]phosphorodithioate}, and metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide}. Soil type was a Wall sandy loam with a pH of 7.8 and an organic matter content of less than 1 percent. Russian thistle (*Salsola iberica Sennen & Pau*) prostrate and redroot pigweed (*Amaranthus blitoides S.Wats*, and *Amaranthus retroflexus* L.) infestations were heavy and kochia (*Kochia scoparia* (L.)Schrad.) infestations were moderate throughout the experimental area. All treatments gave 85 percent or better control of annual broadleaf weeds. The three combinations of trifluralin plus metolachlor plus pendimethalin at 0.5 + 1.0 + 0.5 lb ai/A caused slight pumpkin injury of 10 percent. Pumpkin yields were 22 to 36 T/A higher in herbicide-treated plots compared to the check.

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## CLOMAZONE AS AN ALTERNATIVE TO DINOSEB FOR WEED CONTROL IN GREEN PEAS

Stott W. Howard, Carl R. Libbey, and Eric R. Hall[1]

Abstract. The cancellation of the dinoseb {2-(1-methylpropyl)-4,6-dinitrophenol} registration has left the processing pea industry in a tenuous position as the alternatives were inadequate to meet the broadleaved weed control requirements of this crop. In addition, the short soil residual of dinoseb did not prevent preferred crop rotation systems of western Washington agriculture. Clomazone {2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone} appears to have the greatest potential to fill the weed control void left by the cancellation of dinoseb. When used in green peas, it must be applied at 0.38 to 0.56 kg/ha preplant and immediately incorporated. Adequate and thorough incorporation is essential for good weed control and minimizing off-target movement of this volatile herbicide. Clomazone will not adequately control some of the more problematic broadleaved weeds and, therefore, must be used in tandem with a metribuzin preemergence {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} or bentazon postemergence {3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide}. While these treatments will control many weeds, they will also restrict the free crop rotation that was possible with the use of dinoseb.

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## STRAWBERRY RESPONSE TO PREPLANT APPLICATIONS OF GLYPHOSATE

Harry S. Agamalian[1]

Abstract. Commercial applications of glyphosate {*N*-(phosphonomethyl)glycine} prior to planting of strawberries for annual weed control resulted in severe crop injury.

Greenhouse and field experiments conducted on three soil types caused injury to strawberries (cultivar Chandler). Glyphosate toxicity to strawberries was influenced by soil texture and dosage. Experiments were conducted on Marina sand, Elkhorn loamy sand, and Chualar sandy clay loam. Glyphosate was applied at 2.1, 4.2., and 8.4 kg ai/ha.

Data was obtained from greenhouse experiments on crop symptoms, runner weights, shoot and root dried weights. Glyphosate leaf symptoms were observed on the second developed strawberry leaf with all three rates of the herbicide. When glyphosate was compared to equal concentrations, strawberry phytotoxicity increased with the coarse-textured soils. Crop injury was measured at all three herbicide dosages on sand and loamy sand soils.

Glyphosate-treated clay loam soil resulted in strawberry injury at 4.2 and 8.4 kg ai/ha.

One field experiment, using Marina sand, caused significant strawberry yield reductions at the 4.2 and 8.4 kg ai/ha glyphosate treatments.

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## THE INFLUENCE OF TEMPERATURE AND APPLICATION TIME OF DAY ON THE CONTROL OF BLACK NIGHTSHADE AND CROP VIGOR IN PROCESSING TOMATOES

L. Clement, R. Jessee, and G. Boyd[1]

One of the most common and economically competitive weeds found in California processing tomato fields is black nightshade (*Solanum nigrum*, L.). During the past several years, considerable research has been conducted to find selective herbicides for nightshade control that also provide acceptable crop safety. Over the years many products and methods of application have been evaluated. Current research has centered on the use of acifluorfen-sodium, {sodium 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoic acid} at early stages of growth of the target weed and the tomato crop to maximize weed control and maintain acceptable crop tolerance of the product.

Weed research programs, in several tomato producing counties, have centered around the use of low rates of active ingredient, varying water volumes, and split applications to achieve optimum control parameters with acifluorfen. Table 1, represents summary data taken from black nightshade control trials with acifluorfen in tomato fields near Dixon, California. Early applications of acifluorfen (i.e., 1-2 leaf stage) and at low rates (i.e., 1/32 lb ai/A) were not damaging to the tomato crop; however, they proved to be ineffective in significant black nightshade control. Treatments at higher rates and at slightly

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advanced growth stages and split applications have shown to be the most effective method for black nightshade control.

In many of these trials, it was observed that the time of day (TOD) of acifluorfen application appeared to be influencing the degree of control and the resulting crop sensitivity. Results from several trials were erratic and inconsistent with other trials treated under similar conditions. The trials were either treated in the early mornings (0600 to 0900 hours) or in the mid-afternoon (1400 to 1600 hours) depending on field conditions. It appeared that ambient temperature was the common factor creating these differences between trials. This was first observed in 1984 and again in 1985. Figure 1 represents the linear relationship between daily temperatures, weed control, and crop vigor indexes show a positive relationship with r = 0.803. As temperatures increased, there was a significant increase in weed control at all rates tested. Correspondingly, there was a decrease in crop vigor as temperatures increased at all rates of acifluorfen with the correlation coefficient equaling 0.916.

In 1986, 1987, and 1988, trials were established to determine precisely at what time of day (TOD) weed control and crop sensitivity to acifluorfen would peak while maintaining yields, and utilizing established rates developed in other trials and by other researchers. Thermographs were placed in the field two days prior to treatment and remained for two days following treatment to establish temperature averages.

Table 2 represents data from the first investigation into this phenomenon in 1986. In this trial only mid-morning and mid-afternoon application times were evaluated. The data shows there was a significant influence between ambient air temperatures and crop sensitivity and subsequent weed control. Treatments made during cooler periods gave significantly different results than those treatments applied during warmer periods of the day. Weed control was enhanced with increasing temperatures while crop vigor was reduced.

In 1987 the parameters were expanded and the rates of acifluorfen were redefined to include a narrow range of product rates and to determine precisely during what time of day this phenomenon would influence weed control and crop sensitivity to acifluorfen applications. Table 3 shows there was an increase in the amount of weed control and a reduction in crop vigor between treatments at 0600 hours and 0900 hours; the average yields were not significantly different. As daytime temperatures increased, there was an increase in the amount of control of black nightshade, but a corresponding reduction in crop vigor and a significant yield reduction over early morning applications. Treatments at 1200, 1500, and 1800 hours showed the same phenomenon; however, yields were significantly different from the 0600 and 0900 hours treatments. All yields were significantly different from the untreated check.

Data from Table 4, from trials conducted in 1988, demonstrated once again the influence of the average daily temperature during time of application on the degree of weed control and subsequent relationship of crop sensitivity to aciflurorfen. This data is consistent with previous years control, and a reduction in crop vigor between treatments at 0600 hours and 0900 hours, the average yields were not significantly different. As daytime temperatures increased, there was an increase in the amount of control of black nightshade, but a corresponding reduction in crop vigor and a significant yield reduction over early morning applications. Treatments at 1200, 1500, and 1800 hours showed the same phenomenon; however, yields were significantly different from the 0600 and 0900 hours treatments. All yields were significantly different from the untreated check.

Figure 1. Temperature comparisions between weed control and crop vigor indexes for acifluorfen trials between 1986 and 1988.

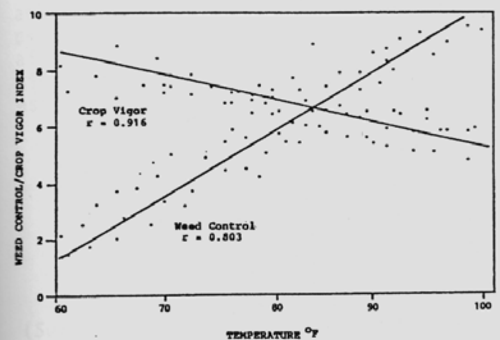


Table 1. Black nightshade control in processing tomato trial summary 1985-1988 with acifluorfen at Dixon, California.

| Timing | Rate lb ai/a | Yield t/a | Crop Vigor Index* | Weed Control Index* |
|---|---|---|---|---|
| 1-2 leaf | 1/3 | 29.7 | 1.1 | 3.8 |
| 2-4 leaf | 1/16 | 31.2 | 1.5 | 5.9 |
| 2-4 leaf | 1/8 | 32.1 | 2.2 | 7.6 |
| Layby | 1/4 | 31.6 | 2.5 | 9.1 |
| Layby | 3/8 | 29.7 | 5.0 | 9.8 |
| 1-2 leaf + 2-4 leaf | 1/32 + 1/16 | 30.1 | 1.3 | 8.0 |
| 1-2 leaf + 2-4 leaf | 1/16 + 1/16 | 32.3 | 1.8 | 8.5 |
| 1-2 leaf + 2-4 leaf | 1/16 + 1/8 | 29.7 | 2.0 | 9.2 |
| 2-4 leaf | 1/8 + 1/8 | 27.2 | 4.1 | 9.7 |
| UNHOED CHECK | | 24.7 | 0.1 | 0.2 |

*INDEX - 0 = no weed control, and/or no crop damage
10 = complete weed control, crop death

Table 2. Data from 1986 acifluorfen black nightshade control trial in processing tomatoes as influenced by time of day (TOD) of application at Dixon, California.

| Rate lb ai/a | TOD | Yield t/a | Ave. Yield /TOD | Crop Vigor Index* | Weed Control Index* |
|---|---|---|---|---|---|
| 1/32 | A.M. | 34.8 | | 1.23 | 3.38 |
| 1/16 | A.M. | 29.9 | 31.6 | 1.43 | 6.80 |
| 1/8 | A.M. | 32.7 | | 1.60 | 7.03 |
| 1/4 | A.M. | 28.8 | | 2.98 | 7.70 |
| 1/32 | P.M. | 32.9 | | 2.47 | 4.65 |
| 1/16 | P.M. | 25.9 | 27.7 | 2.88 | 6.90 |
| 1/8 | P.M. | 27.8 | | 2.90 | 8.58 |
| 1/4 | P.M. | 24.3 | | 4.98 | 9.35 |
| CHECK | A.M. | 24.3 | | 0.20 | 0.15 |
| CHECK | P.M. | 24.5 | | 0.27 | 0.15 |
| L.S.D. 5% | | 4.2 | | 0.16 | 0.28 |
| % C.V. | | 18.1 | | 5.31 | 3.55 |

Average Temperature A.M. = 70°F
Average Temperature P.M. = 90°F

*INDEX - 0 = no weed control, and/or no crop damage
10 = complete weed control, and/or crop death

Table 3. Data from 1987 acifluorfen black nightshade control trial in processing tomatoes as influenced by time of day (TOD) of application at Dixon, California.

| Rate lb ai/a | TOD | Yield t/a | Ave. Yield/TOD | Weed Control Index* | Crop Vigor Index* | Average °F |
|---|---|---|---|---|---|---|
| 1/32 | 0600 hrs | 33.1 | | 4.3 | 0.5 | |
| 1/16 | 0600 hrs | 34.9 | 34.2 | 4.5 | 0.8 | 62.2 |
| 1/8 | 0600 hrs | 34.6 | | 6.5 | 1.8 | |
| 1/32 | 0900 hrs | 33.0 | | 5.0 | 0.8 | |
| 1/16 | 0900 hrs | 34.8 | 34.1 | 5.5 | 1.3 | 75.3 |
| 1/8 | 0900 hrs | 34.4 | | 7.3 | 2.3 | |
| 1/32 | 1200 hrs | 30.7 | | 5.3 | 1.3 | |
| 1/16 | 1200 hrs | 32.0 | 31.2 | 6.3 | 1.8 | 88.6 |
| 1/8 | 1200 hrs | 30.9 | | 7.5 | 2.8 | |
| 1/32 | 1500 hrs | 30.1 | | 5.8 | 2.3 | |
| 1/16 | 1500 hrs | 32.3 | 30.6 | 6.5 | 2.5 | 95.9 |
| 1/8 | 1500 hrs | 29.4 | | 8.0 | 3.8 | |
| 1/32 | 1800 hrs | 31.5 | | 5.8 | 2.3 | |
| 1/16 | 1800 hrs | 31.8 | 31.8 | 6.3 | 2.3 | 89.5 |
| 1/8 | 1800 hrs | 31.0 | | 7.5 | 3.3 | |
| Untreated Check | | 27.6 | 27.6 | 0.0 | 0.0 | |
| LSD 5% level | | 0.73 | 1.53 | 0.95 | 1.53 | |
| %CV | | 8.05 | 2.69 | 7.89 | 2.09 | |

*INDEX - 0 = no weed control, and/or no crop damage
10 = complete weed control, crop death

Table 4. Data from 1988 acifluorfen black nightshade control trial in processing tomatoes as influenced by time of day (TOD) of application at Dixon, California.

| Rate lb ai/a | TOD | Yield t/a | Average Yield/TOD | Weed Control Index* | Crop Vigor Index* | Average °F |
|---|---|---|---|---|---|---|
| 1/32 | 0600 hrs | 29.6 | | 4.5 | 0.2 | |
| 1/16 | 0600 hrs | 30.4 | 30.2 | 4.7 | 0.7 | 65.3 |
| 1/8 | 0600 hrs | 30.6 | | 6.6 | 1.5 | |
| 1/32 | 0900 hrs | 30.0 | | 5.3 | 0.7 | |
| 1/16 | 0900 hrs | 31.5 | 30.4 | 5.8 | 1.5 | 72.9 |
| 1/8 | 0900 hrs | 29.7 | | 7.8 | 2.5 | |
| 1/32 | 1200 hrs | 27.5 | | 5.8 | 1.4 | |
| 1/16 | 1200 hrs | 29.1 | 28.5 | 6.8 | 2.0 | 85.5 |
| 1/8 | 1200 hrs | 28.9 | | 7.8 | 3.0 | |
| 1/32 | 1500 hrs | 28.5 | | 6.6 | 2.8 | |
| 1/16 | 1500 hrs | 27.0 | 27.7 | 6.8 | 2.9 | 98.9 |
| 1/8 | 1500 hrs | 27.6 | | 8.4 | 4.0 | |
| 1/32 | 1800 hrs | 29.8 | | 5.5 | 2.8 | |
| 1/16 | 1800 hrs | 29.2 | 28.6 | 6.5 | 2.6 | 86.7 |
| 1/8 | 1800 hrs | 27.7 | | 7.3 | 3.7 | |
| Untreated Check | | 25.8 | 25.8 | 0.0 | 0.0 | |

*INDEX - 0 = no weed control, and/or no crop damage
10 = complete weed control, crop death

Table 5. Summary Data 1985-88 tomato injury and black nightshade control with acifluorfen with application at varying time of day (TOD) at Dixon, California

| Rate lb ai/a | TOD | Yield t/a | Average Yield/TOD | Weed Control Index* | Crop Vigor Index* | Ave. °F |
|---|---|---|---|---|---|---|
| 1/32 | 0600 | 31.4 | | 4.4 | 0.3 | |
| 1/16 | 0600 | 32.7 | 32.2 | 4.6 | 0.7 | 63.8 |
| 1/8 | 0600 | 32.6 | | 6.6 | 1.6 | |
| 1/32 | 0900 | 31.5 | | 5.2 | 0.7 | |
| 1/16 | 0900 | 33.2 | 32.2 | 5.7 | 1.4 | 74.1 |
| 1/8 | 0900 | 32.1 | | 7.5 | 2.4 | |
| 1/32 | 1200 | 29.1 | | 5.5 | 1.3 | |
| 1/16 | 1200 | 30.6 | 29.9 | 6.5 | 1.9 | 87.1 |
| 1/8 | 1200 | 29.9 | | 7.7 | 2.9 | |
| 1/32 | 1500 | 29.3 | | 6.2 | 2.5 | |
| 1/16 | 1500 | 29.7 | 29.2 | 6.8 | 2.8 | 97.4 |
| 1/8 | 1500 | 28.5 | | 8.2 | 3.9 | |
| 1/32 | 1800 | 30.7 | | 5.7 | 2.5 | |
| 1/16 | 1800 | 30.5 | 30.2 | 6.4 | 2.4 | 88.1 |
| 1/8 | 1800 | 29.4 | | 7.4 | 3.5 | |
| Check | | 25.8 | 25.8 | 0.0 | 0.0 | |

1) INDEX - 0 = no weed control, and/or no crop damage
10 = complete weed control, crop death

Table 5 represents a summary of all collected data from trials and observations between 1985 and 1988. it can be concluded that with the product acifluorfen the time of day of application significantly effects the degree of crop sensitivity to the product and the degree of black nightshade control. It is further suggested that treatments of acifluorfen on processing tomatoes be applied during the cooler early morning hours to reduce crop sensitivity to the product. Although optimum weed control occurred with treatments in the mid afternoon, crop vigor was reduced significantly along with the yield. Black nightshade control with acifluorfen is considered to be acceptable within established parameters.

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## HAIRY NIGHTSHADE AND BLACK NIGHTSHADE CONTROL IN CANNING TOMATOES

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Hairy nightshade (*Solanum sarachoides* L. sendter) and black nightshade (*Solanum nigrum* L.) are widespread weed problems in California processing tomatoes (*Lycopersicon esculentum*). There is a 68 million dollar loss due to hoeing costs and yield reductions. Preplant incorporated herbicides have eliminated many common weed species to compete with tomatoes leaving black nightshade the predominant uncontrolled species.

Metham {*Methylcarbamodithioc acid*} (sodium salt of metham) was applied in numerous trials preplant subsurface layered 25 to 200 gal/a. The 50 gal/a rates provided the most economic control with over 80 percent reduction of black nightshade and excellent tomato tolerance. Hand labor costs were reduced by 73 percent of the control hand labor cost.

Diethatyl-ethyl {*N*-(chloroacetyl)-*N*-(2,6-diethylphenyl)glycine} was applied preplant power tiller incorporated and preemergence sprinkler incorporated. In one preemergence study, black nightshade was reduced over 80 percent with yields over 60 tons per acre compared to 30 tons in the control. In other studies preemergence application of diethatyl-ethyl were more injurious to tomatoes compared to preplant incorporated treatments. Tomato stand reduction was directly correlated to rates from 1.0 to 4.0 lb ai/A.

Metribuzin {4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one} was applied postemergence at various rates as single and multiple applications to tomatoes in the 2- to 3-leaf stage and hairy nightshade cotyledon to the 3-leaf stage. Rates ranged from 0.09 to 0.75 lb ai/A. A single application of 0.20 lbs ai/A gave 85 percent control with early tomato vigor reduction or 23 percent and phytotoxic burn of 13 percent. A split application rate of 0.12 lb ai/A followed 8 days later with 0.20 lb ai/A gave 83 percent control, 30 percent tomato vigor reduction, and 18 percent phytotoxic burn. The tomatoes grew out of the vigor reduction by harvest. In general, the split application gave significantly better nightshade control.

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[1]U.C. Cooperative Extension, [1]Sacramento County, [2]Yolo County, [3]San Joauqin County

TABLE 1: Metham spray blade application in processing tomatoes

| Metham gal/A | Percent Black Nightshade Control | Hand Labor Cost/A $ | Tomato Vigor Reduction | Tomato Stand Reduction |
|---|---|---|---|---|
| 0 | 0 | 77 | 0.0 | 0.0 |
| 50 | 95 | 21 | 0.0 | 0.0 |
| 75 | 97 | 23 | 0.0 | 0.0 |
| 100 | 96 | 22 | 0.0 | 0.0 |
| 125 | 96 | 20 | 0.0 | 0.0 |

TABLE 2: Pre-emergence black nightshade control with diethatyl-ethyl

| Treatment | Rate lb ai/A | Percent Black Nightshade Control | Yield Tons/A |
|---|---|---|---|
| diethatyl-ethyl | 2.0 | 81 | 62.5 |
| diethatyl-ethyl | 4.0 | 93 | 62.3 |
| acifluorfen | 0.5 | 89 | 61.7 |
| Control | --- | 0 | 30.3 |

C.V. = 16.9 LSD @ 5% = 12.9

TABLE 3: Preplant incorporated diethatyl-ethyl and tomato stand reduction

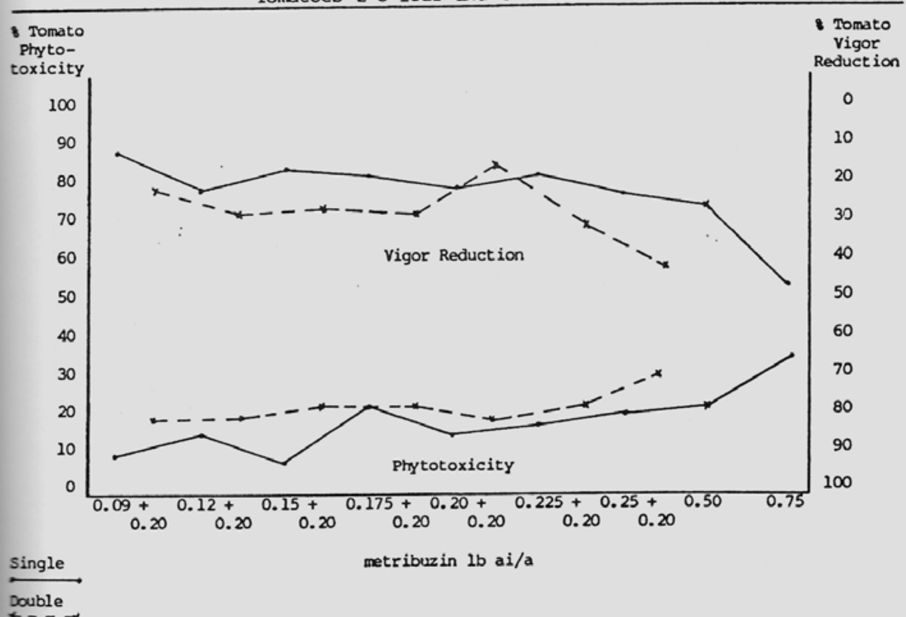
| Treatment | Rate lb ai/a | Number of Tomato Plants Per 20 Feet 08/22/88 | Phyto-toxicity 08/22/88 |
|---|---|---|---|
| diethatyl-ethyl | 1.0 | 74 | 0.0 |
| diethatyl-ethyl | 1.5 | 60 | 0.0 |
| diethatyl-ethyl | 2.0 | 53 | 0.0 |
| diethatyl-ethyl | 2.5 | 54 | 0.0 |
| diethatyl-ethyl | 3.0 | 44 | 0.0 |
| diethatyl-ethyl | 3.5 | 43 | 0.0 |
| diethatyl-ethyl | 4.0 | 43 | 0.0 |
| pebulate | 6.0 | 68 | 0.0 |
| napropamide | 2.0 | 90 | 0.0 |
| Control | --- | 74 | 0.0 |

NS @ 5% level

TABLE 4: Single and split applications of metribuzin
Tomatoes 2-3 and 3-4 leaf; Hairy Nightshade cotyledon to 3 leaf

| Treatment | Rate lb ai/A | Percent Hairy Nightshade Control |
|---|---|---|
| metribuzin | 0.09 | 0 |
| metribuzin | 0.09 +0.20 | 65 |
| metribuzin | 0.12 | 45 |
| metribuzin | 0.12 +0.20 | 83 |
| metribuzin | 0.15 | 55 |
| metribuzin | 0.15 +0.20 | 83 |
| metribuzin | 0.175 | 56 |
| metribuzin | 0.175+0.20 | 75 |
| metribuzin | 0.20 | 85 |
| metribuzin | 0.20 +0.20 | 94 |
| metribuzin | 0.225 | 80 |
| metribuzin | 0.225+0.20 | 88 |
| metribuzin | 0.25 | 79 |
| metribuzin | 0.25 +0.20 | 89 |
| metribuzin | 0.5 | 85 |
| metribuzin | 0.75 | 85 |
| control | ---- | 0 |

TABLE 5: Tomato phytotoxicity and vigor reduction with single and double applications of metribuzin Tomatoes 2-3 leaf and 3-4 leaf



## CHILE PEPPER (*CAPSICUM ANNUUM* L.) RESPONSE TO METOLACHLOR

J. Schroeder[1]

Abstract. Metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide} was registered in 1985 for use in chile peppers. The herbicide has caused crop injury under commercial use; however, factors contributing to the injury have not been determined. Therefore, four chile pepper cultivars were evaluated for tolerance to metolachlor in field experiments at Las Cruces (Belen clay loam, 0.98% OM, pH 7.81) and Artesia (Harkey very fine sandy loam, 2.1% OM, pH 7.75), New Mexico. Experiments were established with a split plot treatments arrangement in a randomized complete block design. Main plots were chile cultivars 'NuMex R Naky', 'NM 6-4', 'TAM', and a coastal cultivar (proprietary). Subplots were metolachlor at 0, 056, 1.12, 2.24, and 4.48 kg ai/ha applied preplant incorporated on raised plant beds. Effects attributable to a cultivar by rate interaction did not occur at either location. At Las Cruces, metolachlor did not insure or reduce yield of chile peppers compared to the nontreated controls. At Artesia, however, metolachlor at 2.24 and 4.48 kg/ha reduced pepper fresh weight to 86 and 59% of the nontreated controls, respectively. A greenhouse study evaluated the response of chile NM 6-4 to metolachlor at 0, 0.125, 0.25, 0.5, 0.75, 1.0, 1.5, and 2.0 µg/g Belen clay loam and Harkey very fine sandy loam soils. In the Belen soil, metolachlor at 0.5 µg/g significantly reduced total plant fresh weight to 81% of the control. Metolachlor reduced root fresh weight (64% of the control at 0.5 µg/g more than shoot fresh weight (94% of the control at 0.5 µg/g). Similarly, metolachlor at 0.75 µg/g reduced total plant, root, and shoot fresh weights to 83, 68, and 96% of the nontreated control, respectively, in the Harkey soil.

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## HERBICIDE COMBINATIONS FOR BROADLEAF WEED CONTROL IN GREEN BEANS

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Abstract. Field trials at three locations in western Oregon compared combinations of new and registered herbicides for use in green beans. Motivation for this research was the imminent change in the registration status of dinoseb {2-(1-methylpropyl)-4,6-dinitrophenol}, which has served as a basic part of the herbicide program for the green bean industry of Oregon. Although the primary objective included finding an alternative to dinoseb effective primarily in controlling broadleaf species, many of the herbicide combinations constitute a complete herbicide program including their effectiveness for grass control.

Standard grower practices for green bean culture were used in these trials. Each experiment consisted of four replications with 8 by 30 ft individual plots. Preplant herbicides (PPI) were soil incorporated by power driven rotary tillers, whereas preemergence herbicides were activated by irrigation or rainfall. Crop

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[1]Oregon State University, Corvallis, OR 97331and weed response to herbicide

and weed response to herbicide treatments were evaluated on one or more dates in each trial, and yields were calculated from single hand harvests of 10 ft of row from each plot. Data were subjected to analysis of variance and means compared by LSD's.

Satisfactory control of a number of weed species with adequate safety to the bean crop was obtained with a number of herbicides and herbicide combinations. Among registered herbicide treatments (Table 1), promising alternatives to dinoseb were chloramben {3-amino-2,5-dichlorobenzoic acid} and metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)-acetamide}. Although metolachlor was ineffective in controlling cruciferous weeds, yields were not significantly reduced by interference from these weeds. Chloramben was less effective than some other herbicides in controlling composite family weeds, but again, this did not significantly detract from its yield overall effectiveness. Plots treated with pendimethalin {(*N*-1-ethylpropyl)-3,4-dimethyl-2,6,dinitrobenzanamine)} suffer bean losses. Crop injury was not observed in plots (not reported here) with preemergence applications of pendimethalin left on the soil surface.

Among the herbicides not registered for use on green beans in 1988 (Table 2), imazethapyr {(±)-2-[4,5-dihydro-4-methyl-4-(methylethyl)-5-oxo-*1H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid}, and lactofen {(±)-2-ethoxy-1-methyl-2-oxoethyl 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate} show promise for inclusion in control programs. These materials gave superior selective control in combination with metolachlor. More information on optimum rates, timing, and method of application is needed before their commercial use is considered. Results with fomesafen {5-[2-chloro-4-(trifluromethyl)phenoxy]-*N*-(methylsulfonyl)-2-nitrobenzamide} were inconclusive, and this herbicide should be tested further for its potential use in green beans. The future of clomazone {2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone} for use in green beans would seem questionable from these results. Crop injury occurred in enough plots treated with this herbicide that it appears to have high risk for use in green beans.

Table 1. Weed control and crop response to herbicides registered for use on green beans.

| Herbicide | lb ai/a | Timing | Weed Control Ratings[1] AMARE[2] | AMARE[3] | MATMT[4] | ANTCO[5] | SOLNI[6] | Radish[7] | Yield (T/a) Site 2 | Site 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. trifluralin | 0.75 | PPI | 100 | 92 | 76 | 96 | 14 | 20 | 7.4 | 2.4 |
| 2. pendimethalin | 1.50 | PPI | 100 | 79 | 91 | 90 | 56 | 41 | 4.7 | 1.6 |
| 3. EPTC | 3.50 | PPI | 100 | 69 | 80 | 93 | 58 | 29 | 6.5 | 2.3 |
| 4. metolachlor | 2.00 | Pre | 83 | 94 | 99 | 96 | 98 | 38 | 7.2 | 4.7 |
| 5. metholachlor | 2.00 | PPI | 85 | 63 | 68 | 73 | 75 | 33 | 6.5 | 3.0 |
| 6. metolachlor | 3.00 | PPI | 99 | 69 | 79 | 81 | 58 | 28 | 6.4 | 3.6 |
| 7. chloramben | 2.50 | Pre | 100 | 76 | 78 | 76 | 97 | 92 | 6.5 | 3.7 |
| 8. trifluralin + | 0.75 | PPI | 100 | 90 | 75 | 69 | 40 | 49 | 6.6 | 2.5 |
| metolachlor | 2.00 | PPI | | | | | | | | |
| 9. pendimethalin + | 1.50 | PPI | 96 | 86 | 85 | 81 | 59 | 23 | 4.1 | 2.8 |
| metolachlor | 2.00 | PPI | | | | | | | | |
| 10. EPTC + | 3.50 | PPI | 100 | 97 | 100 | 98 | 78 | 24 | 8.0 | 3.8 |
| metolachlor | 2.00 | PPI | | | | | | | | |
| 11. EPTC + | 3.50 | PPI | 100 | 89 | 75 | 85 | 99 | 84 | 7.2 | 4.0 |
| chloramben | 2.50 | Pre | | | | | | | | |
| 12. metolachlor + | 2.00 | Pre | 96 | 100 | 69 | 75 | 99 | 97 | 6.7 | 3.4 |
| chloramben | 2.50 | Pre | | | | | | | | |
| 13. trifluralin + | 0.75 | PPI | 100 | 99 | 86 | 96 | 99 | 95 | 6.6 | 3.9 |
| EPTC + | 3.50 | PPI | | | | | | | | |
| chloramben | 2.50 | Pre | | | | | | | | |
| 14. trifluralin + | 0.75 | PPI | 100 | 93 | 81 | 99 | 74 | 35 | 6.4 | 3.3 |
| EPTC + | 3.50 | PPI | | | | | | | | |
| metolachlor | 2.00 | PPI | | | | | | | | |
| 15. trifluralin + | 0.75 | PPI | 100 | 100 | 90 | 98 | 97 | 20 | 6.5 | 3.5 |
| EPTC + | 3.50 | PPI | | | | | | | | |
| metolachlor | 2.00 | Pre | | | | | | | | |
| 16. EPTC + | 3.50 | PPI | 100 | 100 | 95 | 98 | 100 | 96 | 7.1 | 3.7 |
| metolachlor + | 2.00 | Pre | | | | | | | | |
| chloramben | 2.50 | Pre | | | | | | | | |
| 17. trifluralin + | 0.75 | PPI | 99 | 99 | 96 | 96 | 100 | 80 | 7.0 | 4.1 |
| EPTC + | 3.50 | PPI | | | | | | | | |
| dinoseb | 4.50 | Pre | | | | | | | | |
| 18. CHECK - weedy | ---- | --- | 0 | 0 | 0 | 0 | 0 | 0 | 2.6 | 1.8 |
| 19. CHECK - weeded | ---- | --- | --- | --- | --- | --- | 98 | 100 | | 4.7 |
| LSD (0.05) | | | 11 | 11 | 44 | 25 | 25 | 22 | 1.7 | 1.4 |

1) Weed control ratings: 0 = no control, 100 = complete control
2) Pigweed, predominantly *Amaranthus retroflexus*, at site 1, evaluated 8 weeks after plot establishment.
3) Pigweed, predominantly *Amaranthus retroflexus*, at site 2, evaluated 9 weeks after plot establishment.
4) Pineappleweed, *Matricaria matricarioides*, at site 2, evaluated 5 weeks after plot establishment.
5) Mayweed chamomile, *Anthemis catula*, at site 2, evaluated 4 weeks after plot establishment.
6) Nightshade, predominantly *Solanum nigrum*, at site 3, evaluated 6 weeks after plot establishment.
7) Daikon radish broadcast to simulate cruciferous weed population at site 3, evaluated 6 weeks after plot establishment.
8) Site 1 was not harvested.

Table 2. Weed control and crop response to herbicides with potential for use on green beans

| | | | Weed Control Ratings[1] | | | | | | Yield (T/a) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Herbicide | lb ai/a | Timing | AMARE[2] | AMARE[3] | MATMT[4] | ANTCO[5] | SOLNI[6] | Radish[7] | Site 1 | Site 2 | Site 3 |
| 1. imazethapyr | 0.062 | Pre | 59 | 100 | 63 | 63 | 97 | 97 | 3.9 | 5.1 | 4.3 |
| 2. imazethapyr | 0.062 | PPI | 70 | 100 | 51 | 54 | 57 | 86 | 7.0 | 5.3 | 4.5 |
| 3. lactofen | 0.25 | Pre | 97 | 86 | 85 | 85 | 96 | 96 | 5.1 | 4.8 | 4.7 |
| 4. lactofen | 0.50 | Pre | 100 | 98 | 100 | 99 | 84 | 81 | 4.5 | 6.2 | 3.9 |
| 5. clomazone | 0.50 | PPI | 51 | 35 | 75 | 70 | 84 | 43 | 3.7 | 3.4 | 2.3 |
| 6. clomazone | 1.00 | PPI | 74 | 60 | 73 | 73 | 90 | 55 | 4.4 | 2.7 | 2.0 |
| 7. trifluralin + | 0.75 | PPI | 100 | 100 | 69 | 73 | 70 | 78 | 4.8 | 4.6 | 4.0 |
| imazethapyr | 0.062 | PPI | | | | | | | | | |
| 8. EPTC + | 3.50 | PPI | 98 | 100 | 71 | 75 | 95 | 91 | 4.4 | 5.9 | 3.4 |
| imazethapyr | 0.062 | PPI | | | | | | | | | |
| 9. metolachlor + | 2.00 | Pre | 78 | 100 | 90 | 93 | 97 | 92 | 3.6 | 6.1 | 4.9 |
| imazethapyr | 0.062 | Pre | | | | | | | | | |
| 10. trifluralin + | 0.75 | PPI | 100 | 100 | 95 | 95 | 98 | 99 | 3.8 | 4.8 | 3.2 |
| lactofen | 0.25 | Pre | | | | | | | | | |
| 11. EPTC + | 3.50 | PPI | 100 | 99 | 95 | 95 | 95 | 86 | 4.7 | 5.5 | 4.3 |
| lactofen | 0.25 | Pre | | | | | | | | | |
| 12. metolachlor + | 2.00 | Pre | 100 | 100 | 95 | 96 | 100 | 89 | 6.2 | 5.3 | 4.2 |
| lactofen | 0.25 | Pre | | | | | | | | | |
| 13. trifluralin + | 0.75 | PPI | 100 | 88 | 70 | 73 | 86 | 43 | 4.4 | 4.2 | 3.0 |
| clomazone | 0.50 | PPI | | | | | | | | | |
| 14. EPTC + | 3.50 | PPI | 99 | 73 | 84 | 84 | --- | --- | 4.8 | 4.3 | --- |
| clomazone | 0.50 | PPI | | | | | | | | | |
| 15. metolachlor + | 2.00 | PPI | 94 | 76 | 85 | 85 | 89 | 45 | 5.7 | 5.6 | 2.6 |
| clomazone | 0.50 | PPI | | | | | | | | | |
| 16. imazethapyr + | 0.062 | PPI | 81 | 100 | 84 | 86 | --- | --- | 5.0 | 3.5 | --- |
| clomazone | 0.50 | PPI | | | | | | | | | |
| 17. lactofen + | 0.25 | Pre | 99 | 96 | 95 | 95 | 100 | 95 | 5.8 | 5.9 | 3.9 |
| clomazone | 0.50 | PPI | | | | | | | | | |
| 18. fomesafen[8] + | 0.375 | Post | 100 | --- | --- | --- | --- | --- | 3.7 | | |
| 19. EPTC + | 3.50 | PPI | 100 | --- | --- | --- | --- | --- | 6.3 | --- | --- |
| fomesafen | 0.25 | Post | | | | | | | | | |
| 20. EPTC + | 3.50 | PPI | 100 | --- | --- | --- | --- | --- | 4.7 | --- | --- |
| fomesafen | 0.375 | Post | | | | | | | | | |
| 21. EPTC + | 3.50 | PPI | 100 | --- | --- | --- | --- | --- | 4.6 | --- | --- |
| fomesafen | 0.50 | Post | | | | | | | | | |
| 22. trifluralin + | 0.75 | PPI | 100 | 99 | 99 | 100 | 100 | 80 | 6.2 | 5.0 | 4.1 |
| EPTC + | 3.50 | PPI | | | | | | | | | |
| dinoseb | 4.50 | Pre | | | | | | | | | |
| 23. CHECK - weedy | ---- | --- | 0 | 0 | 0 | 0 | 0 | 0 | 3.4 | 2.7 | 1.8 |
| 24. CHECK - weeded | ---- | --- | --- | --- | --- | --- | 98 | 100 | | | 4.7 |
| LSD (0.05) | | | 55 | 13 | 18 | 19 | 25 | 22 | 2.0 | 2.0 | 1.4 |

1) Weed control ratings: 0 = no control, 100 = complete control
2) Pigweed, predominantly Amaranthus retroflexus, at site 1, evaluated 8 weeks after plot establishment.
3) Pigweed, predominantly Amaranthus retroflexus, at site 2, evaluated 9 weeks after plot establishment.
4) Pineappleweed, Matricaria matricarioides, at site 2, evaluated 5 weeks after plot establishment.
5) Mayweed chamomile, Anthemis catula, at site 2, evaluated 4 weeks after plot establishment.
6) Nightshade, predominantly Solanum nigrum, at site 3, evaluated 6 weeks after plot establishment.
7) Daikon radish planted broadcast to simulate cruciferous weed population at site 3, evaluated 6 weeks after plot establishment.
8) All fomesafen treatments included additional surfactant (X-77).

# WILD PROSO MILLET (*PANICUM MILIACEUM* L.) CONTROL IN SWEET CORN IN THE WILLAMETTE VALLEY, 1988

D. Curtis, W.S. Braunworth Jr., D. McGrath, and G. Crabtree[1]

Abstract. Wild proso millet continues to spread rapidly in sweet corn growing areas of the Willamette Valley. In order to remain competitive, Oregon growers must learn to manage this introduced weed. Two trials were established in commercial plantings of sweet corn to test the effectiveness of atrazine {6-chloro-*N*-ethyl-*N*'-(1-methylethyl)-1,3,5-triazine-2,4-diamine}, tridiphane {2-(3,5-dichlorophenyl)-2-(2,2,2-trichloroethyl)oxirane}, EPTC {S-ethyl dipropyl-carbamothioate} plus R 29148 plus dietholate, EPTC plus dichlormid, vernolate {*S*-propyl dipropyl-carbamothioate}, alachlor {2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide}, and metolachlor {2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide} combinations.

Both trials were randomized complete block designs with four replications. Plots were 9-ft wide by 30-ft long. Preplant incorporated treatments (PPI) were applied first at both sites and incorporated with a rototiller. 'Jubilee' sweet corn was planted. Preemergence treatments (PRE) were then applied immediately after planting on each site. Site A was planted on May 5, 1988; site B was planted on June 16, 1988. Postemergence treatments were applied at 3 timings relative to wild proso millet's emergence in the non-treated control plots. The first post treatment (POST) was applied at the 2- to 3-leaf stage of the millet; the second (POST2) was 7 days later at both sites; and the third (POST3) at site A was 11 days following the first and 13 days following the first at site B. Carrier volume was 22.68 gal/a delivered at 30 psi pressure through 8003 flat fan nozzles arranged in a double overlap pattern.

Vernolate plus dichlormid applied PPI combined with postemergence combination treatments of tridiphane plus atrazine plus crop oil resulted in superior season-long control at both sites. Other herbicides including pendimethalin {*N*(-1-ethylpropyl)-3,4-dimethyl-2,6,dinitrobenzanamine)}, alachlor {2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide}, metolacher, EPTC plus R 29148 plus dietholate, and EPTC plus dichlormid were not as effective in controlling wild proso millet. Combinations with alachlor and metolachlor were relatively effective at one site but did not perform adequately at the other. Seed collected at one site (Site A) is olive brown to tan, whereas brown to black seed were collected from the other site (Site B).

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WILD PROSO MILLET CONTROL AND YIELD AVERAGES BY TREATMENT

| HERBICIDE | RATE LBai/A | APPLIC. TYPE | SITE A MILLET %CONTROL | SITE A YIELD T/a | SITE B MILLET %CONTROL | SITE B YIELD T/a |
|---|---|---|---|---|---|---|
| tridiphane | 0.75 | PRE | | | | |
| atrazine | 1.50 | PRE | 56 | 4.9 | 0 | 1.6 |
| pendimethalin | 2.00 | PRE | | | | |
| tridiphane | 0.75 | POST | | | | |
| atrazine | 1.00 | POST | | | | |
| crop oil | 1Gal/a | POST | 35 | 6.3 | 46 | 6.1 |
| pendimethalin | 4.00 | PRE | | | | |
| tridiphane | 0.75 | POST | | | | |
| atrazine | 1.00 | POST | | | | |
| crop oil | 1Gal/a | POST | 25 | 6.8 | 80 | 7.8 |
| alachlor | 4.00 | PRE | | | | |
| atrazine | 1.50 | PRE | 86 | 8.8 | 4 | 2.3 |
| alachlor | 4.00 | PRE | | | | |
| tridiphane | 0.75 | POST | | | | |
| atrazine | 1.00 | POST | | | | |
| crop oil | 1Gal/a | POST | 90 | 8.0 | 45 | 6.0 |
| vernolate[3] | 6.14 | PPI | | | | |
| atrazine | 1.50 | PPI | 80 | 7.5 | 44 | 5.8 |
| EPTC[1] | 4.00 | PPI | | | | |
| atrazine | 1.50 | PPI | 30 | 6.9 | 5 | 1.5 |
| EPTC[2] | 4.00 | PPI | | | | |
| atrazine | 1.50 | PPI | 34 | 5.5 | 10 | 2.4 |
| EPTC[2] | 4.00 | PPI | | | | |
| atrazine | 1.50 | PPI | | | | |
| metolachlor | 2.00 | PRE | 79 | 9.8 | 34 | 6.3 |
| vernolate[3] | 6.14 | PPI | | | | |
| tridiphane | 0.75 | POST | | | | |
| atrazine | 1.50 | POST | | | | |
| crop oil | 1Gal/a | POST | 99 | 8.6 | 90 | 9.6 |
| vernolate[3] | 6.14 | PPI | | | | |
| atrazine | 1.50 | PPI | | | | |
| tridiphane | 0.75 | POST | | | | |
| crop oil | 1Gal/a | POST | 92 | 9.2 | 85 | 9.5 |
| vernolate[3] | 6.14 | PPI | | | | |
| tridiphane | 0.75 | POST2 | | | | |
| atrazine | 1.50 | POST2 | | | | |
| crop oil | 1Gal/a | POST2 | 96 | 10.1 | 91 | 9.1 |

WILD PROSO MILLET CONTROL AND YIELD AVERAGES BY TREATMENT
(CONTINUED)

| HERBICIDE | RATE LBai/A | APPLIC. TYPE | SITE A MILLET %CONTROL | SITE A YIELD T/a | SITE B MILLET %CONTROL | SITE B YIELD T/a |
|---|---|---|---|---|---|---|
| vernolate[3] | 6.14 | PPI | | | | |
| tridiphane | 0.75 | POST3 | | | | |
| atrazine | 1.50 | POST3 | | | | |
| crop oil | 1Gal/a | POST3 | 96 | 8.3 | 78 | 7.6 |
| EPTC[1] | 4.00 | PPI | | | | |
| tridiphane | 0.75 | POST | | | | |
| atrazine | 1.50 | POST | | | | |
| crop oil | 1Gal/a | POST | 78 | 7.7 | 51 | 7.1 |
| EPTC[2] | 4.00 | PPI | | | | |
| tridiphane | 0.75 | POST | | | | |
| atrazine | 1.50 | POST | | | | |
| crop oil | 1Gal/a | POST | 81 | 7.6 | 50 | 6.7 |
| check | | | 0 | 0.1 | 0 | 1.3 |
| LSD (0.05) = | | | 23 | 2.6 | 20 | 2.5 |

1) [1] = EPTC + R 29148 + dietholate, [2] = EPTC + dichlormid, [3] = vernolate + dichlormid.

2) Weed control was evaluated ten weeks after corn sowing.

# PERENNIAL TURFGRASSES AS LIVING MULCHES IN OREGON'S HORTICULTURAL CROPS

Ray D. William[1]

Horticultural crops often require management practices that stabilize soils or improve traffic conditions during adverse weather. Orchardists, for example, maintain sod alleys or living mulches between rows coupled with herbicide strips that reduce competition within the tree row.

Recent developments include dwarf turfgrasses and chemical suppression of grasses using sublethal rates of postemergence grass herbicides. These developments offer additional vegetation management strategies for various horticultural cropping systems including vegetables. Cabbage growers who plant late maturing crops for harvest during rainy weather would benefit from management practices that stabilize the soil while ensuring harvest of clean, high-quality produce. Benefits of these living mulches include reduced erosion, greater water infiltration and nutrient retention, improved trafficability, and suppression of undesirable weeds. Potential disadvantages are competition for moisture and cost of turf maintenance. This paper will review the research conducted at Oregon State University since 1984 by graduate students, extension agents, and staff.

## Methods

Trials involving grapes (1, 2, 6, 9, 10, 12, 15), Christmas tress (1, 7), Marion berries (11), and vegetables (5, 8, 13) have been conducted at various sites in western Oregon since 1983 to evaluate several living mulches and associated management practices. Generally, dwarf or intermediate perennial ryegrass cultivars were selected as living mulches, although other grass species were compared in a low maintenance trial. Management strategies compared bare ground with mechanically or chemically mowed perennial ryegrass strips that covered approximately 60 to 75% of the entire soil surface. Chemical suppression involved applications of fluazifop or sethoxydim with 1% (v/v) crop oil or glyphosate broadcast to actively growing grass. Primary data comparisons included grass suppression, soil water use, and crop growth parameters or yields. In addition to standard field procedures, brief descriptions of specific practices are included within subsequent topics.

## Results

Chemical mowing - Perennial ryegrass (*Lolium perenne*) requires management, especially during the spring when living mulches grow rapidly, yet equipment constraints in close-spaced cropping systems limit acceptability by some growers. Sublethal rates of postemergence grass herbicides might suppress ryegrass growth without killing the living mulch. 'Manhattan II' perennial ryegrass was sown as a living mulch with a Brillion seeder. Although fertilizer was compared in two trials conducted in the spring, responses were similar with data being combined. Otherwise, trials were irrigated frequently throughout summer to simulate spring growth conditions.

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Perennial ryegrass foliage and seed heads were suppressed by 75 to 85% (Table 1) for five to seven weeks with sublethal rates of fluazifop {(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid} (0.2 to 0.4 lb ai/A) or sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} (0.08 to 0.10 lb ai/A). Glyphosate {*N*-(phosphonomethyl)-glycine} provided inadequate suppression of ryegrass, although one trial conducted in a pear orchard demonstrated suppression of tall fescue was feasible. Repeated chemical mowing resulted in turf thinning, possibly caused by chemical disruption of physiological reactions which seem to require greater repair than redirecting hormones within the grass following mechanical mowing.

Soil moisture - Perhaps the greatest concern regarding living mulch management in horticultural crops involves conservation of soil moisture during the dry summer in the Pacific Northwest. Moisture blocks were placed at 1, 2, and 3 feet below the sod and monitored for approximately 105 days in 11 trials. Data are presented in water potentials (negative bars) or as water use (mm/day).

Water potentials under weeds or perennial ryegrass regardless of mowing strategy were similar (Table 3), except in 1984 when rainfall occurred frequently throughout the summer (Table 4). Chemical mowing with fluazifop reduced soils moisture requirements in two of six trials, although results were modest (Table 3). One growth chamber trial suggested fluazifop suppressed root growth only 30% compared to the 75-85% (Table 1) for foliage (13). In another trial comparing evapotranspiration between betgrass (*Agrostis tenuis* L.), tall fescue (*Festuca arundinacea* L.), and three perennial ryegrass cultivars, water depletion was similar under low maintenance with no irrigation and infrequent mowing (3).

Crop response - Perennial ryegrass living mulches often provided a quick ground cover with occasional crop competition during the year of establishment (Table 4). Established sod consistently reduced perennial crop yields or yield parameters. Both cabbage and pak choi grown in 1-foot bareground strips representing 35% of the surface area performed better with chemically suppressed perennial ryegrass between rows compared to mowed or unsuppressed ryegrass between the rows (Table 4). Increasing ryegrass seeding rates reduced pak choi yields both years (13).

## Discussion and Conclusions

Although perennial ryegrass establishes quickly, competes against weeds, and provides reasonable wear tolerance (14), evidence suggests that dwarf or intermediate cultivars with or without chemical suppression failed to reduce competition in several horticultural crops. Other management options include reducing the grass seeding rate to reduce competition, but weed infestation likely would increase. Otherwise, perennial ryegrass could be planted as an annual and killed before establishment each year, thereby eliminating competition. Another alternative involves planting horticultural crops into a dead perennial ryegrass sod which would improve soil stability for approximately 12 months.

Worldwide evidence continues to suggest that annual covers coupled with appropriate management strategies may enhance horticultural cropping systems while minimizing adverse practices involving the soil. For example, several cereal grains including specific varieties of barley or cereal rye provide moderate cover while competing and/or suppressing weeds with allelopathic toxins produced within the plant. Other strategies include selection of herbicides that suppress or encourage beneficial vegetation while controlling noxious weeds. Colleagues, for example, have demonstrated that annual bluegrass (*Poa annua*) and chickweed (*Stellaria media*) can predominate as a winter cover following repeated

Table 1. Perennial ryegrass ('Manhatten II') suppression using sublethal rates of herbicides, 1984 to 1986 (1).[1/]

| Chemical suppressant | Rate (lbs/ac) | Rating[2/] (0 to 10) | Number trials |
|---|---|---|---|
| Check | --- | 0 | 9 |
| Sethoxydim + oil[3/] | 0.04 | 5.0 | 8 |
| | 0.06 | 5.9 | 3 |
| | 0.08 | 7.6 | 3 |
| | 0.10 | 7.7 | 3 |
| Fluazifop + oil[3/] | 0.1 | 5.7 | 9 |
| | 0.2 | 7.6 | 8 |
| | 0.4 | 8.6 | 8 |
| Glyphosate | 0.15 | 1.6 | 8 |
| | 0.25 | 2.7 | 8 |
| | 0.35 | 3.9 | 8 |

1/ Perennial ryegrass suppressed similarly between fertilized and non-fertilized plots.
2/ Rated 5 to 7 weeks after treatment; 0 = no suppression, 10 = complete suppression.
3/ Crop oil 10 to 20% more active than non-ionic surfactant.

Table 2. Soil moisture content measured with gypsum blocks for perennial ryegrass living mulch managed in several horticultural crops in Oregon, 1986-88 (5,7,10,11).

| Vegetation management treatment[1/] | Grapes (Wren) | Christmas trees: Kings Valley | Christmas trees: Cottage Grove | 'Marion' berries (Independence): 1987 | 'Marion' berries (Independence): 1988 | Cabbage Corvallis | Lysi-meter |
|---|---|---|---|---|---|---|---|
| | - - - - - - - - - | - (minus bars) - | - - - - | - - - - | - - - - | --- | mm/day |
| Bareground | -2.5 | -1.0 | -0.4 | -0.3 | -9.8 | -1.8 | 2.2 |
| Pr - mowed | -8.3 | -8.7 | -5.9 | -1.3 | -9.0 | -8.0 | 5.0 |
| Pr - chem mow | -7.6 | -6.6 | -5.7 | -1.3 | -10.5 | -4.4 | 5.0 |
| Weedy or (un-suppressed Pr) | -7.6 | -8.8 | -6.1 | - | - | (-9.3) | 5.5 |
| Data - Year | 1987 | 1987/88 | 1987/88 | 1987/88 | | 1986 | 1987 |
| - Weeks | 18 | 16 | 18 | growing season | | 7 | 5 |
| - Depth (cm) | | 30 to 90 | 30 to 90 | 30 to 90 | | 15 to 90 | - |

1/ Bareground maintained with herbicides; Pr = perennial ryegrass 'Manhatten II' mowed as needed or chemically suppressed with 0.2 lb ai/a fluazifop plus 1% (v/v) crop oil; Weedy represents indigenous vegetation.
2/ Multiply bars by 100 for kilo Pascals (kPa); Field capacity represents 0.1 to -0.3 bars whereas water potentials of -14.0 represent wilting point for most crops.

Table 3. Water use by various perennial living mulches in western Oregon vineyards during a wet year (1984) and in 1987 (6,12,15).

| Vegetation management treatment[1/] | Vineyards: Bethel Heights | Sokol Blosser | Knudsen Erath | Vegetable farm (Corvallis) |
|---|---|---|---|---|
| | - - - - - - - | (mm/day) | - - - - - - - | % |
| Bareground (Cult.) | 4.4 | (3.50) | (3.88) | 28.0 |
| Pr - mowed | 5.6[2/] | 3.48[3/] | 3.56[3/] | 21.6[4/] |
| Fescue - Sheep or red | - | 4.06 | (3.96) | - |
| Weedy or (unsup- pressed grass) | - | 3.26 | 3.88 | - |
| Data - Year | 1984 | 1984/85 | 1984/85 | 1987 |
| - Weeks | 7 | 12 | 12 | once |
| - Depth (cm) | 15 to 105 | -- | -- | -- |

1/ Bareground maintained with herbicides or (cultivated) as required; Pr = perennial ryegrass; sheep fescue Covar; and red creeping fescue 'Pennlawn'.
2/ Pr cultivar unknown, but not improved dwarf or intermediate turf type.
3/ Pr cultivar 'Elka'.
4/ Pr cultivar 'Manhatten II'.

Table 4. Summary of horticultural crop responses to vegetation management treatments involving perennial living mulches in western Oregon, 1984 to 1988 (1,2,6,7,9,10,11,12,15).

| Vegetation management treatments 1/ | Vineyards | | | | | | | | Christmas Trees | | | | Marion berries yield |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bethel Heights | | | Corvallis I | | Corvallis II | | Wren | Trunk girth | | | | |
| | Yields | | Root | Cane | Root | Yield | | Vine | Corvallis I | | Kings | Cottage | |
| | 1984 | 1986 | growth | pruning | growth | 1986 | 1987 | length | 1986 | 1987 | Valley | Grove | |
| | --(mt/ha)-- | | no/m² | kg/vine | no/m² | (g/plant) | | m/pl | -------------cm---------- | | | | mt/ha |
| Bareground | 8.9 | 10.1 | 255 | 0.68a | 148a | 109 | 580a | 10.9 | 2.42a | 18.3 | 1.13a | 0.76 | 9.9 |
| Pr - mowed | 9.4 | 8.5 | 243 | 0.54ab | 17b | 157 | 332b | 9.0 | 2.02b | 18.0 | 0.97b | 0.63 | 9.9 |
| Pr - chem mow | -- | -- | -- | 0.40b | 1c | -- | -- | 9.2 | 2.03b | 18.6 | 1.07b | 0.72 | 9.2 |
| Weedy or (unsuppressed (Pr) | -- | -- | -- | -- | -- | (141) | (266)b | 10.0 | - | - | 0.97b | 0.67 | 9.6 |
| Significance (P = 0.05) | NS | * | * | * | * | NS | * | NS | * | NS | * | NS | NS |

1/ Bareground maintained with herbicides; Pr = perennial ryegrass 'Manhatten II' except at Bethel Heights (unknown) either mowed as required or chemically suppressed with 0.2 lb ai/ a fluazifop-P plus 1% (v/v) crop oil; Weedy represents indigenous vegetation.

Table 5. Vegetable crop yields interplanted with managed perennial ryegrass living mulch in western Oregon, 1985 to 1986 (5,8,13).

| Vegetation management treatments | Newly seed ryegrass: Pak choi yields 1985 | Pak choi yields 1986 | Cabbage yields | Permanent ryegrass sod: Italian bean | Green bean | Cabbage |
|---|---|---|---|---|---|---|
| | -----g/plant----- | | mt/ha | ---(mt/ha)--- | | g/lead |
| Bareground | 0.88[2] | 1.76 | 35 | 6.4 | 5.6 | 1.35 |
| Pr - mowed | | 1.07 | 28 | 3.8 | 4.7 | 0.61 |
| Pr - chem. mow | | 1.20 | 36 | -- | -- | -- |
| Pr - control | | 0.86 | 30 | -- | -- | -- |
| Significance (P = 0.05) | NS | * | * | * | NS | * |

1/ Bareground maintained with herbicides; Pr = perennial ryegrass 'Manhatten II' either mowed as needed or chemically suppressed with 0.2 lb ai/a fluazifop-P plus 1% (v/v) crop oil.

2/ Data combined over management treatments since ryegrass density at 90 Kg/ha was significant in 1985 and both 45 and 90 Kg/ha reduced pak choi yields in 1986.

applications of sethoxydim or fluazifop and 2,4-D (4) or oxyfluorfen {2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene} applied at half rates might suppress fine fescues (pers. comm., G.W. Mueller-Warrant).

Obviously, tremendous diversity exists among potential living mulch species and manageable strategies appropriate for dissimilar soils, sites, species, and manageable strategies appropriate for dissimilar soils, sites, and individual managers. Horticultural leaders suggest keen interest in continuing the study and adaptation of living mulch strategies into diverse horticultural cropping systems to ensure long-term productivity.

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## EFFECTS OF LOW RATE APPLICATIONS OF DPX-M6316 AND DPX-R9674 ON VARIOUS VEGETABLE CROPS

W.J. Steele, G.L. Ritenour[1]

Abstract. A study was conducted at California State University Fresno to determine potential effects associated with low rate applications of DPX-M6316 {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid} and DPX-R9674 (DPX-M6316 + DPX-L5300 {methyl 2-[[[[N-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]sulfonyl]-benzoate} on broccoli (*Brassica oleracea* L.), blackeye beans (*Vigna unquiculata unquiculata* L.), cantaloupe (*Cucumis melo* L.), corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), lima bean (*Phaseolus limensis* L.), lettuce (*Lactuca sativa* L.), safflower (*Carthamus tinctorius* L.), sugarbeet (*Beta vulgaris* L.), and tomato (*Lycopersicon esculentum* L.). Both DPX-M6316 and DPX-R9674 are new short residual cereal herbicides applied postemergence broadcast at rates of 1/4-1/2 oz ai/a.

The herbicides were applied postemergence broadcast to preestablished crop seedlings in Hanford Sandy Loam soil with pH 7.1. All crops were maintained with sprinkler irrigation. DPX-M6316 and DPX-R9674 were applied at 1/64, 1/32, 1/16, 1/8, 1/4, and 1/2 oz ai/a. Evaluations were made 9 and 28 days after application.

Unacceptable crop injury occurred with both compounds at rates down to as low as 1/64 oz ai/a for sugarbeets 70-100%, broccoli 45-75%, cantaloupe 40-75%, cotton 60-80%, tomato 20-75%. Slight crop tolerance to DPX-M6316 at 1/64 oz ai/a but not to DPX-R9674, was observed with lettuce at 15% injury. All other rates

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[1]E.I. DuPont de Nemours and Co. and California State University, Fresno, CA

of DPX-M6316 caused 50-100% lettuce injury. Slight tolerance was also observed with DPX-R9674 at 1/64 oz ai/a but not with DPX-M6316 for blackeye and baby lima bean at 15% injury. Safflower was moderately tolerant at 0-15% injury with either compound up to 1/16 oz ai/a. Rates above 1/16 oz ai/a for safflower obtained 25-55% injury. Corn proved to be the most tolerant to both compounds with no injury from 1/64-1/4 oz ai/a and 25% injury with either compound applied at 1/2 oz ai/a.

## Introduction

Both DPX-M6316 and DPX-R9674 are nonvolatile sulfonylurea herbicides which give excellent contact broadleaf weed control in cereals at rates of 1/4-1/2 oz ai/a. Both compounds have very limited soil residual activity but are very effective at low rates. We know from recropping studies with similar compounds that some rotational crops are very sensitive to herbicide carryover. Because recropping with these compounds is an important issue we also decided to evaluated crop effects due to physical drift.

The objective of this study is to evaluate the effects of low rate applications of both DPX-M6316 and DPX-R9674 when applied postemergence broadcast to various vegetable and row crops that may be growing or could be planted during the time cereal herbicides would normally be applied.

## Materials and Methods

Crops were selected which could be planted or grown during the same period as cereal herbicide applications might occur. All crops were seeded in rows one foot apart with a planet Jr. seeder. The rows were at right angles to the direction the herbicides were applied. To assist in stand establishment .1-.2 inches of water was applied via sprinkler daily for a period of nine days after planting. Plants were sprinkler irrigated with approximately 1.5 inches of water per week for the remainder of the study.

The crops evaluated are listed on Table 1 by common name and variety. Table 1 also includes crop leaf stage at the time of application.

Table 1. Common name and variety of crops and plant leaf stage at time of application

| Common Name | Variety | Leaf stage |
|---|---|---|
| 1. Broccoli | Moran's medium late 423 | 3-5 |
| 2. Blackeye Bean | California No. 5 | 8-10 |
| 3. Cantaloupe | Topscore | 2-4 |
| 4. Corn (field) | Funk's G 4673A | 5-6 |
| 5. Cotton | Acala SJ-2 | 4-5 |
| 6. Lima Bean | Baby White | 6-8 |
| 7. Leaf Lettuce | Greenleaf | 2-3 |
| 8. Safflower | S 317 | 4-5 |
| 9. Sugarbeet | Spreckles SS y-1 | 4-5 |
| 10. Tomato | Sun Seeds AV 5131 | 2-3 |

Treatments were applied with a carbon dioxide powdered backpack sprayer which delivered 20 gallons of water per acre at 29 psi. All plots were randomized in a complete block design and replicated two times. Each plot was 6-feet wide by 20-feet long. All treatments were applied postemergence broadcast to a three-feet wide section in the middle of each plot. The untreated area in each plot served as a control reference during evaluation. Treatments included both DPX-M6316 and DPX-R9674 at the rates of 1/64, 1/32, 1/16, 1/8, 1/4, and 1/2 oz ai/a. The trial was conducted on a Hanford Sandy Loam soil which is common to the area with an organic matter content of .4% and pH of 7.1.

Visual ratings which included percent crop injury and percent stand reduction were obtained at 9 and 28 days after application. The first crop irrigation occurred one day after herbicide application.

## Results and Discussion

Results of this study indicate varying degrees of crop susceptibility. In general DPX-R9674 showed a trend toward less injury than DPX-M6316 at rates of 1/32 oz ai/a or lower for 5 out of 10 crops (broccoli, blackeye bean, cantaloupe, safflower and tomato). Corn, cotton, lima bean, and sugarbeet were consistent between compounds. Leaf lettuce was effected less by DPX-M6316 than by DPX-R9674. Differences between compounds were not identifiable when rates increased to 1/8 oz ai/a or above. Tables 2 and 3 show crop percent injury as related to compound and application rate.

**Table 2. Visual % injury of crops 28 days after treatment with DPX-M6316**

| | Herbicide rate | | | | | |
|---|---|---|---|---|---|---|
| Crop Common Name | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 1/2 |
| 1. Broccoli | 55 | 70 | 65 | 60 | 65 | 75 |
| 2. Blackeye Bean | 20 | 35 | 45 | 45 | 40 | 45 |
| 3. Cantaloupe | 40 | 50 | 65 | 65 | 65 | 75 |
| 4. Corn (field) | 0 | 0 | 0 | 0 | 0 | 25 |
| 5. Cotton | 60 | 70 | 80 | 75 | 75 | 90 |
| 6. Lima Bean | 25 | 30 | 45 | 50 | 55 | 65 |
| 7. Leaf Lettuce | 15 | 50 | 75 | 75 | 100 | 100 |
| 8. Safflower | 10 | 5 | 15 | 25 | 30 | 50 |
| 9. Sugarbeet | 75 | 90 | 95 | 100 | 100 | 100 |
| 10. Tomato | 55 | 60 | 50 | 55 | 65 | 75 |

Table 3. Visual % injury of crops 28 days after treatment with DPX-R9674

| | Herbicide rate | | | | | |
|---|---|---|---|---|---|---|
| Crop Common Name | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 1/2 |
| 1. Broccoli | 45 | 60 | 60 | 65 | 65 | 65 |
| 2. Blackeye Bean | 15 | 20 | 40 | 40 | 50 | 50 |
| 3. Cantaloupe | 30 | 45 | 50 | 55 | 65 | 75 |
| 4. Corn (field) | 0 | 0 | 0 | 0 | 0 | 25 |
| 5. Cotton | 60 | 70 | 80 | 80 | 75 | 80 |
| 6. Lima Bean | 15 | 45 | 60 | 45 | 60 | 65 |
| 7. Leaf Lettuce | 60 | 60 | 50 | 75 | 95 | 100 |
| 8. Safflower | 0 | 0 | 0 | 25 | 30 | 55 |
| 9. Sugarbeet | 70 | 80 | 100 | 100 | 100 | 100 |
| 10. Tomato | 20 | 35 | 20 | 50 | 40 | 60 |

Crops which received high injury ratings when treated with either compound at the 1/64 oz ai/a rate were sugarbeets with 70-75%, cotton 60%, broccoli 45-55%, cantaloupe 30-40%, and tomato 20-55%. Slight crop tolerance was exhibited to DPX-M6316 but not to DPX-R9674 at 1/64 oz ai/a with leaf lettuce at 15% vs. 60% injury. Slight tolerance was observed with DPX-R9674 at 1/64 oz ai/a but not with DPX-M6316 for blackeye bean and baby lima bean with 15% vs. 20 and 25% injury respectively. Safflower seemed to be moderately tolerant with 0% injury for DPX-R9674 and 15% injury with DPX-M6316 at rates up to and including 1/16 oz ai/a. All rates above 1/16 oz ai/a applied to safflower yielded increasing plant injury from 25-55%. Corn proved to be the most tolerant crop to both compounds with no injury from 1/64-1/4 oz ai/a and 25% injury with either compound applied at 1/2 oz ai/a.

Stand reduction remained fairly consistent between both compounds with all crops except broccoli, leaf lettuce, and tomato. With both broccoli and tomato less stand reduction was noted in plots treated with DPX-R9674. Tables 4 and 5 show crop percent stand reduction as related to compound by rate.

Table 4. Visual % stand reduction of crops 28 days after treatment with DPX-M6316

| | Herbicide rate | | | | | |
|---|---|---|---|---|---|---|
| Crop Common Name | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 1/2 |
| 1. Broccoli | 0 | 25 | 30 | 30 | 30 | 50 |
| 2. Blackeye Bean | 0 | 0 | 0 | 0 | 0 | 0 |
| 3. Cantaloupe | 0 | 0 | 0 | 30 | 60 | 60 |
| 4. Corn (field) | 0 | 0 | 0 | 0 | 0 | 0 |
| 5. Cotton | 0 | 0 | 0 | 5 | 50 | 55 |
| 6. Lima Bean | 0 | 0 | 0 | 0 | 0 | 0 |
| 7. Leaf Lettuce | 15 | 0 | 45 | 85 | 100 | 100 |
| 8. Safflower | 0 | 0 | 0 | 0 | 0 | 0 |
| 9. Sugarbeet | 75 | 85 | 90 | 100 | 100 | 100 |
| 10. Tomato | 10 | 40 | 50 | 50 | 45 | 75 |

Table 5. Visual % stand reduction of crops 28 days after treatment with DPX-R9674

| | Herbicide rate | | | | | |
|---|---|---|---|---|---|---|
| Crop Common Name | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 1/2 |
| 1. Broccoli | 0 | 0 | 0 | 0 | 0 | 20 |
| 2. Blackeye Bean | 0 | 0 | 0 | 0 | 0 | 0 |
| 3. Cantaloupe | 0 | 5 | 0 | 20 | 55 | 20 |
| 4. Corn (field) | 0 | 0 | 0 | 0 | 0 | 0 |
| 5. Cotton | 0 | 0 | 0 | 10 | 20 | 45 |
| 6. Lima Bean | 0 | 0 | 0 | 0 | 0 | 0 |
| 7. Leaf Lettuce | 30 | 0 | 70 | 75 | 95 | 100 |
| 8. Safflower | 0 | 0 | 0 | 0 | 0 | 0 |
| 9. Sugarbeet | 65 | 80 | 100 | 100 | 100 | 100 |
| 10. Tomato | 0 | 0 | 60 | 20 | 50 | 50 |

Although crop stand reduction ratings were made, no crop yields were obtained from this study.

Stand reduction ratings show that although broccoli was injured quite severely with DPX-R9674 at all rates tested, no reduction in stand occurred until the 1/2 oz ai/a rate. Whereas with DPX-M6316 stand reduction ranged from 25-50% occurring from the 1/32 oz ai/a rate and above. In general reduction in tomato stand was more severe with DPX-M6316 at 40% with 1/32 oz ai/a vs. 0% with DPX-R9674 at the same rate. Visual stand reduction ratings also indicate that leaf lettuce was affected at low application rates. DPX-R9674 gave greater stand reduction than DPX-M6316 with 15 vs. 30% at the 1/64 oz ai/a rate and 45 vs. 70% for the 1/16 oz ai/ac rate.

## Conclusion

Under the conditions of this study, tolerance to both DPX-M6316 and DPX-R9674 is extremely low to rates that would simulate 1/32 of a normal target crop use rate. Crops such as broccoli, cantaloupe, cotton, sugarbeets, leaf lettuce, baby lima bean, blackeye bean, and tomato would be very susceptible to any off-target movement of rates from 1/32 oz ai/a. Safflower would be slightly less susceptible with good tolerance to rates that would simulate 1/8 normal target crop use rates. Corn would be very tolerant to off-target movement with very little effect even up to the normal target crop use rate.

The results of this study and other trials very similar in nature have prompted numerous product use recommendations. The following label language has been adopted for DPX-M6316 and DPX-R9674 with physical drift in mind.

* Stop spraying when wind speed becomes excessive. DO NOT SPRAY IF WIND SPEED IS 10 MPH OR GREATER. Spray drift can occur at wind speeds of less than 10 MPH. If sensitive crops are downwind, extreme caution must be used even in relatively low wind conditions! DO NOT SPRAY IF WINDS ARE GUSTY.

* High temperatures, drought, and low relative humidity increase the possibility of harmful drift. EXTREME CAUTION MUST BE USED WHEN THESE CONDITIONS ARE PRESENT AND SENSITIVE CROPS ARE NEARBY, REGARDLESS OF WIND SPEED.

* Do not apply when an inversion layer exists. An inversion is characterized by little or no air movement and an increase in air temperature with an increase in altitude. In humid regions, a fog or mist may form. An inversion may be detected by producing a smoke column and checking for a layering effect. Smoke-producing devices on aircraft are recommended. If not sure whether inversion conditions are present, consult with local weather services before making an application.

* Postemergence grass herbicides are often applied using high pressure. When tank mixing with grass compounds, do not exceed 40 psi.

As mentioned earlier no yield information was obtained from this trial. In similar trials we have seen high injury ratings early in the trial with some crops and had little to no effect on crop yield. Future studies of this type should include crop yield information.

# INTERDISCIPLINARY ORCHARD FLOOR MANAGEMENT PROJECT: VEGETATION MANAGEMENT

Clyde L. Elmore[1]

Abstract. In 1984 an orchard floor management project was initiated to evaluate management systems in pests, soils, water, and economics. Common field locations in two almond orchards were established with strip plantings of Blando bromegrass, strawberry clover (Salina), resident vegetation (weeds), and total herbicide treatments. In one orchard the weeds were chemically mowed in spring and summer. All tree rows were strip treated with preemergence and postemergence herbicides.

Vegetation was monitored four times each year: spring, summer, fall, and winter using 100 50 sq. cm rings tossed at random in the treatments. A presence/absence sample was recorded for all species.

The number of species decreased in the total herbicide and chemical mowed plots over four years. When dense clover (TRFFR) population was present, there was also a decline in weed species. Blando bromegrass did not decrease species numbers in spring evaluations.

Major species changes were noted by treatment. In the resident system, there was a static annual spectrum with an increase in dandelion (TAROF), spurge, and fleabane (ERIBO). In the perennial clover there were high populations of common chickweed (STEME), filaree, brassbuttons (CULCO) and annual bluegrass (POAAN). Dandelion increased in number. In the annual bromegrass treatments there were dense populations of annual species. Crabgrass (DIGSA), dandelion, and prostrate spurge (EPHHT) increased in number. In the solid herbicide treatment almost all annual populations were reduced. Dandelion, nutsedge, and prostrate spurge, and at one location large crabgrass, had to be controlled with postemergence treatments.

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# LEAFY SPURGE CONTROL WITH FLUROXYPYR

M.A. Ferrell and T.D. Whitson[1]

Early reports from Oregon and Wyoming indicated that fluroxypyr {4-amino-3,5-dichloro-6-fluro-2-pyridyloxyacetic acid} has activity on leafy spurge (*Euphorbia esula* L.). The following three field studies were conducted near Devil's Tower, in northeastern Wyoming, to further study the activity of fluroxypyr, alone and in combination with other herbicides, for the control of leafy spurge.

The following field study was established to compare the efficacy of initial treatments of fluroxypyr, retreated with dicamba {3,6-dichloro-2-methoxybenzoic acid}, 2,4-D LVE {(2,4-dichlorophenoxy)acetic acid}, picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid}, and fluroxypyr on the control of leafy spurge.

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Three areas, each 90 ft by 120 ft were treated with initial applications of fluroxypyr at 3/4, 1/2, and 5/8 lb ai/a. After initial treatments were applied, the areas were divided into plots 9 by 30 ft. with four replications, to which spring and late summer retreatments were applied. The initial treatments were applied broadcast with a $CO_2$ pressurized six-nozzle knapsack sprayer delivering 30 gpa at 35 psi August 12, 1986 (air temp. 96 F, soil temp. 0 inch 115 F, 1 inch 93 F, 2 inch 83 F, 4 inch 78 F, relative humidity 27%, wind south at 5 mph, sky clear). The leafy spurge was 14 inches tall, and most of the seed had been shed 4 weeks earlier. The soil was classified as a silt loam (22% sand, 58% silt, and 20% clay) with 1.8% organic matter and a pH of 6.3. Spring retreatments were applied May 28, 1987 to a dense stand of leafy spurge 8 to 12 inches tall (air temp. 65 F, soil temp. 0 inch 70 F, 1 inch 60, 2 inch 60 F 4 inch 55 F, relative humidity 63%, wind clam sky clear). Late summer treatments were applied August 27, 1987 to high density leafy spurge 10 to 14 inches tall (air temp. 57 F, soil temp. 0 inch 75 F, 1 inch 70 F, 2 inch 65 F, 4 inch 60 F, relative humidity 77%, wind calm, sky clear).

Visual weed control evaluations made May 28, 1987, prior to retreatment applications, showed the leafy spurge to be in a stunned condition with very little flowering. Visual weed control evaluations were also made June 8, 1988 to evaluate the retreatments. Picloram applied late summer at 0.5 lb ai/a was the only retreatment that resulted in control; however, this control was inadequate (Table 1).

Table 1. Initial applications of fluroxypyr with retreatments of various herbicides for leafy spurge control. Crook County, 1988.

| | | Percent shoot control[2] Fluroxypyr initial treatment lb ai/a[3] | | |
|---|---|---|---|---|
| Retreatment[1] | Rate | 3/8 | 1/2 | 5/8 |
| | (lb ai/a) | | (%) | |
| (Spring) | | | | |
| dicamba | 2.0 | 0 | 0 | 0 |
| 2,4-D LVE | 2.0 | 0 | 0 | 0 |
| picloram | 0.5 | 0 | 0 | 0 |
| fluroxypyr | 0.5 | 0 | 0 | 0 |
| check | 0.0 | 0 | 0 | 0 |
| (Late summer) | | | | |
| dicamba | 2.0 | 0 | 0 | 0 |
| 2,4-D LVE | 2.0 | 0 | 0 | 0 |
| picloram | 0.5 | 43 | 40 | 40 |
| fluroxypyr | 0.5 | 0 | 0 | 0 |
| check | 0 | 0 | 0 | 0 |

[1]Spring retreatments applied May 28, 1987. Late summer retreatments applied August 27, 1987
[2]Visual evaluations June 8, 1988.
[3]Initial treatments applied August 12, 1986.

A second field study involved the use of picloram and fluroxypyr with and without surfactant (X-77) to compare the efficacy of these treatments for the control of leafy spurge.

Plots were 10 by 27 ft. with four replications arranged in a randomized complete block. Treatments were applied broadcast with a $CO_2$ pressurized six-nozzle knapsack sprayer delivering 30 gpa at 35 psi. Picloram treatments were applied May 28, 1987 when leafy spurge was in the full bloom stage and 8 to 12 inches high (air temp. 60 F, soil temp. 0 inch 60 F, 1 inch 55 F, relative humidity 75%, wind west at 5 mph, sky cloudy). Fluroxypyr treatments were applied July 7, 1987 when leafy spurge plants were setting seed and 10 to 14 inches high (air temp. 80 F, soil temp. 0 inch 95 F, 1 inch 80 F, 2 inch 75 F, 4 inch 70 F, relative humidity 75%, wind south at 5 mph, sky partly cloudy). The soil was classified as a silt loam (22% sand, 58% silt, and 20% clay) with 1.8% organic matter and a 6.3 pH. Infestations were heavy throughout the experimental area. Visual weed control evaluations were made June 8, 1988.

The surfactant, X-77, was not effective in increasing the activity of either picloram or fluroxypyr (Table 2).

Table 2. Picloram and fluroxypyr with and without surfactant for leafy spurge control. Crook County, 1988.

| Treatment[1] | Rate | Control[2] |
|---|---|---|
| | (lb ai/a) | (%) |
| picloram | 0.25 | 3 |
| picloram + X-77 | 0.25 | 6 |
| picloram | 0.5 | 10 |
| picloram + X-77 | 0.5 | 8 |
| picloram | 0.75 | 30 |
| picloram + X-77 | 0.75 | 38 |
| picloram | 1.0 | 43 |
| picloram + X-77 | 1.0 | 28 |
| picloram | 1.25 | 38 |
| picloram + X-77 | 1.25 | 43 |
| picloram | 1.5 | 50 |
| picloram + X-77 | 1.5 | 58 |
| picloram | 1.75 | 58 |
| picloram + X-77 | 1.75 | 51 |
| picloram | 2.0 | 61 |
| picloram + X-77 | 2.0 | 56 |
| fluroxypyr | 0.125 | 0 |
| fluroxypyr + X-77 | 0.125 | 0 |
| fluroxypyr | 0.25 | 0 |
| fluroxypyr + X-77 | 0.25 | 0 |
| fluroxypyr | 0.5 | 0 |
| fluroxypyr + X-77 | 0.5 | 0 |
| Check | 0 | 0 |

[1]Picloram treatments applied May 28, 1987. Fluroxypyr treatments applied July 7, 1987. X-77 applied at 0.25% v/v.
[2]Visual evaluations June 8, 1988.

A third field study involved fluroxypyr applied as a tankmix with picloram, dicamba, and 2,4-D LVE for leafy spurge control.

Plots were 10 by 27 ft. with four replications arranged in a randomized complete block. The herbicide treatments were applied broadcast with a $CO_2$ pressurized six-nozzle knapsack sprayer delivering 30 gpa at 35 psi May 28, 1987 (air temp. 60 F, soil temp. 0 inch 60 F, 1 inch 55 F, relative humidity 75%, wind west at 5 mph, sky cloudy). The soil was classified as a silt loam (22% sand, 58% silt, and 20% clay) with 1.8% organic matter and a 6.3 pH. Leafy spurge was in the full bloom stage and 8 to 12 inches high. Infestations were heavy throughout the experimental area. Visual weed control evaluations were made June 8, 1988.

No treatments were effective in controlling leafy spurge (Table 3).

Table 3. Fluroxypyr in combination with various herbicides for leafy spurge control. Crook County, 1988.

| Treatment[1] | Rate | Control[2] |
|---|---|---|
| | (lb ai/a) | (%) |
| fluroxypyr + | 0.5 | |
| picloram | 0.25 | 20 |
| fluroxypyr + | 0.5 | |
| picloram | 0.5 | 18 |
| fluroxypyr + | 0.5 | |
| dicamba | 1.0 | 0 |
| fluroxypyr + | 0.5 | |
| dicamba | 2.0 | 0 |
| fluroxypyr + | 0.5 | |
| 2,4-D LVE | 2.0 | 0 |
| fluroxypyr + | 0.5 | |
| 2,4-D LVE | 4.0 | 0 |
| picloram | 0.25 | 0 |
| picloram | 0.5 | 13 |
| dicamba | 1.0 | 0 |
| dicamba | 2.0 | 0 |
| 2,4-D LVE | 2.0 | 0 |
| 2,4-D LVE | 4.0 | 0 |
| fluroxypyr | 0.5 | 0 |
| Check | 0 | 0 |

[1]Treatments applied May 28, 1987.
[2]Visual evaluations June 8, 1988.

The results of these three studies indicate that fluroxypyr does not have the activity on leafy spurge, either by itself or in combination with other herbicides, that earlier studies showed.

# ABSORPTION, TRANSLOCATION, AND METABOLISM OF PICLORAM AND 2,4-D IN LEAFY SPURGE

Rodney G. Lym and Kevin D. Moxness[1]

Abstract. 2,4-D {(2,4-dichlorophenoxy)acetic acid} at 0.25 to 1 alb ae/A with picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} at 0.25 to 0.5 lb ae/A applied annually provides greater leafy spurge (*Euphorbia esula* L.) control than picloram applied alone at similar rates. Control following three annual applications averaged 85% for picloram plus 2,4-D at 0.25 + 1 lb/A compared to 48 and 90% with picloram at 0.25 and 0.5 lb/A alone, respectively. The purpose of this research was to evaluate the absorption, translocation, and metabolism of 2,4-D and picloram applied alone and together in leafy spurge, and to determine the reasons for increased control when 2,4-D is applied with picloram compared to either herbicide alone.

Approximately 2.5 times more $^{14}$C-2,4-D was absorbed than $^{14}$C-picloram, and more $^{14}$C was absorbed when either herbicide was applied alone than when applied together. An average of 14% of the $^{14}$C-picloram was absorbed when applied alone but declined to 10% when applied with 2,4-D. Similarly, leafy spurge spurge absorbed 34% of the $^{14}$C-2,4-D when applied alone but only 24% when applied with picloram. Adding picloram to $^{14}$C-2,4-D decreased $^{14}$C translocation to leafy spurge roots from 3.3 to 1.5% of applied. Adding 2,4-D to $^{14}$C-picloram increased the amount of $^{14}$C that translocated in leafy spurge from 28 to 48% of absorbed.

Generally, $^{14}$C-picloram and $^{14}$C-2,4-D remained as the parent acid in leafy spurge whether applied alone or together. Approximately 20% of the $^{14}$C translocated to the roots was metabolized when $^{14}$C-2,4-D or $^{14}$C-picloram was applied alone, but less than 5% was metabolized when the herbicides were applied together. The 20 to 30% increased leafy spurge control obtained when these two herbicides were applied together in the field compared to either applied alone is probably due to the increase in unmetabolized picloram present in the root system.

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[1]Crop and Weed Sciences Dept., North Dakota State University, Fargo, ND

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# THE INTERACTION OF TILLAGE AND HERBICIDES FOR CONTROL OF CANADA THISTLE

R.L. Zimdahl and G. Foster[1]

Studies were begun in July 1985 on a site lost to urban development (Site A). A second study was begun on September 27, 1986 (Site B). Canada thistle [*Cirsium arvense* (L.) Scop.] growth was vigorous, stands were dense at each site, and neither had been cropped for several years. There was no history of herbicide use at either site.

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[1]Colorado State University and Sandoz Crop Prot. Fort Collins, CO

The purpose of these studies was to determine if herbicide performance is enhanced by tillage after herbicide application. It was not our intent to determine the efficacy of herbicides for Canada thistle control or to compare efficacy. The herbicides selected all show activity for Canada thistle control.

Important plot data are shown in Table 1. All herbicides were applied in 10 gpa to three replications with a tractor mounted sprayer. Initial plot size was 45 by 90 ft at both sites. The same treatments were reapplied at Site B to Canada thistle in the pre-bud stage on 22 by 90 ft (1/2 of each plot). Disking was done perpendicular to herbicide application after fall and after spring treatments. Stands were counted in 2 or 3 - 2 square foot quadrants in each plot on each date. The results expressed in terms of live Canada thistle plants per 2 sq. ft. are shown in Table 2 for study initiated in 1985 (Site A) and in Table 3 for the study initiated in 1986 (Site B). The data have been analyzed for variance and in general glyphosate {*N*-(phosphonomethyl)glycine}, picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid}, and chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide} are better herbicides for control of Canada thistle than dicamba {3,6-dichloro-2-methoxybenzoic acid} @ 1 lb ai/A or 2,4-D. Dicamba @ 2 lb ai/A is equivalent to the aforementioned herbicides when counts one year after application are compared (Table 3). We found no positive or negative effect in either study from tillage 3, 7, 10, 14 or 30 days after fall herbicide application. In other words, each herbicide worked just as well with no tillage after spraying as it did with some tillage. Tillage was performed with a double pass of a double disk in opposite directions at the prescribed interval after spraying. Disking disturbed the top 2 to 3 inches of soil and separated shoots and roots.

The fields selected for these studies had thistle stands of 10 live shoots per 2 square feet as determined by a pre-spraying count. We assumed a farmer faced with this density of Canada thistle might not attempt to crop the area and opt for a fall herbicide application to reduce thistle stand rapidly. We further assumed a combination of tillage and herbicide would be employed. Data from a spring count after late August application in our first study (Table 2) led us to believe that there was no advantage to tillage after herbicide application and that there might be less control. There is a trend, not supported by statistical analysis, that suggests each herbicide performs better without tillage (Table 3). However, the data clearly shows no advantage for tillage after fall application of any of the five herbicides included in this study (Table 3). Herbicides which controlled Canada thistle best were dicamba @ 2 lb ai/A, glyphosate, picloram, and chlorsulfuron. There was no difference in their efficacy.

Tillage did not contribute to reduction of Canada thistle stand after fall herbicide application. Tillage increased Canada thistle stand in check plots when compared to no tillage. There was no difference between tillage treatments. This is probably related to tillages affect on apical dominance and bud dormancy. By destroying or damaging emerged shoots, tillage may release dormancy in other buds and actually increase stands. Therefore, disking after herbicide application did not increase Canada thistle control over untilled treatments.

Table 2. The interaction of herbicides and disking for Canada thistle control. 1985 Site A.

| Herbicide | Rate | Disking | Canada thistle stand count[a] Fall 1985 | 4/29/86 |
|---|---|---|---|---|
| | (lb ai/A) | (days after spraying) | (live plants/2 $ft^2$) | |
| Dicamba | 1.0 | NO | 2.1 | 2.4 |
| | | 3 | 4.4 | 8.1 |
| | | 7 | 3.6 | 9.4 |
| | | 10 | 5 | 10 |
| | | 14 | 3 | 8.8 |
| | | 30 | 6 | 3.1 |
| Dicamba | 2.0 | NO | .6 | 1.7 |
| | | 3 | 3.1 | 4.6 |
| | | 7 | 1.2 | 3.6 |
| | | 10 | 3.2 | 2.1 |
| | | 14 | 1.2 | 1 |
| | | 30 | 6 | .88 |
| 2,4-D | 2.0 | NO | 1.4 | 4.8 |
| | | 3 | 5.7 | 8.9 |
| | | 7 | 4.5 | 9 |
| | | 10 | 4.4 | 8.5 |
| | | 14 | 3.7 | 8.3 |
| | | 30 | 6 | 2.2 |
| Glyphosate | 3.0 | NO | .6 | 1.2 |
| | | 3 | .8 | 2 |
| | | 7 | .4 | .9 |
| | | 10 | .4 | 2.3 |
| | | 14 | .8 | 2.6 |
| | | 30 | 6 | .8 |

Table 1. The interaction of herbicides and tillage for Canada thistle control.

| | Site and year | | |
|---|---|---|---|
| | Site A | Site B | |
| | 1985 | 1986 | 1987 |
| | | Fall Application | Reapplication |
| Application | 7/22/85 | 9/27/86 | 6/12/87 |
| Herbicides lb ai/A | | | |
| dicamba | 1 | 1 | 1 |
| | 2 | 2 | 2 |
| | 6 | | |
| 2,4-D ester | 2 | 2 | 2 |
| picloram | | 0.25 | 0.25 |
| glyphosate | 3 | 3 | 3 |
| chlorsulfuron | | 0.024 | 0.024 |

Table 3. The interaction of herbicides and disking for Canada thistle control. 1986 Site B.

| | | | Canada thistle stand count[a] after herbicide application on | | |
|---|---|---|---|---|---|
| | | | 9/27/86 | | 9/27/86 and 6/12/87 |
| Herbicide | Rate | Disking | Pre-appl. count | 6/3/88 | 6/3/88 |
| | (lb ai/A) | days after spraying | (live plants/2 $ft^2$) | | |
| Dicamba | 1 | NO | 13 | 9 | 1 |
| | | 3 | 13 | 10 | 8 |
| | | 7 | 8 | 5 | 3 |
| | | 10 | 10 | 5 | 3 |
| | | 14 | 12 | 5 | 6 |
| | | 30 | 11 | 6 | 5 |
| Dicamba | 2 | NO | 9 | 1 | 1 |
| | | 3 | 8 | 6 | 4 |
| | | 7 | 8 | 6 | 2 |
| | | 10 | 10 | 8 | 1 |
| | | 14 | 7 | 4 | 1 |
| | | 30 | 9 | 7 | 4 |
| 2,4-D Ester | 3 | NO | 8 | 7 | 7 |
| | | 3 | 9 | 9 | 8 |
| | | 7 | 10 | 8 | 9 |
| | | 10 | 11 | 8 | 9 |
| | | 14 | 10 | 7 | 8 |
| | | 30 | 11 | 9 | 8 |

| Herbicide | Rate | Disking | Canada thistle stand count[a] Fall 1985 | 4/29/86 |
| --- | --- | --- | --- | --- |
| | (lb ai/A) | (days after spraying) | (live plants/2 $ft^2$) | |
| Dicamba | 6.0 | NO | 2.8 | 1.2 |
| | | 3 | .7 | 2.6 |
| | | 7 | 1.3 | 3.8 |
| | | 10 | 1.1 | 2.1 |
| | | 14 | 2.6 | 2.4 |
| | | 30 | 6 | .8 |
| Control | 0 | NO | 5.7 | 5 |
| | | 3 | 8.7 | 11.3 |
| | | 7 | 7.2 | 10.1 |
| | | 10 | 6.7 | 6.4 |
| | | 14 | 5.5 | 5.6 |
| | | 30 | 6 | 2.6 |

[a]Mean of 3 - 2 sq. ft. counts/plot on each counting date.
[b]Disking not done when count was made.

| | | | Canada thistle stand count[a] after herbicide application on | | |
|---|---|---|---|---|---|
| | | | 9/27/86 | | 9/27/86 and 6/12/87 |
| Herbicide | Rate | Disking | Pre-appl. count | 6/3/88 | 6/3/88 |
| | (lb ai/A) | days after spraying | (live plants/2 ft$^2$) | | |
| Glyphosate | 3 | NO | 7 | 1 | 2 |
| | | 3 | 12 | 11 | 5 |
| | | 7 | 8 | 3 | 2 |
| | | 10 | 12 | 5 | 3 |
| | | 14 | 9 | 3 | 1 |
| | | 30 | 9 | 3 | 3 |
| Picloram | 0.25 | NO | 8 | 1 | 0.5 |
| | | 3 | 9 | 7 | 3 |
| | | 7 | 9 | 6 | 4 |
| | | 10 | 7 | 5 | 2 |
| | | 14 | 10 | 5 | 3 |
| | | 30 | 14 | 5 | 2 |
| Chlorsulfuron | 0.024 | NO | 9 | 9 | 1 |
| | | 3 | 9 | 6 | 1 |
| | | 7 | 11 | 9 | 3 |
| | | 10 | 8 | 4 | 3 |
| | | 14 | 11 | 7 | 3 |
| | | 30 | 8 | 6 | 1 |

| | | | Canada thistle stand count[a] after herbicide application on | | |
|---|---|---|---|---|---|
| | | | 9/27/86 | | 9/27/86 and 6/12/87 |
| Herbicide | Rate | Disking | Pre-appl. count | 6/3/88 | 6/3/88 |
| | (lb ai/A) | days after spraying | (live plants/2 $ft^2$) | | |
| Control | 0 | NO | 11 | 4 | 3 |
| | | 3 | 14 | 9 | 11 |
| | | 7 | 8 | 6 | 8 |
| | | 10 | 14 | 8 | 6 |
| | | 14 | 13 | 10 | 7 |
| | | 30 | 13 | 8 | 10 |

[a]Meanof 3 - 2 sq. ft counts/plot on each counting date.

# CANADA THISTLE *CIRSIUM ARVENSE* (L.)SCOP. CONTROL WITH CLOPYRALID + 2,4-D ALONE AND TANKMIXED WITH METSULFURON

M.B. McKone[1]

## Introduction

Canada thistle *cirsium arvense* (L.) Scop. infests over 2 million acres of cereal grains in Montana. Curtail herbicide, a product of the Dow Chemical Company is a pre-mix of clopyralid + 2,4-D. Containing 170 gm ae of clopyralid {3,6-dichloro-2-pyridinecarboxylic acid} and 910 gm ae of 2,4-D amine {(2,4-dichlorophenoxy)acetic acid as alkanolamine salts} per gallon, Curtail provides superior control of Canada thistle in cereal grains and in fallow.

Another problem weed in Montana that can occur with Canada thistle is kochia (*Kochia scoparia* (L) Schrad.). Since Curtail provides only suppression of kochia, the herbicide is labeled for tankmixing with several herbicides at full labeled rates. Metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]benzoic acid} has been an excellent tankmix partner with clopyralid + 2,4-D for kochia control in previous studies. These combinations at full labeled rates can be impractical for economic reasons, especially in dryland situations.

The objective of this study was to evaluate the tankmix of metsulfuron with clopyralid + 2,4-D at labeled and reduced rates for Canada thistle control in cereal grains.

## Materials and Methods

Three sites were selected in north central Montana. All sites were on irrigated barley to insure the desired weed pressure in a drought year. Barley was between the tiller and early joint stage at application. Canada thistle plants were from rosette to eight-inches tall and averaged 16 plants per .25 $m^2$.

Treatments were metsulfuron alone at 3.15 and 4.20 gm/ha, clopyralid + 2,4-D at 70 + 420 and 110 + 560 gm/ha and tankmix combinations of clopyralid + 2,4-D + metsulfuron at 70 + 420 + 3.15 and 70 + 420 + 4.20 gm/ha. Herbicides were applied using a $CO_2$ pressurized plot sprayer in 150 liters/hectare of spray solution. The plot design was a randomized complete block with three replications. Visual evaluations were made 50 days after application and post harvest, 90 days after application. Data were analyzed by analysis of variance.

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[1]Dow Chemical, U.S.A., Billings, MT

## Results and Discussion

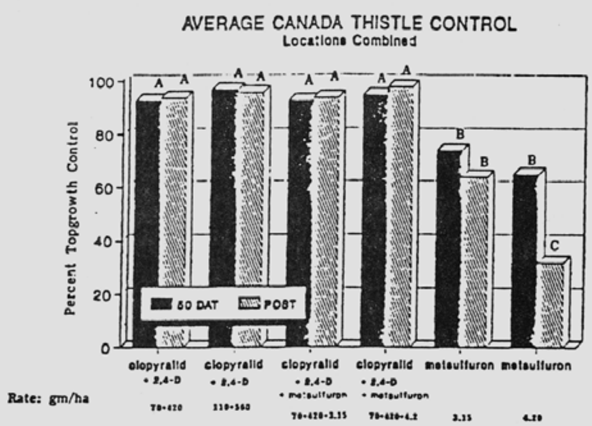
Table 1. Canada Thistle Control at Three Locations

| Herbicide | Rate GM/HA | Site 1 50DAT | Site 1 POST | Site 2 50DAT | Site 2 Post | Site 3 50DAT | Site 3 POST |
|---|---|---|---|---|---|---|---|
| Clopyralid + 2,4-D | 70 + 420 | 92 | 91 | 92 | 96 | 94 | - |
| Clopyralid + 2,4-D | 110 + 560 | 99 | 94 | 95 | 97 | 96 | - |
| Metsulfuron | 3.15 | 73 | 68 | 75 | 60 | - | - |
| Metsulfuron | 4.20 | - | - | 73 | 32 | 57 | - |
| Clopyralid + 2,4-D + Metsulfuron | 70 + 420 +3.15 | 92 | 92 | 93 | 96 | - | - |
| Clopyralid + 2,4-D + Metsulfuron | 70 + 402 +4.20 | - | - | 94 | 98 | 96 | - |
| | LSD (.05) | 10.9 | 8.3 | 4.6 | 7.3 | 5.5 | |

Control of Canada thistle with clopyralid + 2,4-D was > 92 percent regardless of rate, location, or time of evaluation (Table 1). Results with clopyralid + 2,4-D at the labeled rate of 110 + 560 gm/ha were consistent with previous studies. However, clopyralid + 2,4-D at the reduced rate of 70 + 420 gm/ha provided better control in these studies than in previous research. Improved efficacy at this lower rate may be the result of Canada thistle growth conditions under irrigation.

The treatments with metsulfuron alone at 3.15 and 4.20 gm/ha provided 57 and 73 percent Canada thistle control respectively 50 days after treatment. Control at post harvest ranged from 32 to 60 percent with metsulfuron.

FIGURE 1: PERCENT CANADA THISTLE CONTROL ACROSS THREE LOCATIONS 50 AND 90 DAYS AFTER TREATMENT




Means followed by the same letter do not differ significantly at the 5 % level.

The addition of 3.15 and 4.20 gm/ha metsulfuron to clopyralid + 2,4-D at 70 + 420 gm/ha did not improve Canada thistle control over clopyralid + 2,4-D applications alone. These combinations provided significantly better control than metsulfuron alone. This data suggests that metsulfuron does not enhance Canada thistle control with clopyralid + 2,4-D. However, metsulfuron does improve kochia control of clopyralid + 2,4-D and the combination is effective when both kochia and Canada thistle are the target weed species in cereal grains.

## Conclusions

Clopyralid + 2,4-D at 70 + 420 and 110 + 560 gm/ha provided from 93 to 98 percent Canada thistle control 50 days after treatment and post harvest. The lower rate performed above expectations due to the excellent growing conditions in these trials.

The addition of metsulfuron at 3.15 and 4.20 gm/ha to clopyralid + 2,4-D at 70 + 420 gm/ha had no effect on Canada thistle control. Additional studies are needed to determine the effect of these combinations under dryland conditions.

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# INTERACTION OF CLOPYRALID AND 2,4-D ON CANADA THISTLE

M.A. Peterson[1]

Abstract. Experiments were established in 1988 to examine interactions between clopyralid {3,6-dichloro-2-pyridinecarboxylic acid} and 2,4-D amine {(2,4-dichlorophenoxy)acetic acid as mixed alkanolamine salts} on Canada thistle [*Cirsium arvense* (L.) Scop.] control in cereals and fallow. Measurements included visual ratings and Canada thistle density determinations.

Drought conditions caused a great deal of variability in results between locations. Soil moisture at a South Dakota location was sufficient to allow substantial growth and regrowth of Canada thistle. At that location a significant interaction was measured between 2,4-D and clopyralid for early- and mid-season visual ratings and stand counts. This interaction was characterized by additive affects when both compounds were applied at low rates and antagonism as the rates were increased. Control was not reduced below the level achieved with clopyralid alone. Stand counts taken 12 weeks after treatment at the same location indicated no significant interaction between clopyralid and 2,4-D on Canada thistle regrowth.

## Introduction

Canada thistle is a serious weed in the cereal producing areas of the northern United States and southern Canada. It is difficult to control, mainly due to its extensive perennial root system (3). Clopyralid is a growth regulator herbicide which controls Canada thistle and is translocated to the root system of the plant (4). However, clopyralid does not control a number of annual broadleaf weeds which are common in cereals. Consequently, clopyralid is currently formulated in combination with 2,4-D amine to provide cereal grain producers a broad spectrum herbicide which is effective against Canada thistle.

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[1]Dow Chemical, Brookings, SD

Combinations of herbicides may sometimes produce results which differ from those expected. It is possible that the combination of 2,4-D with clopyralid may adversely affect translocation of either or both components in Canada thistle, thereby reducing long-term control. Conversely, in some cases the addition of 2,4-D to another picolinic acid herbicide, picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} has been demonstrated to enhance control of leafy spurge (*Euphorbia esula* L.) (2).

The purpose of this research was to examine the short- and long-term control achieved with various combinations of clopyralid and 2,4-D.

## Materials and Methods

Experiments were established in 1988 to examine interactions between clopyralid and 2,4-D amine on Canada thistle control in cereals and fallow. The experimental design was a randomized complete block with a factorial arrangement of treatments. Levels of clopyralid were 0, 0.5, 1.0, 2.0, and 4.0 oz ae/A. Levels of 2,4-D amine were 0. 2.0, 4.0, 8.0, and 16 oz ae/A. Measurements included visual ratings and Canada thistle density determinations.

Locations included: fallow at Bozeman, MT; Chester, SD; and Riverton, WY, spring wheat at Fargo, ND; and barley at Bozeman, MT. Applications were made when Canada thistle was 3 to 8 inches tall with small plot equipment delivering 10 to 15 gpa, dependent upon location.

Timings of application and data collection are listed in Table 1.

An analysis of variance was applied to the data obtained from each location. A statistical analysis of the South Dakota data as outlined by Flint et al.'s treatment of Colby's method (1).

## Results and Discussion

Dry soil conditions were prevalent at most of the test sites during 1988. The results of visual ratings at the five locations were extremely variable. An overview of results from the visual evaluations are presented in Table 2. Highest overall control was at the Bozeman, MT location (barley). Lowest control was observed at the Fargo, ND location. Significant clopyralid by 2,4-D interactions for visual ratings taken 7 to 12 weeks after application were detected at both Montana locations and at the South Dakota location.

More favorable moisture conditions at the South Dakota site allowed a significant amount of Canada thistle regrowth to occur. Visual ratings taken 8 weeks after treatment and percent stand reductions based on counts taken 8 and 12 weeks after treatment for this location are presented in Tables 3, 4, and 5, respectively. A standard label rate for the current clopyralid/2,4-D pre-mix contains 1.5 oz ae/A of clopyralid and 8.0 oz ae/A of 2,4-D. In this experiment a combination of either 1 or 2 oz ae/A of clopyralid with 8 oz ae/A of 2,4-D gave a visual control rating of 92%, 8 weeks after treatment. This level of control did not significantly differ from the expected values calculated for these combinations. However, the combination of 2 oz ae of clopyralid and 16 oz ae of 2,4-D was significantly antagonistic, as were combinations of 4 oz ae of clopyralid with 4, 8, or 16 oz of 2,4-D. All other combinations were additive. This antagonism was more evident in the stand reduction data 8 weeks after treatment. In that case combinations of 0.5 oz ae of clopyralid and 8 or 16 oz ae of 2,4-D were antagonistic as were combinations of 1, 2, or 4 oz ae of clopyralid with any rate of 2,4-D. However, this antagonism may not be of practical importance since the level of control with the combinations was never less than that achieved with clopyralid alone. A similar pattern was evident in the stand reduction data collected 12 weeks after treatment. These data were more variable than the earlier measurements. Antagonism occurred when the 2,4-D rate exceeded 8 oz ae/A and the clopyralid rate was less than 2 oz ae/A, or when the 2,4-D rate was 4 or 16 oz ae/A and the clopyralid rate was 2 or 4 oz ae/A. Again, stand reduction values were generally not less for clopyralid/2,4-D combinations than for clopyralid alone. Combinations containing 2 oz ae of clopyralid gave approximately 30 to 40% stand reduction while combinations containing 4 oz ae of clopyralid gave approximately 50 to 60% stand reduction.

The results of these trials indicate that control of Canada thistle with combinations of clopyralid with 2,4-D amine should be similar to that achieved with clopyralid alone when clopyralid is applied at 2 to 4 oz ae/A. At lower rates of clopyralid, the combination with 2,4-D will produce an additive effect. Further measurements will be taken at these test sites to examine the effects of these combinations on long-term Canada thistle control.

## Acknowledgments

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Table 1. Timings of application and measurements for clopyralid/2,4-D interaction studies.

| LOCATION | MT | MT | ND | SD | WY |
|---|---|---|---|---|---|
| CROP | Barley | Fallow | S. Wheat | Fallow | Fallow |
| APPLICATION | 6/17/88 | 6/15/88 | 6/22/88 | 5/27/88 | 6/2/88 |
| EVALUATIONS | 7/13/88<br>8/20/88 | 7/8/88<br>8/15/88 | 7/15/88<br>8/12/88 | 6/10/88<br>6/24/88<br>7/28/88 | 8/23/88 |
| STAND COUNTS | 7/13/88 | 7/8/88 | 6/23/88<br>8/15/88 | 5/26/88<br>7/28/88<br>8/31/88 | |

Table 2. Overview of visual ratings for clopyralid/2,4-D interaction studies.

| LOCATION | MT | MT | ND | SD | WY |
|---|---|---|---|---|---|
| CROP | Barley | Fallow | S. Wheat | Fallow | Fallow |
| CLOP*2,4-D ¦ | ** | ** | NS | ** | NS |
| EXP. MEAN | 82 | 68 | 33 | 75 | 60 |
| C.V. | 16 | 16 | 93 | 11 | 20 |

¦ A '**' denotes a significant interaction between clopyralid and 2,4-D at the 0.01 confidence level.

Table 3. Canada thistle control (visual rating) 8 weeks after treatment at Chester, SD.

| 2,4-D (oz ae/A) | CLOPYRALID (oz ae/A) 0 | 0.5 | 1 | 2 | 4 |
|---|---|---|---|---|---|
| 0 | 0 | 47 | 79 | 84 | 96 |
| 2 | 20 | 71 | 79 | 85 | 89 |
| 4 | 44 | 79 | 86 | 87 | 90 * |
| 8 | 59 | 79 | 92 | 92 | 88 * |
| 16 | 79 | 81 | 89 | 91 * | 95 * |

LSD (.05)= 13
A '*' denotes antagonism significant at the .05 confidence level.

Table 4. Canada thistle percent stand reduction 8 weeks after treatment at Chester, SD.

| 2,4-D (oz ae/A) | CLOPYRALID (oz ae/A) 0 | 0.5 | 1 | 2 | 4 |
|---|---|---|---|---|---|
| 0 | -11 | 34 | 68 | 78 | 89 |
| 2 | 21 | 56 | 60 * | 80 * | 87 * |
| 4 | 30 | 63 | 76 * | 74 * | 81 * |
| 8 | 35 | 55 * | 73 * | 78 * | 82 * |
| 16 | 55 | 70 * | 74 * | 84 * | 86 * |

LSD (.05)= 19
A '*' denotes antagonism significant at the .05 confidence level.

Table 5. Canada thistle percent stand reduction 12 weeks after treatment at Chester, SD.

| 2,4-D (oz ae/A) | CLOPYRALID (oz ae/A) 0 | 0.5 | 1 | 2 | 4 |
|---|---|---|---|---|---|
| 0 | -17 | 6 | 10 | 40 | 61 |
| 2 | 2 | 14 | 27 | 47 | 61 |
| 4 | 21 | 26 | 29 | 38 * | 49 * |
| 8 | 3 | 1 | 29 | 29 | 60 |
| 16 | 39 | 24 * | 32 * | 37 * | 60 * |

LSD (.05)= 30
A '*' denotes antagonism significant at the .05 confidence level.

# EVALUATION OF CLOPYRALID RATE AND TIME OF APPLICATION ON SPOTTED KNAPWEED (*CENTAUREA MACULOSA* LAM.)

C.A. Lacey, M.B. McKone, and D. Bedunah[1]

## Introduction

Spotted knapweed (*Centaurea maculosa*) is an introduced perennial that infests over 1.9 million hectares of rangeland and grazable woodland in Montana (Lacey, 1987). An estimated 13.4 million hectares are highly susceptible to invasion by this weed in the state (Bucher, 1984). Although picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} provides excellent control of spotted knapweed, there is concern about the effect of the herbicide on associated forb species. Many forbs contain significant value for livestock and wildlife forage. The objectives of these experiments were to study the effect of clopyralid {3,6-dichloro-2-pyridinecarboxylic acid} on spotted knapweed control and forb diversity.

## Materials and Methods

Herbicide Rate and Timing Study: Two study locations were established on gravelly range sites in southwestern Montana. Site 1 was located near Emigrant and Site 2 was located near Bozeman. Spotted knapweed, bluebunch wheatgrass (*Agropyron spicatum*), junegrass (*Koleria cristata*), sandberg bluegrass (*Poa sandberqii*), and Kentucky bluegrass (*Poa pratensis*) are common species at both locations.

Herbicides were applied in mid-June, July, and September of 1987. Timing of application corresponded to spotted knapweed bolt, flower, and seed dispersal growth stage respectively. Clopyralid was applied at 0.07, 0.14, 0.28, and 0.42 kg/ha. Picloram was applied at the rate of 0.28 kg/ha as a comparative treatment. Herbicides were applied with a $CO_2$ pressurized backpack sprayer in 166 L/ha of spray solution. Plot design was a randomized complete block with three replications. Individual plots measured 3 by 12.2 m. Spotted knapweed control was determined by visual estimates one year following herbicide application. Data were analyzed using analysis of variance.

Forb Diversity Study: Two locations were established in western Montana to determine the effect of 0.28 kg/ha of clopyralid and 0.28 kg/ha of picloram on forb diversity and density. Site 1 was located near Townsend, and Site 2 was located near Missoula. Western yarrow (*Achellia milifollium*), lupine (*Luminus* sp.), prairiesmoke (*Geum triflorum*), pussytoes (*Antennaria* sp.), fleabane daisy (*Erigeron* sp.) and miscellaneous composites were found at both sites. Sticky geranium (*Geranium viscosissimum*) was a significant component of the plant community at Site 1. Sulfur cinquefoil (*Pontentilla recta*) and spotted knapweed were present at Site 2.

Herbicides were applied on May 15, 1987 with $CO_2$ backpack sprayer in 187 L/ha of spray solution. Plot design was a randomized complete block with three replications. Individual plots measured 2.1 by 7.6 m. Each plot was divided into five equal segments and forb density was measured in four of the segments

[1]Consultant, Helena, MT; The Dow Chemical Company, Billings, MT; and University of Montana, Missoula, MT

by using two systematically placed .5 $m^2$ plots per segment. Measurements were taken in June, 1988. Data were analyzed using analyses of variance. Least significant differences were used to separate means when F-values were significant ($p < .05$).

## Results and Discussion

Herbicide Rate and Timing Study: Clopyralid rates greater than 0.07 kg/ha significantly reduced spotted knapweed density one year following application when compared to the control. There was no difference in spotted knapweed control between clopyralid at 0.28 and 0.42 kg/ha and picloram at 0.28 kg/ha. These rates provided the greatest efficacy at both locations (Figure 1).

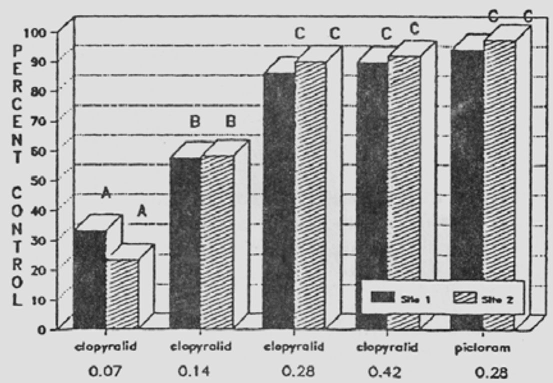


Figure 1: Percent spotted knapweed control with clopyralid and picloram one year after application at two locations. Means within sites followed by the same letter do not differ significantly at the 5% level.

The effect of time application on spotted knapweed efficacy differed between Site 1 and Site 2. Clopyralid at 0.28 kg/ha provided significantly greater control of spotted knapweed when applied at seed dispersal at Site 1. However, at Site 2 clopyralid applied at the bolt growth stage provided significantly greater control than applications made at seed dispersal. Picloram at 0.28 kg/ha provided significantly better control when applied at the flower and seed dispersal stages at Site 1. Time of application did not influence spotted knapweed control at Site 2 with picloram at 0.28 kg/ha (Figure 2). Differences between the two locations may be the result of extremely dry conditions at Site 1 during the spring application.

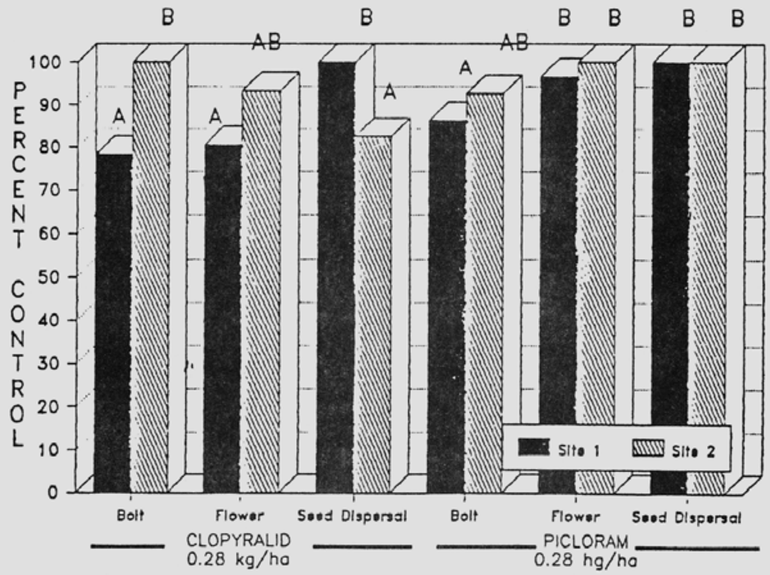


Figure 2: Percent spotted knapweed control at three growth stages with 0.28 kg/ha of clopyralid and picloram at two locations. Treatment means within sites followed by the same letter do not differ significantly at the 5% level.

Forb Diversity Study: There were few significant differences in forb density and diversity between clopyralid, picloram, and the control. The most significant difference measured between the two herbicides was with sulfur cinquefoil. This specie was eliminated from the plant community by picloram but was not damaged by clopyralid. Spotted knapweed was significantly reduced by both clopyralid and picloram when compared to the control (Figure 3).

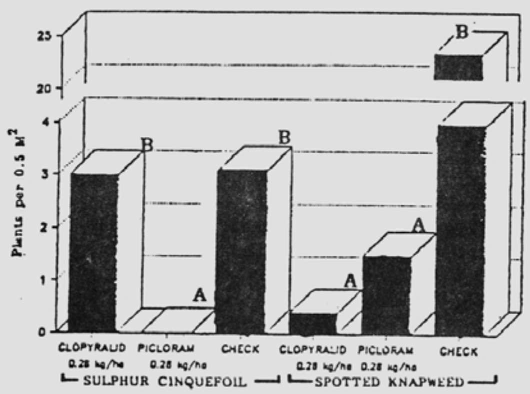


Figure 3: Density of sulfur cinquefoil and spotted knapweed by treatments at Site 2. Treatment means within sites followed by the same letter do not differ significantly at the 5% level.

Western yarrow density was significantly reduced by both clopyralid and picloram and at Site 2, but there was no difference at Site 1. Clopyralid appeared to be slightly more effective than picloram on this specie, however the difference was not significant (Figure 4). There was no significant difference in density of lupine, prairiesmoke, or sticky geranium with either picloram or clopyralid. Density measurements for pussytoes, cutleaf daisy, fleabane daisy, and miscellaneous composites were combined for statistical analysis. There was no significant difference measured for these composites with either herbicide.

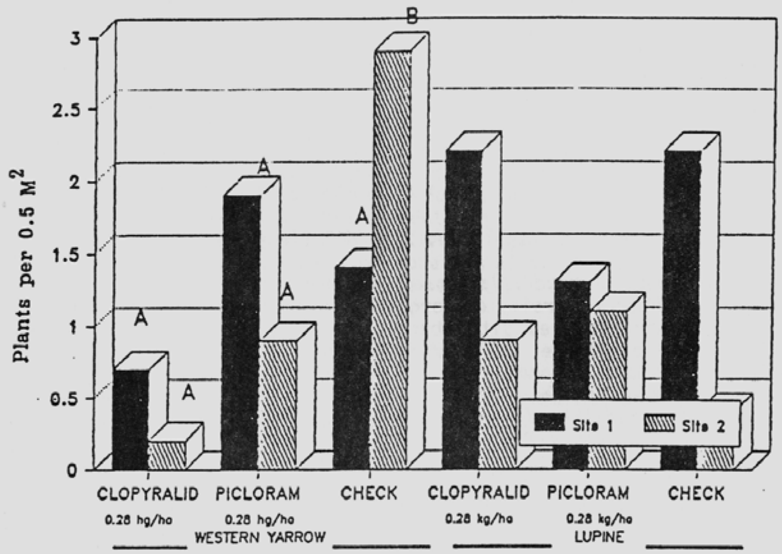


Figure 4: Density of western yarrow and lupine by treatments at two locations. Treatment means within sites followed by the same letter do not differ significantly at the 5% level.

These results suggest that either clopyralid or picloram at 0.28 kg/ha could be utilized for spotted knapweed control without significant detrimental impact to native forb populations. There was no reduction in native forb diversity at either Site 1 or Site 2. With the exception of western yarrow at Site 2, no native forb species showed significant declines in density as a result of herbicide application. Sulfur cinquefoil and spotted knapweed were the forbs species most susceptible to herbicide applications. Both species are introduced forbs considered noxious on rangeland in western Montana.

## Conclusion

Clopyralid at 0.28 kg/ha provides excellent control of spotted knapweed one year following application. No conclusions could be made on the optimum time for clopyralid applications on spotted knapweed. Neither picloram nor clopyralid applications of 0.28 kg/ha significantly reduced native forb diversity and had a minimal impact on native forb density.

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# EFFECTS OF A GALL MIDGE AND A GALL MITE ON RUSH SKELETONWEED

T.S. Prather, R.H. Callihan, J.P. McCaffrey, and B. Shafii[1]

Rush skeletonweed *Chondrilla juncea* L. (Asteraceae) decreases range forage production and species diversity on large acreages in Idaho. Rush skeletonweed is able to dominate depleted sites because it is an aggressive, deep-rooted perennial and is unpalatable. No single control method has been successful; a combination of chemical, entomological, and botanical inhibitors will be required to achieve acceptable control. Chemical control of rush skeletonweed has been well documented but an integrated pest management approach to control has not been developed for western U.S. infestations. We have implemented several experiments to evaluate biological and plant competition control tactics including different composition and densities of control organisms needed to effectively reduce rush skeletonweed. The first investigation was to quantify the effects of arthropod parasites on the rush skeletonweed biotype prevalent in southcentral Idaho.

Rosettes of rush skeletonweed were artificially infested with a gall midge, *Cystiphora schmidti* (Diptera:Cecidomyiidae) and a gall mite, *Eriophyes chondrillae* (Acari:Eriophyidea). The plants were divided into three treatments for each parasite. The treatments with the gall midge consisted of three levels of initial infestation; i.e. 10-15 galls, 35-40 galls, and 60-65 galls per plant. The treatments with the gall mite were: 178 mites, 890 mites, and 1602 mites per plant. Uninfested controls were included. Midges and mites were allowed to freely reproduce after the initial infestation. The number of stems infested, number of stems with flowers, and plant weight were recorded bimonthly beginning two weeks after the infestation and continuing for a period of three months.

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[1]University of Idaho, Moscow, ID

The experiment was designed as a randomized complete block with a factorial arrangement of treatments and four replications where two parasite species were separately applied at the four densities of infestation described above. Regression analyses were conducted using the procedure REG in SAS, 1985. Stem weight, root weight, and seed number were recorded, and data were analyzed using least squares regression with logarithmic transformations of the dependent and independent variables. A significance level of P=0.01 was used for testing parameter estimates.

Root weight was not reduced significantly by the gall midges. The gall mites, on the other hand, reduced root weight according to the equation:

$$\text{root weight}=e^{(2.32-0.12*\ln[\text{mites/plant}])}$$

Root weight was reduced by 28% with the 178-mite treatment, 56% with the 890-mite treatment, and 59% with the 1600-mite treatment. While root weight continually decreased with larger mite numbers, the effect per mite was minimal above the medium treatment and, therefore, the medium treatment was a more efficient infestation level.

Several plants infested with the midge died, and many stems died because of midge galls. Since the midge can be effective for control of rush skeletonweed, another midge-related factor must be affecting the plants. The galls on the plants that died were concentrated on the stem near the base. This location of galls could eventually girdle the stem, killing the plant. Through these observations, we concluded that location of midge galls may be as important as density of galls on the plant. Stem weight was reduced by increased initial mite density according to the equation:

$$\text{g/plant}=e^{(1.64-0.15*\ln[\text{galls/plant}])}$$

Stem weight was reduced by 54% at the low mite treatment, 64% by the medium mite treatment, and 67% by the high mite treatment. The most efficient mite density for stem mass control was with the medium mite treatment which concurs with the results for root mass reduction.

Seed production was reduced by addition of mites but not by addition of midges. An uninfested plant averaged 247 seeds and infested plants averaged 23 to 34 seeds/plant. Very few mites were required to dramatically reduce seed production.

Data are currently being analyzed to examine plant growth from rosette to flowering plant as a function of initial mite density. Results from 1987 analysis produced a satisfactory growth model for biomass through time. Analyses of the 1988 data are still underway.

The mite was a more effective biocontrol agent than the midge as documented by the mite effects on stem and root mass and mite effects on seed production. Rush skeletonweed should have a lower competitive ability with reduced stem and root mass. In addition, propagation of new plants would be hindered by low seed production.

# TALL LARKSPUR (*Delphinium Occidentale* (WATS.) WATS.) CONTROL ON MOUNTAIN RANGELAND

Tom D. Whitson and Gerald E. Fink[1]

Abstract. Tall larkspur, (*Delphinium Occidentale*), a perennial species common in the Western U.S. on high elevation rangeland sites is highly toxic to cattle. In the Western U.S., death loss estimates for cattle is in excess of 5000 head annually. Pasture losses from not grazing infested areas is considerable. Picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid} is labeled for tall larkspur control at rates of 0.25 to 0.5 lb ai/A. Ranchers are not satisfied with controls attained at the labeled rates.

Two identical experiments with 25 treatments replicated four times were established on a dense stand of tall larkspur, near Barnum, Wyoming in the Bighorn mountains, to evaluate various herbicides at two application dates for control of tall larkspur. Tall larkspur plants were counted July 20, 1988, 13 months following the June application and 12 months following the July application. Treatments applied in June at the labeled picloram rates of 0.25 and 0.5 lb ai/A controlled 38 and 60% respectively, of the tall larkspur, picloram applications of 2.0 lb ai/A were required for 98% control. Metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl] benzoic acid} at 0.065 lb ai/A controlled 82% of the tall larkspur. July applications with 0.25 and 0.5 lb ai/A picloram controlled 39 and 29% of larkspur, respectively. Picloram at 1.0 and 2.0 lb ai/A controlled 89 and 98% of the larkspur, respectively. Metsulfuron applied at 0.0625 lb ai/A controlled 44% of tall larkspur or approximately one-half that of the earlier application time. Picloram applications can be made in June or July and obtain tall larkspur control. Metsulfuron applications should be made in earlier growth stages to provide effective control. Other treatments including dicamba {3,6-dichloro-2-methoxybenzoic acid}, 2,4-D {(2,4-dichlorophenoxy)acetic acid}, triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid}, clopyralid {3,6-dichloro-2-pyridinecarboxylic acid}, fluroxypyr {4-amino-3,5-dichloro-6-fluro-2-pyridyloxy acetic acid}, chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide}, and sulfometuron {2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]benzoic acid} were only partially effective in controlling tall larkspur at the times and rates tested.

[1]University of Wyoming, Laramie and Buffalo, WY

# EVALUATION OF PURPLE NUTSEDGE SUPPRESSION USING IMIZAQUIN HERBICIDE

D.M. Kopec, S. Heathman, C.F. Mancino, and H.N. Moharram[1]

Abstract. Field studies were conducted to determine (a) effective rates (ai/a) and (b) weed control efficacy through multiple application of imizaquin {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic

[1]University of Arizona, Tucson, AZ

acid} herbicide on purple nutsedge (*Cyperus rotundus*). During 1987, two (2) applications of imizaquin at 0.50 lb. (ai/a) were necessary to reduce stands of 100% infested plots of nutsedge to 20%, followed by lesser control for the 0.38 and 0.25 lb. (ai/a) treatments. Late season control was the same in late October for the three treatments applied after the third application made on September 27. Increasing rates of imizaquin reduced turfgrass quality due to short lived leaf yellowing (similar to iron chlorosis symptoms). Increased rates also reduced clipping growth of the bermudagrass turf. During repeat applications of 0.50 lb. (ai/a) conducted on 100% nutsedge stands in 1988, there was no reduction until two weeks after the second bi-monthly sequential application. Two additional applications were necessary to maintain suppression. Eight (8) weeks after the initial treatment, the single application developed more nutsedge ground cover than that 9f the control. Repeat applications at 0.50 lb. (ai/a) reduced turf quality through leaf yellowing. Further research is warranted to detect the mechanism(s) of suppression and competitive effects of imizaquin treated nutsedge and bermuda turfs.

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## MULTI-ACCESS WEED IDENTIFICATION BY COMPUTER

Carl E. Bell[1]

Abstract. A common method of weed identification for agriculturalists involves matching a weed sample to a color photograph. Several good photographic weed identification guides are available. In California, the most commonly used reference is the Growers Weed Identification Handbook, published by the University of California.

The actual process of matching a weed specimen of a photograph in the handbook can be frustrating and time-consuming because there is no systematic organization to the handbook. Reorganizing the 231 plates in the handbook in some fashion (e.g. taxonomically, by identifiable characters, by region of occurrence) would be beneficial. Alternatively, an external aid to weed identification to be used with the handbook would have value.

A computer program has been written and compiled for IBM and compatible personal computers using Turbo Pascal as a multi-access weed identification aid to the handbook. The program does not function as a key, guiding the user to precise identification of the weed. Rather, using the photographs of the handbook, the program produces lists of plate numbers that share common, distinguishing characteristics. The purpose of the program is to reduce the number of plates the user has to look at, shortening the time required to identify a weed.

The program works with a database of weeds coded for several easily recognizable characters. These characters for broadleaf plants are in two groups -- leaves and flowers. Leaf characters are further subdivided into shape, arrangement, margins, texture, color, and petioles. Flowers characters are color, shape, arrangement, number of petals, and fruit. The grass database codes each entry for color, collar region, inflorescence type, and texture. All data were extracted from the plates in the handbook. Terminology used to name the characters is the same as used in the handbook wherever possible. When using

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[1]University of California, El Centro, CA

the program, searches are made by groups (e.g. broadleaf leaves, broadleaf flowers, grasses). After selecting a group at the opening menu, the search continues with subdivisions of the group. This search can use any combination of one to the total number of the subdivisions in each group. This ability is multi-access, allowing the user to decide how to proceed instead of prescribing a path as a dicotomos key does. The greater number of subdivisions used together, the smaller the resulting list of plates. For example, of the 155 broadleaf plants in the handbook, a selection for oval to triangular leaf shape will produce a list of 56 plates. If oval to triangular leaf shape is combined with opposite arrangement, and a toothed to wavy margin, the list will be only five plates.

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## JAPANESE KNOTWEED HERBICIDE SCREENING TRIAL APPLIED AS A ROADSIDE SPRAY

P.F. Figueroa[1]

Japanese knotweed (*Polygonum cuspidatum* Sieb & Zucc) is a weed species that is becoming increasingly common along roadways and stream sides in Washington state. This weed has also been referred to as knotweed, Japanese bamboo, Mexican bamboo, fleece-flower and sometimes Dock. Knotweed is a semi-woody perennial whose stem has similar characteristics of bamboo i.e. hollow stems with distinct internodes.

Knotweed is native to China, Japan, and Korea and was imported as an ornamental to England in 1825 (Patterson 1976). It was subsequently introduced to the United States and has been used for ornamental hedges and erosion control (Pridham and Bing 1975). Knotweed has since escaped and is widespread along the east coast (Locandro 1978) and can now be found in Oregon and Washington (Figueroa 1988).

Knotweed has rhizomes that are extremely vigorous and develop a deep, dense mat. Excavation of roots is difficult due to the high rhizome densities. Colonies rarely develop from seed. Meade and Locandro (1979) reported on observations of knotweed colonies over 15 years that no shoots developed from seeds. Primary spread of knotweed is reported to be through mechanical movement of plant parts.

Roadside mowing and grading are the primary mechanism which spread knotweed into roadways. Vehicle traffic further moves material to other locations. Public dumping of yard clippings and debris creates a problem especially when knotweed clippings are a part of the material being dumped illegally. Knotweed colonies are being spread along waterways from dislodged plant parts falling into the water, thus creating new colonies downstream.

Herbicide screening trials for Japanese knotweed control have included glyphosate {*N*-(phosphonomethyl)glycine}, dicamba {3,6-dichloro-2-methoxybenzoic acid}, 2,4-D {(2,4-dichlorophenoxy)acetic acid}, picloram {4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid}, triclopyr {[(3,5,6-trichloro-2-pyridinyl) oxy]acetic acid}, simazine {6-chloro-*N*,*N*'-diethyl-1,3,5-triazine-2,4-diamine} and fosamine {ethyl hydrogen (aminocarbonyl) phosphate} (Bing 1977, Meade and Locandro 1979, Pridham and Bing 1975, Scott and Marrs 1984). Of these trials only picloram gave successful control and only after multiple applications.

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[1]Weyerhaeuser Company, Weyerhaeuser Research Center, Centralia, WA

Those study results, however, showed conflicting degrees of control for various herbicide rates and application timing. Consistent control using a single herbicide has yet to be demonstrated.

A study was established to screen herbicides used for roadside brush control to determine their efficacy on Japanese knotweed growing in typical roadside conditions. The Dow Chemical Company had shown that clopyralid {3,6-dichloro-2-pyridinecarboxylic acid} had been effective controlling several species in the buckwheat family (*Polygonaceae*) in earlier trials[1]. Additionally two relatively new herbicides, imazapyr {(±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid} and metsulfuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl] benzoic acid} have shown very broad spectrum weed control and appeared to be potential candidates for knotweed control in a roadside spray treatment.

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[1]Personal communication with Vanelle Carrithers, technical representative for Dow Chemical, Mulino, OR

## Methods

The study sites were located on the Weyerhaeuser's Cascade Region. One site was on the 4000 mainline logging road near the junction with Tokul Road. The other was on 396 Drive SE between the Reining Road at the Snoqualmie Mill (sec 20, 29 T24N R8E). The 4000 main line road is a frequently traveled, unpaved, gravel logging road. Traffic is sufficiently heavy to provide a continual source of dust that coats knotweed leaves with fine dust. The 396 Drive SE site is adjacent to a paved road which would not cause additional roadway dust to accumulate on plants.

The study was locate don a Barneston soil series which is a deep, well-drained, coarse textured soil developed from loose, gravelly glacial outwash material. Soil depths are about 60 cm of gravely sandy loam (Webster and Steinbrenner 1974). Soil site index is estimated at 34 m at breast height age 50 for Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco). Soils at both sites have high rock content due to road construction and/or road maintenance moving material towards road edges. Road maintenance on the 4000 main line would include periodic mowing and grading along the roadside.

## Analysis and Treatment Procedures

The experimental design for this study was a randomized block design with two replicates, as shown in the following ANOVA Table:

| Source of Variation | Degrees of Freedom |
|---|---|
| Blocks | 1 |
| Treatment | 8 |
| Error | 8 |
| Total | 17 |

Treatment differences were analyzed using analysis of variance procedures described by Steel and Torrie (1980) and hypothesis tested at the 0.05 probability level. The hypothesis tested was that herbicide treatment would not effect knotweed density or height. Each of the nine treatments were randomly assigned within a block. Blocks were the two separate locations, paved and non-paved roadways. Two 1-meter square vegetation sampling plots were systematically established on a diagonal across each plot. Number of knotweed plants and maximum total knotweed height was recorded for each plot on May 15, 1988 one year after treatment.

Treatments were applied on June 16, 1987 using a Spraying Systems Orchard Gun[R] with a D4 nozzle attached to a Solo backpack sprayer. Pump pressure was 276 kPa which produced a solid cone stream with a 4.6 m reach. This approximated a 306 liter per km application rate (both sides of the road). Plot size was 4.6 m x 4.6 m bordering the roadway. Plants were at 90% of their full height at treatment time (approx. 2 meters tall).

Herbicide treatments were as follows:

| Treatment | Rate |
|---|---|
| | (kg ai/ha) |
| Check - no treatment | - |
| Clopyralid | 0.14 |
| Clopyralid | 0.3 |
| Clopyralid | 0.6 |
| Clopyralid | 1.1 |
| Imazapyr | 0.6 |
| Dicamba | 1.1 |
| 2,4-D | 2.2 |
| Glyphosate | 3.4 |

Subsequent to these treatment applications, metsulfuron (210 g/ha) was applied to three knotweed colonies adjacent to this study (but not part of this study design). Those colonies were treated using material available from a different test. The metsulfuron treatment was applied to give a visual demonstration of efficacy.

## Results

Analysis of variance determined there were significant differences between the paved and unpaved locations for knotweed density (P=0.0967). No significant differences between sites for knotweed height. Significant differences were detected among treatments for knotweed height (p=0.0178).

Table 1 and Figure 1 show densities among treatments ranged between 15 stems per square meter on the untreated check plots to 0.5 stems per square meter for the imazapyr treatments. Those differences were not significantly different due to the variation between the plots on the paved and unpaved roads. Table 2 and Figure 2 show treatment effects on knotweed height after one year. Only the imazapyr treatment significantly reduced knotweed height.

This test was not designed to allow statistical testing of differences among treatments within each location. Table 3 and 4 (Figure 3) show treatment effects on knotweed density separating treatments by paved and unpaved logging roads. The data showed higher knotweed densities on the unpaved logging road. Repeated roadside mowing and grading road edges increase populations by the mechanical spreading of plant parts. This data also showed roadway dust accumulation on leaves probably limits efficacy of glyphosate and clopyralid. Imazapyr tends to have the greatest control regardless of location.

Tables 5 and 6 (Figure 4) show treatment effect on knotweed height one year after treatment by roadway condition. This data tends to show knotweed height was independent of growing location. Roadway dust appears to be probably a factor for reducing effectiveness of glyphosate. Imazapyr appears to have the greatest effect without regard to location.

## Conclusions/Discussions

Applications of herbicides were done to simulate a roadside spray application. At this time, observations of knotweed colonies has been primarily along roadways. Eradication efforts will primarily begin with roadside treatment to prevent knotweed from moving along and into the waterways, conifer plantations or second-growth stands where harvesting will further spread plants.

Imazapyr gave the most effective control under the conditions of this study. Greater control may have been possible had the spray been applied to the entire colony rather than only a roadside spray application. With the high density of knotweed, it is possible that stems were sprouting from rhizomes of plants outside the sprayed zone. Typical roadside spray equipment usually treats vegetation in the 2-4 meter zone adjacent to the roadside. From observations of other colonies and control results from this study, it appears that current roadside application may need to be modified to treat all plants in a colony and not those in the immediate area of the roadside.

Data from this study showed higher knotweed densities along unpaved logging roads. Repeated roadside mowing probably spreads the plant parts, although mowing is necessary to improve road visibility along corners to reduce traffic blind spots. These results showed imazapyr will effectively control knotweed along unpaved roads. Imazapyr works both from leaf and root absorption. Glyphosate and clopyralid effectiveness appeared to be impacted by dust accumulation.

Greater herbicide efficacy was observed on the knotweed adjacent to the paved road. Both imazapyr and glyphosate reduced knotweed density and height compared to the untreated check plots. Imazapyr did give superior knotweed control over glyphosate with this application method and timing.

Monsanto representatives[1] stated that they had seen greater glyphosate efficacy when applied as a late foliar spray in September and October. They also note that repeated herbicide application may be required to eliminate colonies with glyphosate.

Since clopyralid had shown to be effective on other species in the buckwheat family, it is possible that a spring clopyralid application was not the best timing for control. Plant vigor was not assessed in this study; however, the clopyralid treated plants did exhibit low vigor with curled and deformed leaves in the second year's growth. This condition was also visible

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[1]Personal communication with Mary Gilmore, Technical Representative, Monsanto Company, Lynnwood, WA

in the imazapyr and glyphosate treatments. Rates and timing need to be further evaluated before the efficacy of clopyralid is understood on knotweed.

Adjacent to this study a herbicide screening trial to control scotch broom (*Cytisus scoparius* (L) Link) had been established using metsulfuron. Metsulfuron was applied to three knotweed colonies in the buffers for observational purposes. Observations of those plants after one year showed metsulfuron had no effect on knotweed survival, vigor, or height growth.

Application of herbicides was made after the plants had attained 90% of their final height growth for the year. Better control may be obtained treating plants before they reach their maximum height by mid-summer. Use of granular product forms may facilitate control efforts by allowing application before the plants fully develop.

## Conclusions

1. 2,4-D, dicamba, and metsulfuron were not effective controlling Japanese knotweed.

2. Clopyralid showed some positive trends for knotweed, but was not effective at the rates and timing tested.

3. Roadway dust from logging roads reduced the effectiveness of glyphosate and clopyralid.

4. Imazapyr was effective regardless of roadway conditions.

5. Glyphosate was more effective controlling colonies adjacent to paved roads; however it may require follow-up treatment.

6. Control of the entire knotweed colony may be needed to prevent resprouting and re-invasion.

## Acknowledgements

The author would like to extend his appreciation to Vanelle Carrithers of the Dow Chemical Company for their cooperation; Meg Whipp of the scientific computing center for her assistance developing the data analysis; Tom Terry, Willis Littke, Yasu Tanaka and Byron Carrier for their review of this manuscript.

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Table 1. Herbicide screening trial in Japanese knotweed. Effects of treatment on knotweed density.

| Treatment | Rate | Density | |
|---|---|---|---|
| | (kg ai/ha) | stems/$m^2$ | (se) |
| Check - No Treatment | | 15.0 [1] | (7.8) |
| Clopyralid | 0.14 | 10.3 | (10.3) |
| Clopyralid | 0.3 | 13.5 | (7.1) |
| Clopyralid | 0.6 | 11.3 | (10.3) |
| Clopyralid | 1.1 | 8.8 | (1.1) |
| 2,4-D | 2.2 | 14.8 | (1.8) |
| Dicamba | 1.1 | 11.3 | (1.1) |
| Glyphosate | 3.4 | 6.8 | (5.3) |
| Imazapyr | 0.6 | 0.5 | (0.0) |

[1] Treatments were not significantly different using an analysis of variance at p-0.05.

Table 2. Herbicide screening for Japanese knotweed. Effects of treatment on knotweed height.

| Treatment | Rate | Height | |
|---|---|---|---|
| | (kg ai/ha) | (m) | (se) |
| Check - No Treatment | | 2.6 a[1] | (0.0) |
| Clopyralid | 0.14 | 2.1 a | (0.1) |
| Clopyralid | 0.3 | 2.6 a | (0.2) |
| Clopyralid | 0.6 | 2.2 a | (0.1) |
| Clopyralid | 1.1 | 1.5 a | (0.2) |
| 2,4-D | 2.2 | 2.2 a | (0.6) |
| Dicamba | 1.1 | 2.4 a | (0.7) |
| Glyphosate | 3.4 | 1.6 a | (1.0) |
| Imazapyr | 0.6 | 0.1 b | (0.1) |

[1] Treatments with the same letter are not significantly different using Duncan's new multiple range t-test at P - 0.05.

Table 4. Herbicide screening trial in Japanese knotweed. Effects of herbicides on knotweed density growing adjacent to unpaved logging roads.

| Treatment | Rate | Density | |
|---|---|---|---|
| | (kg ai/ha) | stems/$m^2$ | (se) |
| Check - No Treatment | | 20.5 | (1.5) |
| Clopyralid | 0.14 | 17.5 | (2.5) |
| Clopyralid | 0.3 | 18.5 | (3.5) |
| Clopyralid | 0.6 | 18.5 | (5.5) |
| Clopyralid | 1.1 | 9.5 | (0.5) |
| 2,4-D | 2.2 | 16.0 | (1.0) |
| Dicamba | 1.1 | 12.0 | (5.0) |
| Glyphosate | 3.4 | 10.5 | (0.5) |
| Imazapyr | 0.6 | 0.5 | (0.5) |

Table 3. Herbicide screening trial in Japanese knotweed. Effects of herbicides on knotweed density growing adjacent to paved roads.

| Treatment | Rate | Density | |
|---|---|---|---|
| | (kg ai/ha) | stems/$m^2$ | (se) |
| Check - No Treatment | | 9.5 | (0.5) |
| Clopyralid | 0.14 | 3.0 | (2.0) |
| Clopyralid | 0.3 | 8.5 | (0.5) |
| Clopyralid | 0.6 | 4.0 | (1.0) |
| Clopyralid | 1.1 | 8.0 | (1.0) |
| 2,4-D | 0.6 | 13.5 | (0.5) |
| Dicamba | 2.2 | 10.5 | (1.5) |
| Glyphosate | 3.4 | 3.0 | (1.0) |
| Imazapyr | 0.6 | 0.5 | (0.5) |

Table 5. Herbicide screening trial in Japanese knotweed. Effects of herbicides on knotweed height growing adjacent to paved roads.

| Treatment | Rate | Total Height | |
|---|---|---|---|
| | (kg ai/ha) | (m) | (se) |
| Check - No Treatment | | 2.5 | (0.1) |
| Clopyralid | 0.14 | 2.2 | (0.2) |
| Clopyralid | 0.3 | 2.7 | (0.1) |
| Clopyralid | 0.6 | 2.3 | (0.1) |
| Clopyralid | 1.1 | 1.4 | (0.1) |
| 2,4-D | 2.2 | 2.6 | (0.1) |
| Dicamba | 1.1 | 2.9 | (0.1) |
| Glyphosate | 3.4 | 0.9 | (0.3) |
| Imazapyr | 0.6 | 0.1 | (0.1) |

Table 6. Herbicide screening trial in Japanese knotweed. Effects of herbicides on knotweed Height growing adjacent to unpaved logging roads.

| Treatment | Rate | Total Height | |
|---|---|---|---|
| | (kg ai/ha) | (m) | (se) |
| Check - No Treatment | | 2.6 | (0.4) |
| Clopyralid | 0.14 | 2.1 | (0.3) |
| Clopyralid | 0.3 | 2.5 | (0.5) |
| Clopyralid | 0.6 | 2.2 | (0.1) |
| Clopyralid | 1.1 | 1.7 | (0.1) |
| 2,4-D | 2.2 | 1.8 | (0.4) |
| Dicamba | 1.1 | 2.0 | (0.2) |
| Glyphosate | 3.4 | 2.4 | (0.2) |
| Imazapyr | 0.6 | 0.2 | (0.2) |

**Figure 1. Herbicide effects on knotweed density. Effects one year after roadside application.**

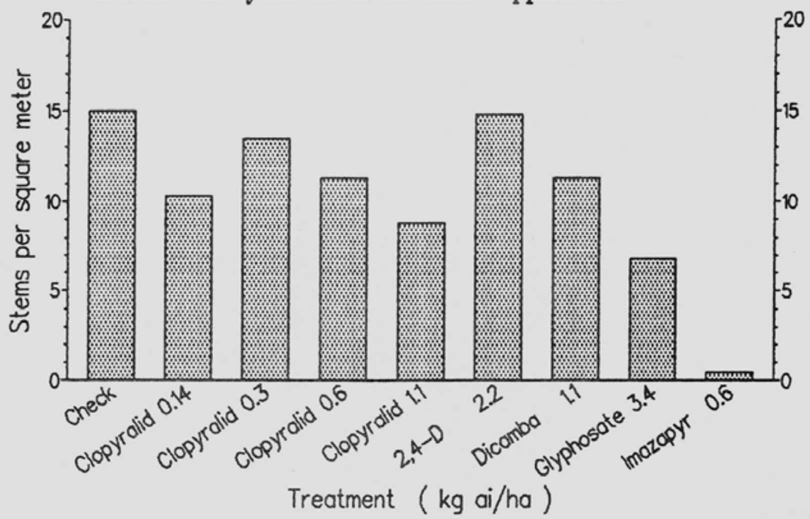



**Figure 2. Herbicide effects on knotweed height. Effect one year after roadside application.**

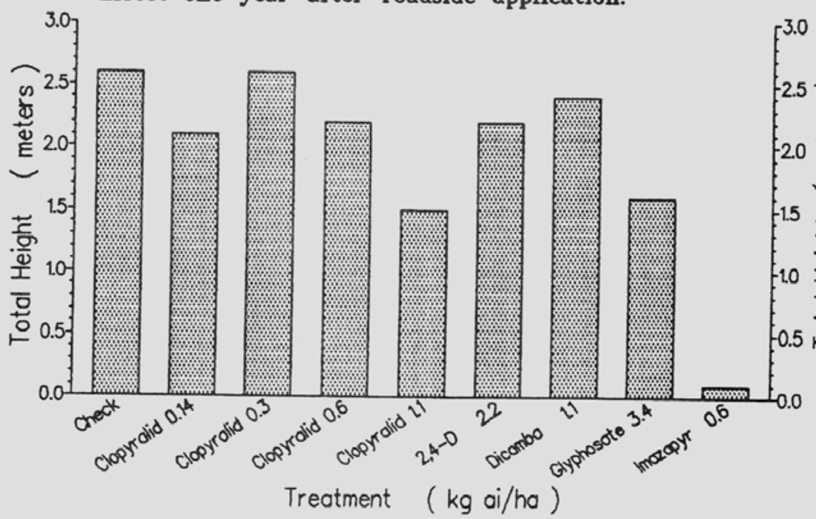


Figure 3. Herbicide effects on knotweed density.
Effect one year after roadside application.

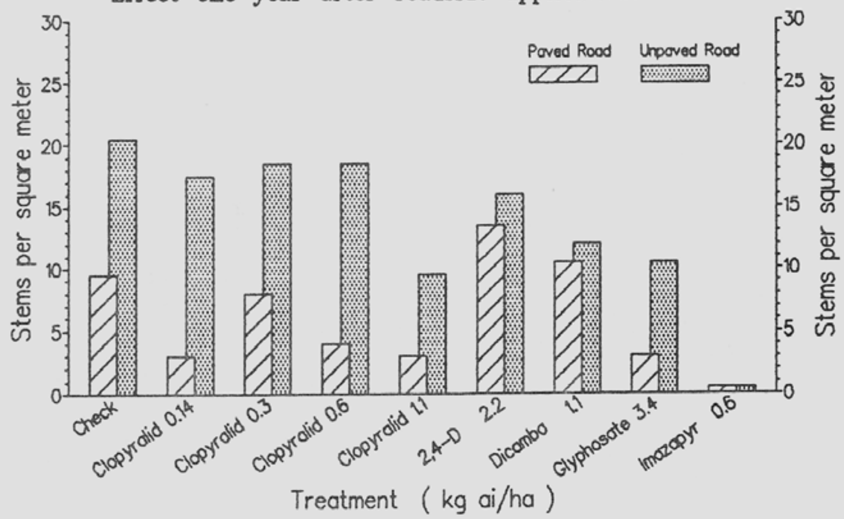
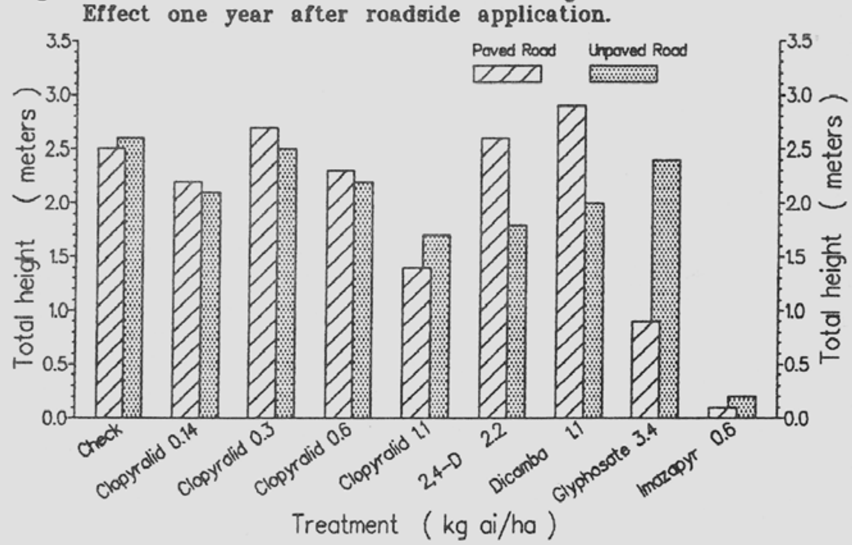



Figure 4. Herbicide effects on knotweed height.
Effect one year after roadside application.



# MINUTES OF THE BUSINESS MEETING
# WESTERN SOCIETY OF WEED SCIENCE
# HONOLULU, HAWAII
# MARCH 16, 1989

The meeting was called to order by President Donn Thill at 7:30. The minutes of the 1988 Business meeting were approved as published in the Proceedings of the 1988 meeting in Fresno.

Financial Committee/Treasurer

LaMar Anderson reported that 300 people registered for the meeting. We have a balance of just over $59,000, an increase over last year. Spouse registration is the highest ever at 127.

Rod Lym reported that we are now over $60,000 in the black, and the books are in order.

Local Arrangements

Ken Dunster reported that we had a bill of $12,000 for meeting rooms. However, there will not be a deficit balance for the meeting due primarily to industry use of the facility. Allan Tushima was very helpful and handled lots of local details. We are grateful for his help. The tour on Monday was also a great success. President Thill expressed our gratitude for a job well done to Ken and Allan. Our next meeting will be March 13-15, 1990, at the Nugget in Sparks, NV.

Program Committee

Sheldon Blank reported that the new deadline for abstracts for the meeting is December 1, which greatly facilitates printing of the program in a timely manner. This year there were 118 abstracts, 66% more than the last few years. We had 7 graduate student papers this year, down from 11 last year. Twenty posters were given, up from 17 last year. Authors from 19 states submitted abstracts.

Research Section

Steve Radosevich reported that 221 reports were submitted to the Research Progress Report, the most in recent years. Common lambsquarters and redroot pigweed were the most common weeds studied, and 2,4-D was the most tested herbicide. The cost of printing the Research Progress Report this year was $12.84 each for 375 copies. The Chemical and Physiology Section had very few (3) papers submitted this year, so it might be a good idea to change this section to include weed biology. The section chairmen for 1990 are:

Project 1 - Mike Foster, Texas Agricultural Experiment Station
Box 9000, Fort Stockton, TX

Project 2 - George Beck, Colorado State University
115 Weed Research Lab, Fort Collins, CO

Project 3 - Mike Newton, Oregon State University
Dept. of Forest Science, Corvallis, OR

Project 4 - Steve Bowe, Sandoz
1300 E. Touhy Ave., Des Plaines, IL

Project 5 - Rod Warner, DuPont
502 Mountain View Dr., Bozeman, MT

Project 6 - Shafeek Ali, Alberta Agriculture
7000 - 113 St., Edmonton, Alberta, Canada

Project 7 - Jill Schroeder, New Mexico State University
Box 30003, Dept. 3BE, Las Cruces, NM

Education and Regulatory

Paul Ogg reported that the video tape by Dr. Bruce Ames which was presented in the Education and Regulator section is available to anyone who might want to use it. Paul reported that Bert Bohmont feels the Endangered Species Act will be in place by 1991, and that GLP's are a fact of life and must be adopted by all in our industry. The Chairman for 1990 is Celestine Lacey. Chairman-Elect is Robert Parker.

Poster Committee

Tracey Sterling reported there were 20 posters presented this year, the fifth year we have had a poster section.

Student Paper Judging Committee

Nelroy Jackson reported that there were 7 papers in the contest, down from last year. The papers were presented in a block which helped judging immensely. The winners were: First place - Blake Willis, USU ($100); Second place - Sandra Halstead, WSU ($75); and Third place - Richard Evans, Univ. of Idaho ($50). Plaques will be mailed to the winners.

Member-at-Large

George Beck reported the graduate student breakfast was attended by 12 people on Tuesday.

Public Relations

Jack Schlesselman presented his report. He distributed several news releases about our meeting.

Awards Committee

Stan Heathman reported there were four nominees for Outstanding Weed Scientist from the public sector but none from the private sector. The winner was Jean Dawson, USDA-ARS, Prosser, WA. There were no nominees from the private sector, and it is hoped there will be in the future. The nomination packets of the unsuccessful nominees will be carried over for the next year.

Resolutions Committee

Tom Whitson presented three resolutions which passed. They are printed below:

RESOLUTION

WHEREAS, in November 1988, Plant Protection and Quarantine Officers of USDA, APHIS in Jacksonville, Florida, and Houston, Texas, found three shipments of tall fescue (*Festuca arundinacea*) seed from Argentina contaminated by seeds of serrated tussock (*Nassella trichotoma*); and

WHEREAS, *Nassella trichotoma* has been designated a noxious weed by authority of the Federal Noxious Weed Act; and

WHEREAS, Plant Quarantine Officers determined they had no authority to prevent the entry of the above contaminated shipments due to a provision in Section 12 of the Federal Noxious Weed Act that states, "The provisions of this act shall not apply to shipments of seed subject to the Federal Seed Act . . ."; and

WHEREAS, the Western Society of Weed Science deems it in the public interest to prevent any such future circumvention of the Federal Noxious Weed Act;

THEREFORE, BE IT RESOLVED, that the Western Society of Weed Science urge the Congress of the United States to repeal the above quoted provision in Section 12 of the Federal Noxious Weed Act that prohibits the application of that Act to shipments of seed subject to the Federal Seed Act.

RESOLUTION

WHEREAS, in November 1988, Plant Protection and Quarantine Officers of USDA, APHIS in Jacksonville, Florida, and Houston, Texas, found three shipments of tall fescue (*Festuca arundinacea*) seed from Argentina contaminated by seeds of the Federal Noxious Weed serrated tussock (*Nassella trichotoma*); and

WHEREAS, the Federal Seed Act does not prohibit importation of seed contaminated with Federal Noxious Weeds not specifically named in the Act or its administrative rules or in the laws of the state for which the shipment is destined; and

WHEREAS, most species of noxious weeds, including species listed under the Federal Noxious Weed Act, that have not been known to be present in the United States, are not listed in the Federal Seed Act or in rules and regulations thereunder promulgated by the Secretary of Agriculture; and

WHEREAS, it was intended by the legislature that weeds designated noxious under the Federal Noxious Weed Act be also listed as noxious under the Federal Seed Act;

THEREFORE, BE IT RESOLVED, that the Western Society of Weed Science urge the Secretary of Agriculture to issue an executive order to list in the rules and regulations of the Federal Seed Act all weeds designated noxious under the Federal Noxious Weed Seed Act, and require a zero percent noxious weed tolerance for contamination of import shipments of seed.

RESOLUTION

WHEREAS, on March 12 to 17, 1989, the Western Society of Weed Science was conducted in the Ala Moana Hotel in Honolulu, Hawaii, and

WHEREAS, meeting and sleeping accommodations were excellent and whereas personnel and services provided were outstanding.

THEREFORE, LET IT BE RESOLVED, that the management and staff of the Ala Moana Hotel be commended for superior service to the Western Society of Weed Science with our deepest appreciation for a job well done.

WSSA Representative

Jack Evans reported that the WSSA is calling for donations of weed-related publications to send to libraries in third world countries. The WSSA made $4,000 this year instead of the projected loss of $52,000. WSSA-sponsored publications are still not selling as well as expected, and Jack encouraged our membership to purchase WSSA publications. The WSSA annual meeting will be held in Montreal next year. Weed Technology is doing very well with 150 papers in 1988. The WSSA handbook is supposed to be printed in 1989.

Nominations Committee

Ken Dunster reported 143 ballots were returned. Our new officers for 1989-90 are: Pete Fay, President-elect; Doug Ryerson, Secretary; Frank Young, Research Chairman-elect; Robert Parker, Extension-Regulator Chairman-elect.

CAST Representative

Lowell Jordan introduced William Marion, the new director of CAST who spoke to us. The next two reports to be published are on Aflotoxins and the Conservation Reserve Program. The magazine of CAST is being sent to 16,000 science programs in U.S. schools. Dr. Marion reported that CAST urgently needs a prompt statement on Alar from the agriculture industry since the environment movement has already provided their position paper.

Past President's Report

Larry Mitich reported that we will have a new treasurer/business manager, Wanda Graves, from Newark, California. She has a great deal of experience and will attend our summer executive meeting in Reno. A special thanks was conveyed to LaMar Anderson for his years of service to the WSWS.

Placement Committee

Tom Lanini reported that the job market in Weed Science is quite strong with 50 positions available at this time.

Legislative Committee

George Beck reported that the IMWAC report will be presented to a number of Federal Legislators this year.

Necrology Committee

Joan Lish reported that Boysie Day, a long-time member fellow and past president of WSWS, passed away in 1988.

New Business

A. Three ad hoc committees - Necrology, Poster, and Student Paper - were changed to standing committees by a vote of the membership. The membership voted to approve the constitution and by-law changes shown below:

ITEM 1 -- THE WSWS CONSTITUTION

| Present wording | New wording |
| --- | --- |
| ARTICLE VII - Standing Committees | ARTICLE VII - Standing Committees |
| Section 1 There shall be ten Standing Committees: Program Finance, Resolutions, Local Arrangements, Nominations, Public Relations, Placement, Nominations of Fellows and Honorary Members, Site Selection, and Awards appointed by the President with the advice and consent of the Executive Committee. | Section 1 There shall be thirteen Standing Committees: Program, Finance, Resolutions, Local Arrangements, Nominations, Public Relations, Placement, Nominations of Fellows and Honorary Members, Site Selection, Awards, Poster, Student Paper Judging, and Necrology appointed by the President with the advice and consent of the Executive Committee. |
| Sections 12-14 are new. | New Sections |
| | Section 12 The Poster Committee shall consist of a chairperson and two additional members. Terms of office of this committee shall be as in Section 3 above. |
| | Section 13 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. |
| | Section 14 The Necrology Committee shall consist of a chairperson and two additional members. Terms of office shall be as in Section 3 above. |

B. Tom Whitson and his committee are preparing a Western region Weed Identification book which will be associated with the WSWS.

C. Thanks were expressed to Elanco for sponsoring the business meeting breakfast.

D. Jean Dawson encouraged us to purchase books and other publications from the WSSA.

E. Sheldon Blank, our new President, presented a plaque and the gavel to Donn Thill.

There being no further business, the meeting was adjourned at 8:50 a.m. by President Blank.

Respectfully submitted,

Pete Fay
Secretary, WSWS

WESTERN SOCIETY OF WEED SCIENCE
Financial Statement
March 1, 1988 - March 2, 1989

| Income | 1988-89 |
|---|---|
| Registration, Annual Meeting | |
| At Registration Desk | $4,020.00 |
| Preregistration, next year's meeting | 7,614.00 |
| Spouse preregistration | 1,600.00 |
| Tour (preregistration + at desk) | 2,385.00 |
| Dues, members not attending annual meeting | 520.00 |
| Extra luncheon tickets | |
| Current year's Research Progress Report sales | 2,570.11 |
| Current year's Proceedings sales | 2,972.51 |
| Next year's Research Progress Report sales | 2,143.29 |
| Next year's Proceedings sales | 2,150.00 |
| Sale of back issues of publications | 388.50 |
| Payment of outstanding invoices | 14.00 |
| Coffee break donations | 700.00 |
| Total fiscal year income | $27,077.41 |
| **Expenditures** | |
| Annual Meeting incidental expenses, last year | 140.37 |
| Annual Meeting incidental expenses, this year | 1,343.95 |
| Luncheon, annual meeting | 3,165.99 |
| Guest Speaker expenses | 841.30 |
| Graduate Student room subsidy | 510.00 |
| Graduate Student paper awards | 354.50 |
| Business Manager honorarium | 1,000.00 |
| CAST dues | 560.00 |
| CAST, development program | |
| Tour | 1,419.60 |
| Research Progress Report, publication costs | 3,841.50 |
| Proceedings, publication costs | 3,530.68 |
| Postage | 1,012.76 |
| Newsletters, printing costs | 398.74 |
| Office supplies | 465.72 |
| Refunds | 165.00 |
| Program, printing costs | 759.01 |
| Spouse Program | 90.64 |
| Executive expenses | 690.00 |
| Total fiscal year expenditures | $20,289.76 |
| Fiscal year operational balance | 6,787.65 |
| Interest on checking | 245.96 |
| Interest on savings certificates | 3,758.10 |
| | 10,791.71 |
| **Assets** | |
| Savings certificates | $43,247.24 |
| Checking Account balance | 15,822.46 |
| Cash on hand | 50.00 |
| | $59,119.70 |

Summaries of Research Project Discussion:

## Summary of Project 1: Perennial Herbaceous Weeds

The meeting was called to order by Chairman George Beck at 10:15 a.m. with 29 people present. Topics discussed were: (1) the role of allelopathy in perennial herbaceous weed interference, (2) methodology to study allelopathy, and (3) separating competition from allelopathy.

Interference has been defined as the adverse effects of neighboring plants in an association. Competition results in mutually adverse effects to organisms which utilize a common resource in short supply. Allelopathy involves the inhibition of one organism by another via the release of metabolic by-products into the environment. Competition and allelopathy are two distinct interactions; however, does competition plus allelopathy result in interference? Many studies have indicated that something more than competition is occurring.

Allelopathy research has generally focused on the above ground portion of plants. Dr. C.S. Tang, Chairman, Department of Agricultural Biochemistry, University of Hawaii began studying the effects of root exudates in range grasses in Hawaii. Analyzing the various compounds released by plant roots into the soil is difficult. When the soil is disturbed, the rhizosphere is also affected. Root tissue may be broken, causing the allelochemicals to be released 100,000 times as much as normal. In order to guarantee the tranquility of the rhizosphere, Dr. Tang developed a continuous root exudate trapping system. The system was constructed by cutting the bottom out of a 4 l solvent bottle, tipping it upside down, and adding growing media. Nutrient solution was recirculated through the system, and hydrophobic compounds exuded by the roots were trapped in a column attached below the bottle. Dr. Tang was able to identify 30 to 40 compounds. This paper was published in Plant Physiology, and was the first manuscript on allelopathy to be accepted by the journal.

Dr. Tang has worked on many species including *Bidens pilosa*. Compounds were identified in the root exudate, verifying that chemicals were being continuously produced. Quantitative collections of compounds were first demonstrated with papaya. When discussing a toxic principle or biological activity, just demonstrating that the compounds are present is not sufficient. We must know how much is being released and the condition of the compounds.

Dr. Tang emphasized that roots of affected plants are often the first plant organs to be damaged by allelochemicals. During seed germination, chemicals are released from the seedcoat which suppresses the growth of other seedlings, a demonstration of autotoxicity. The allelochemical sphere is influenced by water availability under field conditions. Inhibitors are continuously transported to target species under irrigation.

Intraspecific chemotypes are important when studying allelopathy. Dr. Tang has studied the sesquiterpene compounds produced in four types of purple nutsedge. He found that certain terpenoid compounds released by three plant types were highly toxic, however essential oils and waxes were not as toxic.

Bob Zimdahl suggested that Cook's Postulates, the basic principle of plant pathology, should be applied to the study of allelopathy. Cook's Postulates involve observing some phenomena in nature, determining a cause, isolating the cause, and reproducing the effect in nature. Dr. Zimdahl reviewed a method which may help to separate the two phenomena of competition and interference, and to determine if competition plus allelopathy equals interference. [R.P.A. Unamma and I.O. Akobundu. 1989.] Effects of tropical weeds on yield in white yam (*Diostcorea rotundata*) Weed Research 29:1-6]. The authors constructed a large wooden box (12" x 17" x 60") with an upper weed seed zone and a lower yam zone where the tubers were planted. Four systems were established in the box: (1) weed free or hand weeded check, (2) full weed interference, (3) no weed root or lechate contact -- the two zones were separated by four layers of black plastic and anything produced by the plant was trapped and taken out of the system, and (4) no weed root contact but with lechate - offset holes were punched through the plastic allowing any lechate from the weed zone to penetrate into the yam zone; however, weed roots could not grow through the successive layers of plastic. The authors stated that these experiments demonstrated allelopathic phenomena and there was proof of competition and allelopathy occurring. However, they could not identify the chemical and reproduce the effects by reintroducing it into the system. Dr. Zimdahl stressed that although a chemical can be collected and reintroduced, there is still no evidence that the plant produced it. The compound could have been made in the transition or during storage, or could perhaps be microbial phenomena -- not just a plant phenomena. One risk in allelopathic studies is introducing an artifact just by the particular methods used. To understand interference, its two components (competition and allelopathy) must be separated and studied separately. The method of Unamma and Akobundu may be a valuable tool in studying interference.

Barbra Mullin, Montana Department of Agriculture, was nominated as Chairman-elect for 1990. The nomination was approved by unanimous ballot.

**Summary of Projects 2 and 3: Herbaceous Weeds of Range and Forest, and Undesirable Wood Plants**

Projects 2, Herbaceous Weeds of Range & Forest, and 3, Undesirable Woody Plants, met concurrently on March 14, 1989, in Honolulu, Hawaii.

Steve Radosevich, Oregon State University, opened the session by addressing the utility of models as management tools. There are three major components to models: generality, predictability, and reliability. Empirical models describe how a system works, theoretical models describe how a system ought to work, and management models predict how a system will work. Management models should be reliable.

Watson's demographic model for leafy spurge based on phenological stages was discussed and pointed out that the model was not reliable as written. The model was improved by a simple competition/density function, which was introduced at the buds to shoots, or G2, portion of the model. Without the density function, the model predicted leafy spurge to increase exponentially. The density/competition function indicates leafy spurge populations fall off at a particular density rather than continuing to increase exponentially. When management is invoked, e.g. picloram application or grazing at different intensities, the improved model more reliably predicts leafy spurge recovery and subsequent population contribution to the flora.

In Douglas fir models, competitive species cover or height of all species is used to drive the model. Mathematical expressions of growth are fit into differential equations. Up to ten such equations may be solved simultaneously in the Douglas fir model. When salmonberry and Douglas fir growth are simulated, the cover driven model indicates Douglas fir will dominate over time. If red alder is added to this system, salmonberry and Douglas fir growth is suppressed. When height is used as the driver, the model predicts good Douglas fir growth without competition. A slight loss is predicted when salmonberry is added to the system. However, the model indicates salmonberry and Douglas fir growth will be suppressed when in competition with Red Alder.

Models allow use of limited data to explain competition relationships mathematically. These relationships can be modified as more data become data.

This information can be used as an outcome predictor of forest management decisions.

A management model, Vegepro, was discussed. It is a data matrix used to provide vegetation management recommendations. The user inputs cover by species and may modify the model to fit other local conditions. The model predicts management decision results by species and seasonal control and provides a recommendation; i.e., the program generates management choices, chooses an optimum herbicide treatment based on user input, and provides treatment options. This model helps to document the foresters' decision making process. Vegepro will be melded with the "young stand" Douglas fir model to predict long-term consequences of management/treatment decisions.

The validity of conceptual models was questioned. Conceptual models predict responses, but do not address causes of a response. However, mechanistic models are designed to address response causes. Conceptual forestry models have been developed from 20 to 30 years of response data where response causes were not addressed. However, these models help to organize research, i.e., give indications as to the important mechanistic research questions to ask rather than conducting another experiment just because it "appears" to be an area of concern.

Models also function to address experimental reliability. Models can be used to "repeat an experiment" (as opposed to physically repeating the work), then an experiment designated to validate the model. Models then become a tool to generate reliable information. Thus, conceptual models predict plant response to specified conditions based upon response data, but do not address causes. However, conceptual models provide a basis for judging the importance of asking certain research questions. Mechanistic models address plant response causes under specified conditions. Management models are used to aid decision making, and when combined with conceptual models, predict the outcome of decisions. Management models do not necessarily have to be precise, but flexible enough to predict plant response or growth under different conditions.

Paul Figueroa, Weyerhaeuser, addressed the need for cost/benefit relationships for weed control. Historically in the forest industry, management decisions were made on the basis that the outcome was believed to be beneficial, possibly without a sufficient knowledge base or cost/benefit analysis. The first process in weed control cost/benefit analysis is to determine the management objectives of a forest stand. Crop survival, increased yield, access maintenance, water quality maintenance, noxious weed abatement, or habitat improvement as objectives, all will require different inputs and affect cost/benefit analysis. A non-managed conifer stand may require 200 years from harvest to harvest wheras when weed management or vegetation management is practiced, elapsed time to harvest may be dramatically decreased, e.g. 40 to 100 years.

Increased survival as a management objective will cost much less and affect management input compared to increases survivability and growth. Cost/benefit analysis also would be different under these two regimes. Not enough data exists on different forest species to accurately predict the outcome of management decisions. Many short-term experiments have been conducted, but the forest is a long-term environment; thus, the need for long-term research is apparent. Information gained from long-term studies could be melded with short-term study data to generate predictive models. This would aid management decisions and cost/benefit analysis.

To generate an accurate cost/benefit analysis, one needs to identify management objectives, identify all alternatives for vegetation management, develop and/or use long-term response data, and utilize all this information in a growth/management model to aid the decision making process. Results of the cost benefit analysis are lower costs, better return, and more beneficial use of vegetation management money. Good cost/benefit analysis provides greater credibility to management decisions that are made and makes it easier to obtain an appropriate budget.

Jerry Stuth, Texas A & M University, addressed decision support systems as a natural resource management tool. A decision support system must be able to respond to unique environments, i.e. a good decision support system should be highly user driven. Each landowner has specific strategic goals that normally include maintaining ownership of their farm or ranch, maintaining a desired standard of living, avoiding catastrophic losses, obtaining a desired profit level, and lastly, improving their ranch or farm environment.

University research deals with the latter item. This presents a challenge to get ranchers/farmers to adopt recommendations because our information is used only in their lowest of hierarchal needs (ranch improvement). Researchers are confronted with several other challenges to provide useful information to benefit the ranch or farm industry. Information generated by universities is filtered by an individual based upon what they know or believe and this "perception" of information can be difficult to overcome. Changes in the ranch or farming environment drive changes in research direction and also, present a challenge for researchers to fill these needs.

Changes in the ranching environment, e.g. demographic shifts in ownership/management and better educated or informed consultants, helped cause evolution of user driven models as management tools -- tailored to fit particular situations by input options available in the model. This allows an individual to draw their own conclusions and decisions rather than simply "trusting experts".

Texas A & M developed a user driven model adaptable to a particular ranching situation. Input is based on management objectives of the ranch and plants to manage. The software requires very detailed user input, so it can be tailored to fit an individual's needs. The model is heuristically driven rather than based strictly or mostly on research results. Lots of heuristic information is available and fills an apparent need. Research results will be incorporated into the model as they become available. This encompassing model is currently being tested and should be distributed for use in June, 1989.

The business meeting was held at the session's end. The group decided that projects 2 & 3 should remain together. George Beck and Mike Newton are chairs of projects 2 & 3, respectively, for 1990. Diane White and John Brock were elected chairs of projects 2 & 3, respectively, 1991. Gary Lee, University of Idaho Experiment Station Director, asked the session attendees if a special project concerning larkspur management should be addressed at the Western Region level. The group indicated a special project addressing poisonous plants would be appropriate, but not one specifically dealing only with larkspur.

## Summary of Project 4: Weed Control in Horticultural Crops

Project 4 met on Tuesday, March 14, from 3:30 to 5:00 p.m. with approximately 25 people in attendance and a discussion led by Stott Howard, Washington State University. There were two subjects covered during the discussion: 1) IR-4/GLP and what effects they would have on public and private sector research, and 2) the current status, development and needs of the "Living Mulch" technology.

The first topic, IR-4/GLP, covered some of the problems researchers had during the "trial year" for GLP compliance on IR-4 research projects. In general, public and private sector research organizations expressed frustration regarding the inflexible nature of the GLP. Specific comments regarded: 1) uncertainty of the role the Quality Assurance Officer (QA) and their ability to provide the QA requirements of GLP, 2) the pros and cons of tractor vs. backpack sprayer applications, 3) the accuracy of volume vs. area calibrated spraying, 4) inadequate funding of research projects, and 5) need for equipment to upgrade research projects to comply with GLP requirements.

The second topic, "Living Mulch Technology", covered topics such as experimental design, research needs, interdisciplinary cooperation, and new and innovative research techniques. Several concerns were raised regarding the capability of research methods to adequately investigate parameters of living mulch effects on the production system.

A review of WRCC-61 (Living Mulches to Improve Soil and Vegetation Management Practices on Agricultural Lands and Reclamation Sites) annual meetings and attendance was provided. There have been four annual meetings with an average attendance of 14. There was a suggestion for increased involvement by those attending Project 4.

A product of WRCC-61 efforts has been the submission of a preproposal to the LISA program. The proposal is titled "Minimizing Nitrogen Fertilizer and Pesticide Impacts in Perennial Fruit Cropping Systems through the Use of Cover Crops". The project involves 12 scientists from 4 western states (Utah, California, Oregon, and Washington). The preproposal was accepted, and now the LISA program has requested a more in depth proposal for consideration.

## Summary of Project 5: Weeds in Agronomic Crops

This project was chaired by Roderick W. Warner and the topic of discussion was "Herbicide Resistant Weeds in Agronomic Crops".

The discussion began with an examination of the scope of the problem in the Western United States as it exists today. Roderick Warner reviewed the situation with sulfonylurea herbicides in Montana. This state currently has the most confirmed resistant sites with 7 kochia and 1 confirmed case of Russian thistle resistant to this class of herbicides. As the discussion progressed, it was noted that triazine resistant common groundsel has become a problem in orchards in Washington. Diclofop resistant ryegrass in Oregon is of concern but so far is localized and appears to have been contained. A number of suspected cases of herbicide resistant weeds were cited ranging from Canada thistle in Washington to bromacil resistant grasses in California citrus.

The second area of discussion was the potential of the resistance problem if current trends continue. While the current situation has not yet progressed to the point where herbicide resistant weeds are a widespread and economically devastating problem in the Western U.S.A., the potential is there should similar mode of action herbicides be continuously used. Dr. Homer LeBaron noted that it is not just persistence but also frequency of use and that switching to short residual herbicides alone will not solve the problem.

The next topic of discussion was factors which favor selection of weeds for herbicide resistance. Jo Cotterman presented the Gressel and Segal equation as a possible model that highlighted important factors involved in selecting for resistance. Steve Radosevich commented that this equation is too simplistic in that it forces the conclusion that resistance is inevitable and permanent -- two assumptions that have not historically been true. He indicated that the model needs to be improved by taking into account gene flow and many other traits. He suggested this could result in some useful management strategies, in particular, managing the susceptible weeds rather than just trying to kill all of the resistant ones. Donn Thill indicated that in his opinion the Gressel and Segal equation has worked well and has accurately predicted what has indeed been seen in the field in areas such as NE Montana where continuous use of chlorsulfuron resulted in resistance in 4-5 years.

Strategies to manage or prevent herbicide resistant weeds were the final topic of discussion. The discussion began with the observation that efforts to develop herbicide resistant crops could pose the danger that these same crop plants could become "super weeds" in other crops. The suggestion was made that herbicide resistant crops also be given a gene for increased susceptibility to other herbicides. Another idea to manage herbicide resistant weeds was to fill field voids with "good weeds" that could easily be killed by herbicides, thus providing a mulch to choke out the herbicide resistant weeds. Steve Radosevich indicated that if nothing is done, herbicide resistant weeds are likely to become an increasing, if not unmanageable problem. He indicated that we need to broaden our knowledge base and integrate factors such as fitness, competition, gene flow and gene expression to come up with sound programs to manage herbicide resistant weeds.

Homer LeBaron summed up the discussion by reminding us what has happened in the area of resistance to insecticides and fungicides and that it would be a terrible waste to stand idly by and see valuable chemistry made useless by mismanagement. It is the responsibility of all involved; industry, university, and the end user, to manage these products in a responsible way.

The session ended by choosing a chairman and a chairman elect for the 1990 session. Charles E. Osgood agreed to be the Chairman and Pat Fuerst is the Chairman-elect.

## Summary of Project 6: Aquatic, Ditchbank and Non-Crop Weeds

The meeting was called to order at 9:15 a.m. by Chairman, Kurt Getsinger. Six papers were presented, and there were 34 people in attendance.

Axillary Turion Production by the dioecious *Hydrilla verticillata* from different sources and under various conditions - Joan S. Thullen, U.S. Bureau of Reclamation, Denver, Colorado.

> Floating dioecious *Hydrilla verticillata* will readily produce axillary turions under an 8-hour photoperiod, aeration, and a daily water temperature range of 17 to 27°C. Up to 49.6 axillary turions can be produced by 1.0 gram of dry plant material (or 6697 turions per cubic meter volume of water) within six weeks. Care should be taken when designing a control program to consider the production of turions. Control techniques, such as chaining or disking should be avoided particularly during the spring and fall to prevent the spread of *Hydrilla* by fragments and the possible subsequent production of turions.

Japanese knotweed herbicide screening trial applied as a roadside spray - Paul F. Figueroa, Weyerhaeuser Company, Centralia, Washington.

> Japanese knotweed (*Polygonum cuspidatum*) is an aggressive weed species that has begun to invade roadsides, streamsides, and conifer stands in the last few years. The plant develops primarily from spreading rhizomes and has exceptionally rapid lateral growth. Roadside cutting, mowing vegetation, and transportation of plant parts to dump sites are increasing the incidence of colonies of knotweed along roadsides. There

are very few proven control methods for knotweed control. Clopyralid, imazapyr, dicamba, glyphosate, and 2,4-D were evaluated for control of Japanese knotweed in western Washington. After one growing season only imazapyr gave significant control of Japanese knotweed. Glyphosate showed some control but control decreased considerably where there was road dust. Dicamba and 2,4-D had no effect on Japanese knotweed. Clopyralid did not reduce knotweed cover, but rates of 1 lb ai/a appeared to reduce knotweed vigor.

Factors affecting control of common cattail (*Typha Latifolia L.*) with glyphosate - R.D. Comes and A.D. Kelley, USDA-ARS, Prosser, Washington.

Common cattail is a major problem in drainage canals in Washington. Since amitrole plus thiocyanate is no longer registered for aquatic use in Washington, glyphosate was evaluated to determine its effectiveness on common cattail.

Glyphosate applied at 3.3 and 4.4 kg/ha in mid-August or about 10 days before the first autumn frost in September reduced the stand of cattail 96 and 98 percent respectively, one year later. Glyphosate applied earlier in the season or at a lesser rate was much less effective. Amitrole plus ammonium thiocyanate at 8.8 + 7.3 kg/ha controlled cattail equal to glyphosate at 3.3 kg/ha.

Purple Lythrum control - Daryl Jackson, Grant County Noxious Weed Control Board, Ephrata, Washington

Purple loosestrife (*Lythrum salicaria*) has become established in the wetlands and waterways throughout the middle latitudes in the continental United States and Canada. Within central Washington during the last ten years, purple loosestrife has grown in size from one hundred acre estimate in 1978 to a current estimated amount of 55,000 acres in Grant County alone. It is estimated that one plant can invade a one acre lake in one year.

Several herbicides have been used on a limited trial basis, but Rodeo (*glyphosate*) has proven to be effective and is currently labelled for use. Biological agents currently have not proven to be effective, and very little research is being done at this time in the United States.

Control measures in the State of Washington have been largely those of containment and public awareness. Containing the large populations to their current site and eliminating the single plants by either the use of herbicides or plant removal have been the extent to which the program has progressed. A program of public awareness such as the one devised and instituted by the State of Minnesota would be the pattern of a program to undertake to prevent the establishment of purple loosestrife.

The Myriophyllums of North America - Richard Couch and Edward Nelson, Oral Roberts University, Tulsa, Oklahoma.

Richard Couch presented a paper on the *myriophyllum* spp. found in North America. In their study, they encountered 14 species of *myriophyllum* that are of the genus of aquatic macrophytes, four are introductions to North America. Only one of these, Eurasian water milfoil (*Myriophyllum spicatum*) is considered to be a weed. Eurasian water milfoil is a major problem in the lakes of British Columbia, Canada.

Computer enhances imagery for delineation of aquatic and wetland plants, a system capability update - Terry McNabb, Aquatics Unlimited, Kent, Washington.

Terry McNabb presented a paper on the potential use of aerial imagery for aquatic weed mapping, herbicide application effectiveness and detection of exotic plants. The method has been used quite successfully in water quality monitoring.

The system uses a VHS video format and provides a pixel solution 2' x 2' from 5000' above ground level. Using IBM Lotus 123 program, the computer can digitize the video image. By using a video image, it allows for instant replay, so the operator can review and retake an area while still in the air.

<u>Chairman-elect 1990</u>

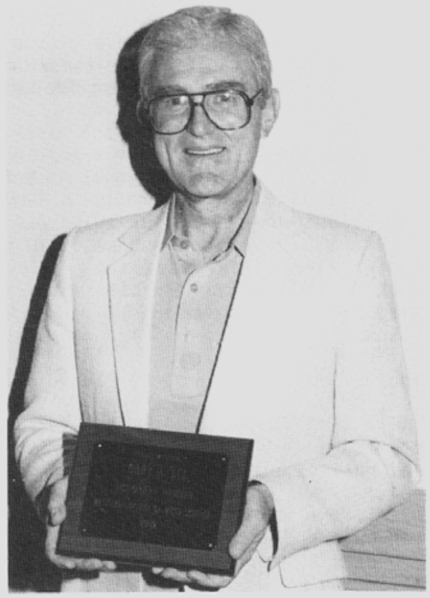
By vote, Dave Spenser, UC Davis, Davis, Co., was nominated as Chairman-elect for 1990.

1989 WSWS Student Paper Winners

(Left to Right) Third - Richard M. Evans
Second - Sandra J. Halstead
First - Blake D. Willis

# 1989 Honorary Member
# Western Society of Weed Science

## Gary A. Lee



Dr. Gary A. Lee was born in Scottsbluff, Nebraska. Gary entered Chadron State College in 1959 and received a B.S. and M.S. in Plant Science in 1963 and 1965, respectively, from the University of Wyoming. He did additional graduate work at Colorado State University and received a Ph.D. in Plant Science with specialization in Weed Science from the University of Wyoming in 1971. Gary and his wife, Georgia, live in Moscow, Idaho. They have three children: Michael, Michelle, and Megan.

From 1965 to 1971, Gary was an instructor at the University of Wyoming. In 1970, he was a research fellow at Colorado State University. From 1971 to 1975, Gary was an Assistant and Associate Professor of Weed Science at the University of Wyoming. Gary accepted a position as Professor of Weed Science at the University of Idaho in 1975, a title he still holds.

Dr. Lee began a successful administrative career at the University of Idaho in 1979, which included Assistant Director of the Idaho Agricultural Experiment Station, Head of the Department of Plant, Soil and Entomological Sciences, and currently Director of the Idaho Agricultural Experiment Station and Associate Dean of the College of Agriculture.

Gary has conducted extensive weed research in field and row crops and rangelands. He taught several upper division, undergraduate, and graduate level weed science courses. Many of his former graduate students are active in the agricultural chemical industry.

Dr. Lee is a member of many scientific and honorary societies such as the Weed Science Society of America. He has held many offices in the WSWS and served on numerous committees. For his research and professional accomplishments, he was named a Fellow of the WSWS in 1979.

1989 Fellow
Western Society of Weed Science

Dr. John O. Evans

Dr. Evans completed a Bachelor of Science degree in Agronomy and received a high school teaching certificate from the University of Wyoming. He received his Master of Science in Plant Breeding from Utah State University and his Ph.D. in Weed Science from the University of Minnesota. Prior to moving to Logan, he was a member of the Botany staff at Colorado State University.

For the past twenty years, he has taught undergraduate and graduate courses in weed science at Utah State University and organized a graduate level laboratory and field research class entitled "Methods of Plant Science Research." Dr. Evans insists on a highly professional performance from undergraduate and graduate students.

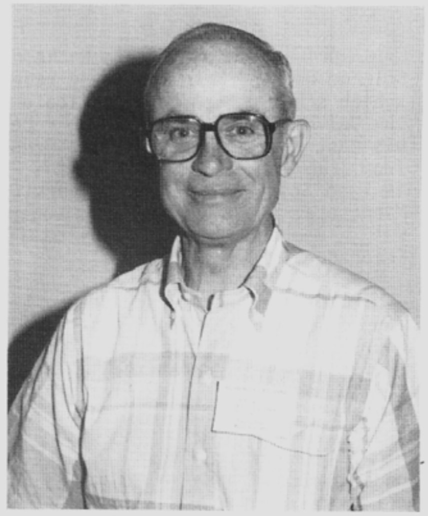
Dr. Evans made remarkable contributions toward our understanding of herbicide behavior in surface moving waters as a result of 2,4-D and picloram mobility in water and soils studies. Other important research includes a series of studies concerning environmental effects of herbicides on crops and non-target plants, and on the accumulation of Simazine in a three-step food chain system which provides guidelines for scientists throughout the world.

Dr. Evans has also conducted weed research studies in Latin America and East Africa. He currently directs research programs for graduate students from South Africa, Turkey, Latin America, and the United States. He has served as major professor for 25 M.S. and 7 Ph.D. students at Utah State University.

He has been active in the Western Society of Weed Science (WSWS) throughout his professional career and has held most of the offices in the society. He served as President of WSWS in 1986 and currently serves as the society's representative to the Weed Science Society of America. He has held several offices in the national organization and is presently a member of its Board of Directors. Jack is a member of the Western Society of Crop Science and frequently makes presentations in their conferences. In 1987 he was presented the Outstanding Service Award in recognition of twenty years service to the state weed organization.

# 1989 Fellow
# Western Society of Weed Science

## W.B. "Jim" McHenry



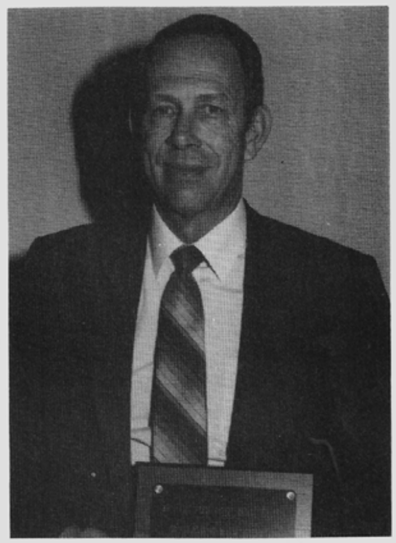
Jim McHenry, a University of California Extension Weed Scientist, is a native Californian. He served as a naval aviator in World War II. Following his service duty, he attended Oregon State University where he received a B.S. degree in 1950. He joined the staff of the OSU Federal-State Cooperative Seed Testing Laboratory in 1949. His duties for three years at the seed laboratory included research and instructing classes in seed testing technology.

Jim McHenry joined Cooperative Extension in 1953 at the Humboldt County Extension Office on California's north coast. In 1955 he assumed the responsibilities of Extension Weed Scientist at the UC Davis campus with state-wide program responsibilities in aquatic and non-crop weed control. Rangeland and forest weed control were added to his program in 1971; these areas have received program emphasis over the past 17 years. His applied research encompasses both chemical and non-chemical alternatives for competition control in seedling conifers and in eucalyptus and Australian beefweed grown for fuel or pulp.

Jim served as President of the California Weed Conference in 1976 and was awarded Honorary Member status in 1981. He has served on a number of committees in both the Weed Science Society of America (charter member) and the Western Society of Weed Science. He contributed to the creation of the Forest Vegetation Management Conference in California in 1979-1980 and received an Outstanding and Dedicated Service Award from that organization in 1985. For five years, 1978 to 1983, Jim served as state-wide Unit Director for the Cooperative Extension Weed Specialists.

# 1989 Outstanding Weed Scientist Award
## Western Society of Weed Science

### Jean H. Dawson



Beginning in 1957, Jean H. Dawson has devoted his entire distinguished professional career in weed science, with ARS-USDA cooperating with Washington State University at the Irrigated Agricultural Research and Extension Center, Prosser, Washington. He has been the Research Leader for the USDA Weed Science Research Unit since 1972 and for the Weed, Soil, and Water Mangement Unit since 1985.

Jean's contributions and accomplishments for weed science are of the highest order and indicate unusual productivity. The tangible end results of Dawson's research are a) contributions to knowledge concerning the nature of phenomena and b) new or improved technology. The research that produced these results represents a blend of basic and applied studies, usually conducted concurrently and interrelatedly. Often the same results become part of the body of knowledge supporting a contribution to theory as well as that supporting development of a practice.

His research accomplishments have been extensive and most of them highly innovative and original. A partial list would include the chief discoverer of a) herbicide uptake by emerging shoots of grasses, b) dodder control, c) weed-crop ecology (when during the crop season does harmful weed competition occur), and d) seed treatment with volatile herbicides. He has published extensively, been invited to symposiums and workshops around the world, and served as advisor to other research groups.

Jean Dawson has served weed scientists well by, among other things, serving as Chairman of the Research Section and the Auditing Committees of the WSWS, editor of the WSSA newsletter, reviewer of Weed Science Journal, Associate Editor of Weed Science Journal, and as Vice-President, President Elect, and President of WSSA.

Jean has received many previous honors including Fellow of both the WSWS and WSSA, and recipient of USDA Science and Education Administration Directors Award for Special Achievement.

As the first recipient of the WSWS Outstanding Weed Scientist Award, Jean H. Dawson is a weed scientist of national and international stature. He has conducted his research with a keen awareness that his eventual objective is to develop better programs for growers. At the same time, he delves deeply enough into each subject to explore the principles behind his work and publishes these for his peers to evaluate. As the first recipient of this award, Jean H. Dawson, sets a standard of excellence that will make this honor of even greater significance in the future.

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