PROCEEDINGS

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WESTERN SOCIETY OF WEED SCIENCE

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1993

PROCEEDINGS

OF

THE WESTERN SOCIETY OF WEED SCIENCE

VOLUME 46

PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 9, 10, 11, 1993

DOUBLETREE HOTEL

TUCSON, ARIZONA

PREFACE

The Proceedings contain the written summary of the papers presented at the 1993 Western Society of Weed Science Annual meeting plus summaries of the research discussion groups and of the business transacted by the Executive Board. Authors submitted either abstracts or full papers of their presentations.

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

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

Cover: Prickly lettuce (*Lactuca serriola* L.). Also, introducing the new Western Society of Weed Science Publication logo as approved by the Publication and Editorial Committee.

Proceedings Editor: Rodney G. Lym

TABLE OF CONTENTS

GENERAL SESSION

POSTER SESSION

RESEARCH SECTION I (Weeds of Range and Forest)

RESEARCH SECTION II (Weeds of Horticultural Crops)

RESEARCH SECTION III (Weeds of Agronomic Crops)

RESEARCH SECTION IV (Extension, Education, and Regulatory)

RESEARCH SECTION V (Weeds of Aquatic, Industrial, and Non-Crop Areas)

No papers presented.

RESEARCH SECTION VI (Basic Sciences)

RESEARCH SECTION VII (Alternative Methods of Weed Control)

WSWS HERBICIDE RESISTANCE SYMPOSIUM

RESEARCH PROJECT MEETINGS

PROCEEDINGS DEDICATED TO

WENDELL R. MULLISON

DR. WENDELL R. MULLISON

The Western Society of Weed Science dedicates this 46th Edition of the Proceedings of the Western Society of Weed Science to Dr. Wendell R. Mullison in recognition of his lifetime of outstanding contributions in the field of chemistry and in particular to the impact on weed science. Wendell retired from Dow Chemical Company in 1978 after 32 years of service. He held various positions including manager of technical service and development for agricultural chemicals, manager of government contract research and registration specialist in charge of phenoxy herbicides. He has published more than 60 scientific papers and written more than 60 research reports dealing with herbicides and plant physiology.

Wendell was born on September 24, 1913 in Philadelphia, Pennsylvania. He received his B.A. degree in 1934 at the University of New Mexico with a Biology major and minor in chemistry and anthropology. He received his Ph.D. in 1940 from the University of Chicago in Plant Physiology with a minor in genetics.

Wendell began his career as a biology instructor, and later an assistant professor at Purdue University. He taught biology, plant nutrition and chemistry. During World War II he worked for Shell Oil Company in Curacao, N.W.I., designing and managing a hydroponic vegetable farm for refinery employees. He began his career with Dow Chemical Company in 1946 as a plant physiologist in the Biochemical Research Laboratory screening herbicides and conducting research on the physiological aspects of plant responses. During that time Wendell obtained early patents on the phenoxy compounds that covers low volatile esters of 2,4-D and 2,4,5-T and use patents for both 2,4-D and 2,4,5-T. During the next 32 years his career at Dow Chemical Company involved many positions and activities including: International Technical Service Advisor for agricultural issues writing technical bulletins for pesticides, manager of herbicides and soil fumigants for Dow International; and writing correlating chemical structure with biological activity.

Wendell was a member of the Western Weed Science Society, Weed Science Society of America, Northeastern Weed Science Society, life member of the American Society of Plant Physiologists, Botanical Society of America, American Chemical Society, Midland Metaphysical Society, and a life member of the Council for Agricultural Science and Technology. He was editor and chairman of the committee that revised the fourth edition of the Herbicide Handbook. He has been awarded the highest honors in several societies including being made a fellow in the Weed Science Society of America, and Distinguished Member Award from the Northeast Weed Science Society.

His retirement from Dow Chemical Company in 1978 did not signal an end to his professional involvement in chemistry, herbicide, or weed science fields. He devoted a significant portion of his time working with his various society affiliations including appointments to federal task forces. During retirement he was even more active publishing and speaking on the toxicology of herbicides and interpreting Weed Science to the public.

Wendell is survived by his wife of 55 years, a son George, and two daughters, Dorothy and Helen. He has always been a gentlemen, a superb professional, a cherished and esteemed friend, and will always be affectionately referred to as "the father of 2,4-D."

GENERAL SESSION

PRESIDENTIAL ADDRESS

Stephen D. Miller
University of Wyoming
Laramie, WY 82071

Welcome to the 46th meeting of the Western Society of Weed Science. I have been honored to serve as your president for the past year. It has especially been an honor to serve along with the many volunteers who keep our society functioning. The job of President of the WSWS is actually made quite easy because we have a host of volunteers who carry out the duties of the society throughout the year.

The Western Society of Weed Science continues to grow and prosper as a regional scientific society. This is possible only because of the unselfish contributions of the membership. Our membership is comprised of many talented and dedicated individuals. You here in this audience, you are the WSWS. I wish to say "thank you for making this year enjoyable and special for me".

Doug Ryerson and his Program Committee have put together an excellent general session and program. In addition, Charolette Eberlein has developed an excellent symposium on weed resistance that I hope you will attend. We owe an extra "thank you to Kai Umeda and his Local Arrangements Committee for getting everything setup for this meeting". This is no small task. It takes a special person to volunteer to be local arrangements chairperson. Kai has organized several special tours which I hope you have or will participate in.

Student participation in WSWS activities is one of the most important facets of our society. With this in mind, Paul Ogg, Past President, has developed a Student Educational Enhancement Program, which will provide students the opportunity to learn, observe, exchange ideas and views with individuals in another part of the WSWS geography. This will be first year of this program and it should do nothing but grow in the future. In addition, we have 6 student posters entered in the student poster contest and 14 student papers entered in the student paper contest at this meeting. To the students, I say "thank you for participating and for helping to make the quality of our meeting the best it can be". Joan Lish and her Graduate Student Paper/Poster Judging Committee have their work cut out for themselves. Joan must be commended for her willingness to step in and chair this committee at the last minute after Dave Zamora's resignation.

At the request of the Executive Committee Arnold Appleby completed work on the history of the WSWS. The book is titled "The Western Society of Weed Science 1938-1992". Arnold is another example of volunteerism at its best. Arnold's only payment is seeing people purchase the book and being told that you enjoyed it. If you have not purchased it be sure and do so before you leave. It is excellent reading and a real credit to the Society.

The Executive Committee has unanimously agreed to have this years Proceedings dedicated to Wendell Mullison who passed away earlier last year. Wendell spent many years with Dow Chemical Company and was a walking encyclopedia on the phenoxy herbicides, especially 2,4-D. Wendell will be dearly missed by the Society.

Sustaining membership in the Society continues to grow and has had a significant impact on the well being of the Society. I would like to thank the following companies and organizations for their support. Agro-Linz Inc., American Cyanamid Co., BASF, Ciba-Geigy Corp., DowElanco, Dupont, FMC, Helena Chemical, Hoechst-Roussel Uclaf, ICI Americas Inc., ISK Biotech Corp. Monsanto Co., Mycogen Corp., R&D Sprayers, Rhone-Poulenc Ag. Co., Rohm & Haas Co., Sandoz Crop Protection, Uniroyal and Wintersteiger. It is our responsibility to thank and support these participating companies and encourage other companies, organizations, commodity groups and universities to become sustaining members of our Society.

The WSWS jointed the tri-societies of ASA, WSSA and the other regional Weed Science Societies last year in sponsoring two Congressional Science Fellows. This years fellows are J. Richard Hess from Utah State University and Marsha Stanton from the University of Arkansas. We are extremely fortunate in having two people of their caliber working on our behalf and on behalf of agriculture in Washington D.C. on a day to day basis. I am pleased we are able to participate in this program.

I would now like to turn my attention to issues we are facing in the 90's. These issues can be lumped into four categories - health, environmental, regulatory and budgetary concerns (HERB).

I will address each topic separately. Health issues will continue to be at the forefront. Dr. Bruce Ames at last years meeting stated that "there is a persistent widespread belief among many groups in this country that nature is benign and that man-made things - i.e. modern technology - have destroyed our benevolent relationship with nature". Health issues will continue to be impacted by public pressure/perceptions, survey vs. science and chemophobia. These unrealistic fears of the unknown can often be moderate by educations. We must be more proactive in this regard and be able to present our case to the public in a honest believable manner.

President Clinton has placed the protection of the environment and wise use of our natural resources as a high priority on his agenda. The WSSA has produced position statements on safe/clean water and the clean air act and basically feel continued monitoring is vital to show contamination is limited and below levels that are health concerns. Practices that reduce soil erosion from both wind and water, such as conservation tillage, reduce environmental contamination even further. In addition; new application technology, Integrated Pest Management Systems and new low rate chemistry can reduce the environmental load further. We must continuously strive to do a better job of communicating both the risk and solution. Time and time again we have put ourselves in the position of saying nothing which has then put us in the position of being defensive.

Regulatory issues continue to be a concern from both the pesticide industry and end user. Issues which must be addressed include such items as container management, time from discovery to market for new pesticides, local preemption which gives more than 80,000 municipalities the legal right to go beyond FIFRA in establishing their own regulations, pesticide cancellations which could exceed 30% of the currently registered pesticide use by completion of the reregistration process in 1997, minor use registrations by IR-4 which is currently backlogged by 1300 requests and pesticide export reform which will not allow the export of non-registered U.S. produced pesticides to countries where they are registered. The WSSA has developed position statements on many of these issues which they have taken to Washington D.C. and distributed. However, if we are to make progress in this regulatory arena we must be able to network and form coalitions with other groups with similar concerns. Similar to what has been done with the Congressional Science Fellows Program.

As budgets continue to shrink it becomes more difficult to bring forth new technology required by a changing agricultural systems. This impact is being felt not only in the public but private sector as well. The cost of development and the time from discovery to market of new pesticides are major concerns. This makes recovery of development costs more difficult and increases the cost of the new technology to the end user. University and USDA budgets are being impacted by reduced federal and state funding as well as less grant-in-aid dollars from the private sector. The reduced funding has impacted the public sectors ability to respond to the changing needs of the agricultural system. With reduced budgets it becomes increasingly important that weed science is able to compete for dollars in the competitive grants arena. While the costs of weeds to agriculture is at least one-third the cost of all pests only 16.7 and 8.5% of the competitive grants within Plant Pathology/Weed Science has gone to weed research the last two yr. This must change if applied and fundamental research on weed biology, ecology, physiology, genetics and biocontrol is to expand.

We need to look at these issues I have raised (HERB) today as challenges rather than obstacles. We have the resources, which is you the audience, to provide the solutions. Our strength has always been research and it should continue to be, but we need to improve our ability to communicate and network with other groups in the future.

Thank you for your attention. I have enjoyed serving as your president and hope you enjoy the remainder of the meeting.

COMMUNICATION WITH THE PUBLIC. Elin D. Miller, DowElanco Government Relations Manager, Sacramento, CA 95814.

ACT I

A variety of lessons can be learned from the successful campaign that brought defeat to California's Proposition 128 ("Big Green") in November, 1990. Most important among them were:

- Getting started early.
- Basing strategy on sound issues and public opinion research.
- Involving the broad business community to fund the effort and the hiring of the campaign professionals, necessary to get the job done, while keeping on course, despite heavy pressures.

Unlike some other states, California's laws can be enacted, changed or repealed without involving the State Legislature. An issue -- food safety, ozone depletion or whatever -- may be included in an initiative proposition placed on the statewide ballot by voter signatures. If it is approved by a majority of the voters, it becomes law -- with greater strength than if it had been passed by both houses of the Legislature and signed by the Governor.

An industry might do everything in its power to resolve an issue prior to it coming before the voters in an initiative on the ballot. But some politicians are likely to seize upon a popular issue, embrace it and push the initiative for reasons that are strictly political.

> *Example*: The birth and nurturing of "Big Green" was a major platform of Attorney General John D. Van de Kamp's campaign for the Democratic gubernatorial nomination -- and to assist State Assemblyman Tom Hayden (actress Jane Fonda's ex-husband) in his quest for a higher office.

In the mix of "Big Green" supporters were many, but certainly not all the environmental groups. In fact, even from the beginning, there seemed to be an uneasiness among some in the environmental community as to whether "Big Green" would result in good public policy.

Getting started early. Nothing can be emphasized more than the need to get started early. Money can't buy the loss of time in dealing with public opinion. This challenge was far from easy in light of a resounding defeat for the business community involving an environmental initiative in 1986 -- Proposition 65 -- the Safe Drinking Water and the Toxic Enforcement Act. Many in the industry felt that an environmental initiative could not be beaten in California. Believe it or not, this was a strong sentiment felt by many, even up to the day before the election.

The initial business reluctance was also fueled by environmental organization pressure in an attempt to depict any company opposing Prop. 128 as against the environment. The "No-on-128" campaign dealt with this issue through a theme established early: "You can be for the environment, and against Proposition 128, the issues are not mutually exclusive." The theme worked.

Finally, the lack of understanding regarding polling results was a deterrent to getting started early. The first polls showed Prop. 128 winning by a great margin; however, with a strong education campaign, the same polls showed that support would diminish (Dec. 1989) and that Prop 128. could be beaten (March 1990).

Luckily, the agricultural chemical industry, through WACA and NACA, got started early, regardless of the general reluctance. However, it took more time than planned to get the campaign rolling. In fact, had further delays occurred, the campaign could have been in jeopardy. An early start was a major factor in this campaign's success.

Issue and public opinion research. It is of paramount importance to base any political strategy on sound issue and public opinion research. This forms a credible base for key message development plus a vehicle by which the messages are delivered.

The issue research for the "No-on-128" campaign was performed by one core independent economic firm and supplemented by a variety of other sources. Since supporters of "Big Green" intended only to discuss the benefits of 128, it was up to "No-on-128" to discuss the costs -- costs, not only in real dollar terms, but unwanted results not envisioned by the initiative drafters. The core economic and health impact analysis began to be collaborated by a variety of other unbiased and independent sources and finally by the government itself. In doing issue research, the measure's vulnerabilities were uncovered which were essential in developing an effective strategy.

After some of the issue research was accomplished, the impact of these results was subjected to public opinion through polling. Early on, our industry discovered that with an issue as devastating as "Big Green" it is not prudent to rely on what we think the messages should be. Instead, extensive polling was done to test Prop. 128s popularity, the proponents best arguments and our best arguments. The issue research was tested to see if the arguments would move public opinion. As in the market research utilized by companies launching new ventures, public opinion polling can be very detailed in defining the proper messages for the proper audiences. The polling also showed the demographic clusters of the population which were likely to move to opposition (switchers) and those that regardless of the advertising education would never oppose the initiative. This information was vital early in the game not only to prioritize and segment advertising, but to identify credible spokespersons and target key grassroots organizations we needed to recruit.

The polling for this campaign in December 1989, March 1990 and June 1990 showed that the initiative could be beaten and that August, September, and daily tracking through October showed the trend line from 77% in support down to the ultimate 36% in support on November 6, 1990, election day.

Business leaders involvement. Funding an effort which ultimately cost $12 million over a 6 month period was vital. A core group in industry took on this challenge, but more importantly, was willing to allow the professionals -- our hired political consultants (Woodward & McDowell) to run the show.

The consultants were able to bring to the table not only obvious campaign coordination and advertising, but just as vital, coalition-building and media relations. Many times our industry is very myopic and rarely works with unrelated groups on issues. This is a fatal error in that unrelated groups can bring more credibility to an issue, since they have little or no vested interest. The coalition opposing Proposition 128 grew to more than 1,000 organizations, law enforcement and health professionals, with unlikely participants like water agencies, labor, Mother's Watch, minority groups, attorneys and many others. The lesson to be learned is simple. Coalition-building over time is vital for every industry and there are times when an industry must reach out to help others in unrelated areas to set the stage for receiving help from others in the future.

Secondly, work with the media was vital. Newspapers and TV reports had to be echoing what was being said in paid advertising. "No-on-128" was successful in securing opposition from nearly every newspaper in California. The campaign consultants brought in experts to discuss the issue with editorial boards. These efforts coupled with ongoing contacts tipped the balance of the amount of articles that reported information opposing the initiative.

As the campaign moved forward, it would have been easy to react to the proponents' accusations instead of stating our own message. This would have been a major error. Luckily, the business leadership listened to political consultants and the campaign stayed with the course of education to move public opinion our way rather than spending time attempting to refute outrageous claims made by proponents.

End of Act I. All told, the strategy's success can serve as a general model in the future. Utilization of issue and public research, aggressive media relations, coalition-building and getting started early are laments to success. Every issue however is different. "Costs" and "too many issues" were themes the campaign pushed and drove 128 to its defeat. In other settings, the themes may be completely different. However, our industry can learn generally from this campaign to help chart our strategies in the future.

ACT II: TURNING A WIN INTO A BIGGER WIN

It was about time we did something. Instead of resigning on its win, the industry, through NACA wanted to find out what the public's concerns really were about pesticides. Additionally, messages which dealt with those concerns, needed to be developed and communicated. Key points developed in the "Consumer Information Program" are as follows:

1. There is rigorous testing of pesticide products. On average, **only one in 20,000 chemicals makes it** from the chemist's laboratory to the farmer's field. To ensure that a product will not present any health or environmental concerns, they are subjected to **more than 120 separate tests**. The development, testing and EPA approval process **takes 8 to 10 yr and costs manufacturers between 35 and 50 million dollars** for each pesticide product. States maintain their own complete pesticide regulation and monitoring system. If a product is to be used in the state, it must first pass inspection by the Department of Agriculture.

2. There is no scientific evidence that ingestion of pesticide residues on fruits and vegetables causes cancer in human beings according to the National Cancer Institute. No one really knows what causes cancer. What we do know is that the National Cancer Institute, the National Academy of Sciences and the American Medical Association all recommend that Americans eat fruits and vegetables at least five times a day to reduce the risk of cancer.

3. The amount of pesticide residue that may remain on any fruit or vegetable crop are far below any level of potential risk. The legally allowable amount of pesticide that may remain is set at a level that includes wide safety margin buffers. For example, **a 150 lb adult would have to eat 3000 heads of lettuce each day for the rest of his or her life** to ingest the amount of pesticide that is found to cause health problems in laboratory mice.

4. The agricultural chemicals industry supports sustainable agriculture and IPM (Integrated Pest Management) because they make good economic and environmental sense. Along with supporting sustainable agriculture, the National Agriculture Chemicals Association is a member of the National Coalition on IPM with other industry, consumer and environmental organizations.

5. Dr. C. Everett Koop, former U.S. Surgeon General. "Our food supply is not only the safest, but it is the most abundant in the world and pesticides are one of the important tools that have made that abundance possible."

ACT III

Let's see that happens when we use the messages that work and omit those that don't. I am hopeful that this educational program will be incorporated into all organization and company programs. Although, the messages may be obvious to us, we have to make them obvious to consumers too. This program works, it only has to be implemented.

Whatever issues are facing us in the future can be overcome, but it can't just be DowElanco, Monsanto, or one organization like the Western Society of Weed Science, it's got to be all of us working together and your involvement and leadership can make that happen!

OFF-TARGET MOVEMENT OF PESTICIDES, CONCERNS AND SOLUTIONS. J. H. 'Bud' Paulson, Associate Director Arizona Department of Agriculture, Phoenix, AZ 85007.

As public awareness of pesticide exposure has increased, off-target pesticide movement has emerged as a major concern. Several locations in Arizona have been extremely volatile with respect to the issue of the Ag-Urban interface as it relates to pesticides. In dealing with this, sound science is often sacrificed in the interest of political expediency. The ability of toxicologists to evaluate the risks associated with chronic exposures to low levels of pesticides has failed to keep pace with the increasing power of analytical chemists to detect trace levels of agricultural chemicals.

Generally, the term "drift" has been used to refer to the off-target movement of pesticide sprays. Most regulatory programs historically have imposed strong sanctions against pesticide users who have been found to be responsible for such occurrences. With modern analytical techniques it is now possible to detect low levels of pesticides in both air and rain water that have resulted from the volatility of these compounds. We are familiar with such problems arising from the use of certain ester formulations of 2,4-D. We can now detect the widespread presence of other pesticides having significantly lower vapor pressures in the environment. Should this be considered to represent drift, and if so, how should it be dealt with by regulatory agencies?

There have been few significant advances in application technology in recent years that have assisted in reducing pesticide drift. Electrostatic sprayers are often given as an example of new technology, but these sprayers have been available for a number of years. In their efforts to reduce drift, farmers nave expanded the use of existing technologies into new situations such as:

- the use of set-a-side acreage for buffer areas between agricultural lands and urban areas and, the substitution of ground application for aerial application and,
- the increased use of electrostatic sprayers, originally designed for use in orchards, in row crops.

The need to control certain pests may require sprayer technology that could increase off-target movement of pesticides. Our recent experiences with the whitefly are a potential example of this. This insect spends most of its time under leaves where it is protected from exposure to most pesticide applications. The need to utilize sprayers and blowers that operate under higher pressures to induce air turbulence under the crop canopy in order to reach such pests will tend to increase the off-target movement of pesticides.

Herbicides can vary in their potential for drift due to 1) the way the material acts within the plant and 2) to the characteristics of the formulation itself. Products formulated as granules which are applied to the soil, activated by water, taken up by the roots of weeds and translocated within the plant will obviously have minimal risk of moving off-target in air currents.

Foliar systemic herbicides which, because of their ability to move within the weed, do not require complete coverage of the targeted plant and, therefore, would have intermediate risks of drift as the applicator is able to utilize larger spray droplet sizes under such circumstances. Larger spray droplets are less likely to be blown off-target. Contact herbicides that require essentially complete coverage of foliage in order to provide effective weed control will tend to present the greatest risks for drift due to the fact that applicators will need to utilize smaller spray droplets to obtain full coverage of the plants. These factors, in conjunction with other factors such as environmental fate, surface/groundwater protection and the like, should be taken into consideration when selecting herbicides for which resistant crop strains are to be genetically engineered.

The Arizona Department of Agriculture is attempting to handle drift cases in a manner that is based upon good science. We have implemented an enforcement policy that attempts to base sanctions imposed on those responsible for off-target movements of pesticides upon the magnitude of the adverse impacts that relate to the particular case. We have treated drift cases as our lowest level violation when no health effects or property damage can be attributed to the event, and when laboratory analysis shows no residue levels that exceed the maximum edible food tolerance for the chemical involved. Drift cases with more serious consequences are acted upon appropriately. We have encountered resistance on the part of the Attorney General's Office in following this policy. What we genuinely need is an accurate understanding of the dangers that exposures to low levels of pesticides represent to the public and the environment.

POSTER SESSION

INTERFERENCE OF BROADLEAF AND GRASSY WEEDS IN SUGARBEETS. A. Mesbah, S. D. Miller, K. J. Fornstrom and D. Legg; Graduate Assistant, Professor; Department of Plant, Soil and Insect Sciences, Professor; Department of Civil Engineering and Assistant Professor; Department of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY 82071.

Abstract. Sugarbeet yield losses due to weed competition are usually based on individual weed species. However, yield losses in a sugarbeet field which is infested with more than one weed species may be less or more than a combined loss of each weed alone. A 2 yr study was conducted in 1990 and 1991 at Torrington, Wyoming to determine the influence of mixed densities and durations of green foxtail and kochia competition in sugarbeet. Sugarbeet root yields were reduced by all examined densities of green foxtail and kochia, alone and in combination. Root yield reduction was less than additive with mixed densities of green foxtail and kochia. Sugar content and sugarbeet plant height were not influenced by any of the examined densities. Similarly, root yield decreased as the duration of competition after sugarbeet emergence from mixed densities of green foxtail and kochia increased, while no significant effect was shown on sucrose content. Based on regression analysis, the biological equations to estimate the economic yield loss were: $Y = A - 19X$ for 1990 and $Y = A - 20X$ for 1991. While the duration of time that a mixed density of kochia and green foxtail can compete with sugarbeet before realizing appreciable yield loss was approximately 2 wk.

INFLUENCE OF IMAZETHAPYR ON ALFALFA ESTABLISHMENT AND QUALITY. Corey V. Ransom, J. O. Evans, and S. A. Dewey, Research Assistant, Professor, and Associate Professor, Department of Plants, Soils, and Biometeorology, Utah State University, Logan, UT 84322-4820.

Abstract. Weed control is necessary in seedling alfalfa plantings to ensure stand establishment by reducing weed competition and to improve forage quality. Since imazethapyr exhibits good control of annual mustards as well as some grasses its, registration for establishing forage alfalfa stands would greatly benefit alfalfa growers. Postemergence applications of imazethapyr were conducted to demonstrate the affects of imazethapyr on seedling alfalfa establishment and forage quality. Weed numbers and yields, alfalfa yields, injury, height, and nutritive quality were evaluated.

Applications of imazethapyr were applied at three rates (53, 71, 105 g ha^{-1}) and with various surfactant levels and tank mixes. Surfactants and rates used include X-77 (0.25% v/v) and Sun-it (1.2 and 2.3 L ha^{-1}). Herbicides used in tank mixes included 2,4-DB amine (280 g ha^{-1}), bromoxynil (140 g ha^{-1}), and pyridate (1000 g ha^{-1}).

NIRS values were not significant between treatments for any of the parameters tested, including protein and acid detergent fiber. Alfalfa yields also were not different between treatments. Weed yields were significantly lower with all treatments than the control. Imazethapyr at 71 g ha^{-1} with both rates of Sun-it (1.2 and 2.3 L ha^{-1}), as well as one of the bromoxynil/imazethapyr and one of the pyridate/imazethapyr tank mixes exhibited significantly more visual damage than any other treatment. The highest injury rating assigned to any plot was 3.5 on a scale of 1 to 10, 10 representing death of the entire plot. Alfalfa height was reduced by all treatments compared with the control except imazethapyr alone. Shepherdspurse numbers were significant between treatments particularly imazethapyr alone or imazethapyr plus bromoxynil and Sun-it. Lambsquarter numbers were lower than the controls in all treatments except for the low rate (53 g ha^{-1}) of imazethapyr with X-77 surfactant. Green foxtail was not significantly reduced by any of the treatments. Total weed counts revealed that the low rate of imazethapyr with X-77, medium rates of imazethapyr with Sun-it (1.2 and 2.3 L ha^{-1}), 2,4-DB amine tank mixed with imazethapyr and X-77, bromoxynil tank mixed with imazethapyr and Sun-it, and pyridate alone did not significantly decrease total weed numbers when compared to the control.

Alfalfa quality and yield were not affected by any of the treatments applied. Any injury symptoms observed following application lessened as the crop matured and resulting yields showed no significant differences. Less competition from weeds may enhance alfalfa stand establishment and longevity.

PICLORAM METABOLISM BY RANGELAND WEEDS. C. A. Welker and T. M. Sterling, Research Assistant and Assistant Professor, Department of Entomology, Plant Pathology, and Weed Science, New Mexico State University, Las Cruces, NM 88003.

Abstract. A primary mechanism of herbicide selectivity is the ability of a plant species to degrade the parent herbicide to a nonphytotoxic compound. Picloram is a major herbicide used to control rangeland weeds. Information concerning the behavior and metabolic fate of picloram in several rangeland weed species has not been reported; therefore studies were initiated to determine metabolism of picloram in six rangeland weed species: broom and threadleaf snakeweed, silky crazyweed, woolly locoweed, Russian knapweed, and yellow starthistle. Picloram metabolism was determined by using non-woody terminal shoots or leaves (ca. 10 cm in length) excised from greenhouse-grown plants. Cut ends of stems or leaves were submerged in a 7-ml vial containing 1 ml distilled water and 30 MBq ml^{-1} of picloram-2, 6-^{14}C. Tissue was allowed to take up the solution at room temperature for 72 h. Water was added to the vial as needed. Control vials contained ^{14}C-picloram but no plant tissue. After 72 h, plant tissue was homogenized and radiolabel was extracted using MeOH:H_2O (80:20; v/v). The homogenate was centrifuged at 1500g for 15 min to remove soluble radiolabel from plant debris. The final pellet was oxidized and radiolabel remaining in supernatant was quantitated by liquid scintillation spectrometry (LSC). The clear supernatant was concentrated to an aqueous concentrate using an air stream at room temperature. The aqueous concentrate was adjusted to pH 7.5 and was eluted through a C_{18}-Seppak cartridge. Metabolites of picloram were separated using a water (4% acetic acid): acetonitrile linear gradient from 0 to 60% acetonitrile over 15 min through a C_{18} HPLC column and detected with an in-line radioactivity monitor. Total recovery of radiolabel was $\geq$ 95% of ^{14}C-picloram applied. HPLC results indicate that approximately 20 to 30% of the absorbed picloram is metabolized to compounds more polar and less polar than picloram in all six species within 72 h.

MECHANISMS OF DIFFERENTIAL TOLERANCE TO PICLORAM AND METSULFURON IN LOCOWEED. H. J. Jochem and T. M. Sterling, Research Assistant and Assistant Professor, Department of Entomology, Plant Pathology, and Weed Science, New Mexico State University, Las Cruces, NM 88003.

Abstract. Two locoweed genera represent problem weeds on New Mexico rangeland. From these genera, two of the most threatening species are *Astragalus mollissimus* and *Oxytropis sericea*. Herbicides such as picloram and metsulfuron, represent one avenue of control over these weeds. Initial efficacy studies revealed differences in tolerance between the two species for both picloram and metsulfuron. For the efficacy study, herbicides were applied at rates of 0, 0.14, 0.28, 0.56, and 1.12 kg/ha for formulated picloram and 0, 8.75, 17.5, 35, and 70 g/ha for formulated metsulfuron plus WK (0.125% v/v). *O. sericea*, compared to *A. mollissimus*, incurred much more damage from both picloram and metsulfuron at increasing herbicide rates.

To understand the mechanisms for these differences, uptake and translocation studies were performed. For uptake studies, the terminal leaflets of excised leaves were treated with 2.5 µL of formulated picloram and ^{14}C-picloram (11 nCi) at 6.2 mM or formulated metsulfuron and ^{14}C-metsulfuron (11 nCi) at 0.492 mM plus WK (0.125% v/v). After a 24 h incubation, *O. sericea* absorbed significantly more picloram than *A. mollissimus*. Each species absorbed similar amounts of metsulfuron. *O. sericea* translocated more picloram than *A. mollissimus*, but there were no significant differences in the translocation of metsulfuron out of the treated leaf, suggesting differential translocation does not contribute to differences in metsulfuron efficacy. Reduced uptake

and translocation probably contributes to increased picloram tolerance in *A. mollissimus* compared to *O. sericea*. Since differences in metsulfuron uptake and translocation do not appear to contribute to increased tolerance of *A. mollissimus* to metsulfuron, acetolactate synthase (ALS) inhibition by metsulfuron was measured for both species. Protein was extracted from leaf tissue using liquid nitrogen and precipitated with 50% ammonium sulfate. Protein was incubated for one hour with different concentrations of metsulfuron in the reaction buffer. Acetolactate, the product of ALS, was decarboxylated with 6N sulfuric acid to acetoin which can be measured spectrophotometrically. Overall, ALS activity (nmol acetoin$\cdot$mg protein$^{-1}\cdot$h^{-1}) was almost twice as great in *A. mollissimus* as it was in *O. sericea* over all metsulfuron concentrations. Both species had similar sensitivity to metsulfuron with 50% inhibition of ALS occurring around 10 nM metsulfuron. Therefore, ALS activity differences, not the similar sensitivity, probably account for increased tolerance to metsulfuron in *A. mollissimus* compared to *O. sericea*.

RESTRICTION FRAGMENT LENGTH POLYMORPHISM ANALYSIS OF TWO LOCOWEED SPECIES. J. A. Parreira, M. E. Waugh, and T. M. Sterling, Graduate Assistant, Research Specialist, and Assistant Professor, Department of Entomology, Plant Pathology and Weed Science, New Mexico State University, Las Cruces, NM 88003.

Abstract. Woolly locoweed and silky crazyweed are problem weeds on New Mexico rangeland because they are toxic to cattle and sheep. An understanding of the genotypic relationships among these different plants may be important in designing biocontrol methodologies. A preliminary analysis of genetic variability utilizing restriction fragment length polymorphisms (RFLP) in conjunction with chloroplast-specific probes was conducted on individuals of woolly locoweed and silky crazyweed. Total DNA was extracted via a modified CTAB/PVP method from young leaves etiolated for 16 h, followed by restriction digests with either Eco RI, Sal I, Pst I, or Nru I. Bands were resolved on 20 cm 0.8% agarose gels, stained and photographed prior to transfer to ZetaBind membranes for Southern analysis. Total chloroplast DNA (cpDNA) isolated from tomato (*Lycopersicon esculentum*) was oligolabelled with 32P-dCTP and used as a probe. Preliminary data indicate variation between woolly locoweed and silky crazyweed at the chloroplast cpDNA level. Further work on these locoweeds should yield more information on the extent of woolly locoweed and silky crazyweed genotypic variability as well as markers for biological control agent specificity.

POPULATION DYNAMICS OF THREE WINTER GRASSES UNDER VARIOUS DRYLAND CROPPING SYSTEMS. W. E. Stump and P. Westra, Graduate Research Assistant and Associate Professor, Colorado State University, Fort Collins, CO 80523.

Abstract. The winter annual grasses jointed goatgrass, downy brome, and volunteer rye infest more than 1.2 million acres in Colorado (1989 data). Since there are no selective control measures for these weeds in winter wheat, rotation with alternative dryland crops is being implemented by some growers. The objective of this study was to determine the effects of various crop rotations on the population dynamics of these three weedy grasses. In the fall of 1991, blocks of jointed goatgrass, downy brome, and volunteer rye were seeded at a rate of 1,500,000 seeds/ha in a split block design on a dryland site near Platteville, Colorado. Superimposed over these blocks will be four different crop rotation regimes utilizing winter wheat, proso millet, and sunflower in various combinations. All rotations started with winter wheat to allow for establishment of the grasses. Initial seedling establishment rates were volunteer rye > jointed goatgrass > downy brome. After one season, jointed goatgrass and downy brome populations (fall emergence counts) increased four-fold and volunteer rye increased seven-fold. Seed banks experienced similar increases. After the first year of the study volunteer rye was found to be the most aggressive in establishment. In the long term, however, it would be premature to predict population behavior of the three grasses. The study will be monitored for 4 yr.

WATER STRESS EFFECTS ON PICLORAM TRANSLOCATION AND CARBOHYDRATE MOVEMENT IN BROOM SNAKEWEED. Y. Hou and T. M. Sterling, Graduate Assistant and Assistant Professor, Department of Entomology, Plant Pathology and Weed Science, New Mexico State University, Las Cruces, NM 88003.

Abstract. Plant water status can affect carbohydrate movement and may be related to herbicide translocation in plants. A study was conducted to determine the effect of water stress on picloram translocation and on water-soluble carbohydrate movement in broom snakeweed. Picloram was applied at the recommended rate of 0.28 kg/ha to greenhouse-grown plants. Plants were maintained under water stressed or well-watered conditions for 7 d before and after picloram treatment. Uptake and translocation of picloram were determined using ^{14}C-picloram applied immediately to an individual leaf of a middle branch in plants after foliar-application of picloram. Seven days after treatment, plant tissues, including treated leaf and tissues above and below treated leaf, were harvested and washed two times using methanol:water (1:1 v/v). Other plant tissues (leaves and green stems above and below treated branch, woody stems above and below treated branch, other green parts, woody stem parts and roots) were separated and dried independently. Tissue was oxidized and radiolabel in each sample was quantified using liquid scintillation spectroscopy. Carbohydrates were extracted from plant tissues using 0.2N H_2SO_4 and determined using spectrophotometry. Water stressed (ca.-3.3 MPa) compared to well-watered plants (ca.-1.5 MPa) reduced picloram foliar absorption and translocation to tissues above the treated leaf. Water stress had no apparent effect on picloram movement into other green and woody tissues of plants. ^{14}C-picloram was not detected in the roots of well-watered or water-stressed broom snakeweed plants. Water stress significantly increased the green tissue carbohydrate content by 50% but decreased woody stem and root carbohydrate levels by 75% and 200%, respectively. Picloram did not affect green tissue and woody stem carbohydrate content but significantly reduced carbohydrate content approximately 40% in roots of well-watered plants. These results indicate that picloram uptake and translocation were affected by plant water status. Carbohydrate analysis suggests that picloram movement was independent of carbohydrate distribution patterns in green tissues and woody stems in broom snakeweed plants.

THE EFFECT OF WATER AND NITROGEN ON DOWNY BROME IN THE FIELD. S. O. Link, J. L. Downs, M. E. Thiede and H. Bolton, Jr., Research Scientist, Scientist, Scientist, and Senior Research Scientist, Environmental Sciences Department, Pacific Northwest Laboratory, Richland, WA 99352.

Abstract. Water and nitrogen strongly influence plant productivity, and water and nitrogen use efficiency in arid ecosystems. We investigated the response of downy brome to several levels of water and nitrogen in the field. There was no relationship between water and biomass at the control level of nitrogen in the soil. When nitrogen was added, biomass increased with increasing water. There was no relationship between nitrogen and biomass at the control level of water. When water was added, biomass increased with increasing nitrogen to an optimal nitrogen level (10.937 g N m^{-2}) with a decrease at higher levels. Water and nitrogen use efficiencies were strongly related to nitrogen and weakly related to water. The results of this experiment indicate that nitrogen and water at natural levels are both severely limiting to downy brome shoot biomass production and that responses are more sensitive to nitrogen than to water. This work was supported by the U. S. Department of Energy under contract DE-AC06-76RLO 1830.

SIMULATED THIFENSULFURON-TRIBENURON DRIFT INJURY TO SPRING PEAS. Carol A. Mallory-Smith and Donn C. Thill, Research Scientist and Professor, Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID 83843.

Abstract. Injury to spring peas from off-target movement of thifensulfuron-tribenuron has been reported at several sites in the Pacific Northwest since 1988. This problem is of particular concern because the herbicide is often applied to cereal grains in the early spring when peas are emerging. Therefore, greenhouse and field experiments were conducted to determine the herbicide rates at which injury symptoms would appear and seed yield loss would result. Ten herbicide rates ranged from 0.034 to 17.52 g/ha. Two pea varieties 'Columbian' and 'Green Giant 274' were used.

Greenhouse pea biomass means were averaged over experiments because there was no experimental interaction. Peas treated with 0.068 g/ha or higher rates of thifensulfuron-tribenuron produced less biomass per plant than the untreated control plants. Chlorosis appeared on the new growth of the treated peas 2 to 3 d after treatment. Plants sprayed with 1.095 g/ha and higher rates were stunted, chlorotic, and had deformed new growth. Peas produced secondary branches when treated with all but the 17.52 g/ha rate. Branches per plant were greatest with the 0.548, 1.095, and 2.19 g/ha treatments.

Field experiment means were averaged over treatment dates because there was no interaction of treatment date and variety. 'Columbian' pea biomass per plant from the 0.034, 0.068, and 0.137 g/ha treatments was not different from the untreated control. 'Green Giant' peas treated with 0.548 g/ha and higher rates produced less biomass per plant than the untreated control plants. 'Columbian' peas treated with 0.137 g/ha and higher rates yielded less seed than the untreated control. 'Green Giant' peas treated with 0.274 g/ha and higher rates yielded less seed than the untreated control. The highest seed yields for both varieties was with the 0.034 g/ha treatment, although they were not different from the untreated control. Secondary branch production was similar to peas grown in the greenhouse experiment. The most branches per plant were produced on peas treated with the 1.095 and 2.19 g/ha.

SIMULATED SPRAY DRIFT FROM SULFONYLUREA AND PHENOXY HERBICIDES ON PEAS AND LENTILS. David R. Gealy, Chris M. Boerboom, *Kassim Al-Khatib, and Alex G. Ogg Jr., Plant Physiologist, Extension Weed Specialist, Weed Scientist, and Plant Physiologist, USDA-ARS, Department of Crop and Soil Sciences, Washington State University, Pullman, WA 99164, and *Mt. Vernon,WA 98273.

Abstract. To simulate drift of sulfonylurea and phenoxy herbicides from spring cereal fields to nearby spring pea and lentil crops, 2,4-D or thifensulfuron plus tribenuron (Harmony Extra) were applied to peas and lentils with a spray boom at rates of 0, 0.3, 1, 3, or 10% of recommended use rates (X rates) for spring cereal crops approximately 3 and 5 wk after planting. 2,4-D had minimal inhibitory effects on both crops at all rates tested. Lentils appeared to be slightly more damaged by 2,4-D than by thifensulfuron plus tribenuron and 10% X 2,4-D reduced lentil grain yield by about 10% in 1991, a cool moist growing season. Thifensulfuron plus tribenuron had no effect on either crop at rates less than 3% X. Within the first week after application of thifensulfuron plus tribenuron, 10% X , and to a lesser degree 3% X rates, turned newly emerged leaves chlorotic, reducing chlorophyll content 25 to 50%, and reduced or halted growth of the main stem. Two to three additional secondary branches per pea plant and 5 to 25 additional secondary branches per lentil plant began to form within several weeks after application of 10% X thifensulfuron plus tribenuron. Flowering and maturity dates were delayed. Plants recovered from the stunting to varying degrees depending on environmental conditions. Final grain yield generally was reduced less than 25%. Visual symptoms and yield reduction from thifensulfuron plus tribenuron drift were more pronounced in peas than in lentils. In controlled greenhouse studies with thifensulfuron on peas, growth was stunted more as droplet size decreased, and percent absorption increased with increasing droplet concentration, indicating that phytotoxicity of drift may be shifted somewhat depending on drift particle size and herbicide concentration.

METHAM FOR COTTON WEED CONTROL. Ron Vargas and Steve Wright, Farm Advisors, University of California Cooperative Extension, 328 Madera Avenue, Madera, CA 93637 and 2500 W. Burrel Avenue, Visalia, CA 93291.

Abstract. The most persistent and difficult weeds to control in cotton have evolved due to their tolerance of dinitroaniline herbicides and the rotation of cotton with crops such as tomatoes and peppers which are in the same family as nightshade (Solanaceae). Hairy nightshade and black nightshade infest thousands of acres within the San Joaquin Valley of California. Yellow nutsedge and purple nutsedge are increasing dramatically. Research conducted at the Shafter Cotton Research Station has documented yield losses greater than 50% due to 3 wk of early season competition from black nightshade.

Fields known to be infested with nightshade and nutsedge were divided into plots, that were four 38 inch wide rows by 1300 feet long and replicated three times in a randomized complete block design. Metham was applied to preirrigated, preformed beds in an 8 inch bank on top of the bed. Single and double spray blades were both used. A soil cap was applied over the top of the treated area to seal the soil, preventing volitalization losses. Cotton planting occurred from 20 to 28 d after application.

An evaluation of hairy nightshade (Table 1) control, based upon actual weed counts, on May 8, 1992 exhibited 100% control with all rates of metham. No cotton injury was evident. Cotton stand counts indicated a 9 to 19,000 higher plant population with the metham treatments as compared with the control. These large differences can be attributed to control of soil born seedling disease pathogens. Seed cotton yields on October 26, 1992 indicated 267 to 375 lb/A more yield with the metham treated plots as compared with the control, although they were not statistically significant.

An evaluation of purple nutsedge (Table 2) 27 d after treatment indicated excellent control with all rates tested. The 100 gpa rate was exhibiting 99% control as opposed to 86 and 90% control with the 50 and 75 gallon rates respectively. At 48 d after treatment control was unacceptable. Nutsedge had emerged from below the treated layer, requiring close cultivation and hand weeding. No cotton injury symptoms were observed.

Table 1. Hairy nightshade control with metham.

Treatment	Rate	Hairy nightshade	Cotton	Seed cotton yield
	GPA[a]	Counts[b]	Plants/A	lb/A
1. Metham	50	0	70,000	3405
2. Metham	75	0	60,400	3503
3. Metham	100	0	60,000	3478
4. Control (blade only)	--	8	51,200	3138

[a] Gallons per treated acre.
[b] Plants in 8 by 12 inch band.

Table 2. Purple nutsedge control with metham.

Treatment	Rate	Nutsedge control	
		27 DAT	48 DAT
	GPA[a]	——— % ———	
1. Metham	50	86	8
2. Metham	75	90	35
3. Metham	100	99	35
4. Check (blade only)		0	0

[a] Gallons per treated area.

SIMPLE METHOD FOR MAPPING WEED INFESTATIONS AND OTHER DATA WITH COMPUTERS.

L. W. Lass and R. H. Callihan, Department of PSES, University of Idaho, Moscow, ID. 83843.

Abstract. COUNTYCAD is a computer-driven mapping software that displays roads, streams and other bodies of water, towns, and political boundaries within a county. Positions or boundaries of weed populations and other things are easily entered with a mouse, digitizer, arrow keys, or global positioning system. The system is designed for recording and tracking over 200 kinds of information for 15 yr. Data may be exchanged with most GIS packages. The program runs on any IBM or compatible computer with a hard disk and printer. Best performance is obtained on a 386 with a math co-processor, or on a 486. A mouse, color monitor, and laser printer improve efficiency. This low-cost mapping software will allow for simple record-keeping of pest locations and management planning.

WHEAT VARIETAL HERBICIDE INTERACTIONS INFLUENCED BY POSTEMERGENCE APPLICATION TIME.

Jack P. Orr, Mick Canevari, and Lee Jackson, Weed Science Advisor, Field Crops Farm Advisor, and Extension Agronomist, University of California Cooperative Extension Sacramento and San Joaquin Counties, Sacramento, CA 95827 and Stockton, CA 95205 and Department of Agronomy and Range Science, University of California, Davis, CA 95616.

INTRODUCTION

Each year in Sacramento and Northern San Joaquin Valleys of California, there have been several cases of significant injury to wheat fields. Grain fields are planted in November and December and irrigated one to two times in the spring, dependent upon conditions. The grain heads and awns showed slight to severe epinasty. The symptoms were characteristic of the type phenoxy and benzoic herbicides cause. Postemergence herbicides are applied predominately by airplane at the tillering stage through jointing to early boot stage.

In 1989 through 1992, three experiments were established to research the effect of five postemergence herbicides applied to three wheat varieties at three stages of growth. A control was included in each year's experiment.

MATERIALS AND METHODS

The three wheat varieties - 'Serra', 'Yolo', and 'Klasic' - were planted in November each year, grown in an Egbert muck soil, and irrigated by means of spud ditches. This field experiment was established on Tyler Island in Walnut Grove, California. The experimental design was a split-split plot with three main application times arranged in four randomized blocks. These main plots were split for five herbicide treatments and a control. The sub-plots were split for three cultivars. Chickweed, was the only weed species in the experiment with a population ranging from 10 to 30 plants/ft^2, dependent upon year and time of year.

Herbicide applications were made with CO_2 backpack sprayer, 8002E flat fan nozzles, at a rate of 15 gpa. The first application was made to grain in the two-leaf stage; the second at well tillered; and the third at jointing/elongation. Herbicide rates at the first application consisted of the lowest labeled rate. Since weeds would be considerably larger at later stages, rates were increased to the maximum rate for the second and third application times. Herbicide treatments consisted of dicamba, MCPA, 2,4-D, dicamba plus MCPA, and bromoxynil. Bromoxynil was not included in the 1990 experiment.

Chickweed control ratings were taken, and grain injury ratings were taken after heading. Plots of 5 by 20 feet were harvested with a small plot harvester in June each year.

RESULTS AND DISCUSSION

In each of the experiments for 3 yr, there was one common factor. There was no interaction between herbicides and varieties. There was a significant difference between herbicides each year and herbicides by time of application for the three stages of growth. In 1992, there was a significant three-way interaction between herbicides by time by varieties. This was not true for 1991 and 1990.

In regard to time of application to various growth stages (Table 1), 1990 yield results showed application of herbicides at the jointing stage caused a significant loss in yield to all three varieties. Dicamba plus MCPA and 2,4-D significantly reduced yields to all three varieties. In addition to these, dicamba significantly reduced Yolo and Klasic yields, and MCPA significantly reduced Klasic yield when applied at jointing. Results in 1991 showed no significant yield differences overall between herbicide applications at the three growth stages. There was a significant yield reduction to Serra and Yolo when 2,4-D was applied at the two-leaf stage. Dicamba plus MCPA caused a significant yield reduction to Serra when applied at tillered stage and caused significant yield loss to Klasic when applied at jointing stage. In 1990, dicamba caused a significant yield reduction to Yolo when applied at two-leaf and jointing stage; and Klasic at jointing. In 1992, overall herbicide application at two-leaf stage caused a significant yield reduction compared to application at jointing stage. Tillered and two-leaf growth stages showed no significant difference. Yolo, Serra, and Klasic showed significant injury from 2,4-D and dicamba plus MCPA caused injury to Yolo.

Table 1. Wheat varietal herbicide interaction influenced by postemergence application time in Sacramento and San Joaquin Delta.

		1992			1991			1990		
		Time of application			Time of application			Time of application		
Variety	Herbicide	Two-leaf	Tillered	Jointing	Two-leaf	Tillered	Jointing	Two-leaf	Tillered	Jointing
		Yield lb/A			Yield lb/A			Yield lb/A		
Serra	Dicamba	7469 B[1]	7408 A	7844 A	8965 A	8343 BC	8548 BC	6700 A	6619 A	6510 A
	MCPA	7443 B	7410 A	7731 A	8755 AB	8499 ABC	8892 AB	6994 A	6804 A	6756 A
	2,4-D	6075 C	7402 A	7501 A	8004 C	8272 BC	8707 ABC	7202 A	6754 A	6316 A
	Dicamba + MCPA	7312 B	7696 A	7743 A	8644 AB	8131 C	8471 C	6907 A	6859 A	6084 A
	Bromoxynil	8058 A	7674 A	6917 B	8816 AB	8688 AB	8970 A	---------	---------	---------
	Control	7312 B	7676 A	7642 A	8457 B	8771 A	8685 ABC	6517 A	6650 A	6271 A
Yolo	Dicamba	6900 B	6722 B	7606 A	8595 A	7985 A	8431 A	6304 B	6904 A	6162 AB
	MCPA	6855 B	7501 A	7589 A	8587 A	8139 A	8656 A	6590 AB	7156 A	6534 A
	2,4-D	5560 C	7215 AB	7456 A	7406 B	8227 A	8219 A	7100 A	6578 A	5666 BC
	Dicamba + MCPA	5840 C	7355 A	7754 A	8297 A	8028 A	8290 A	6855 AB	6746 A	5476 C
	Bomoxynil	7653 A	7333 A	7379 A	8306 A	8251 A	8405 A	---------	---------	---------
	Control	7095 AB	7327 A	7225 A	8605 A	8465 A	8517 A	6670 AB	6634 A	6728 A
Klasic	Dicamba	7420 AB	6912B	7271 B	8216 AB	8000 AB	7936 BC	6759 AB	6985A	6033 A
	MCPA	7404 AB	7122 AB	7856 A	8434 AB	7994 AB	8236 AB	6513 B	6865 A	6118 A
	2,4-D	6848 C	7467 AB	7530 AB	8166 B	8111 AB	8161 AB	6863AB	6617 A	5029 B
	Dicamba + MCPA	7251 B	6947 B	7658 AB	7997 B	7969 AB	7827 BC	7161 A	6761 A	4693 B
	Bromoxynil	7830 A	7607 A	7398 AB	7983 B	8400 A	7493 C	---------	---------	---------
	Control	7153 B	7278 AB	7640 AB	8667 A	7812 B	8411 A	6478 B	6727 A	6269 A

LSD (0.05)

Between herbicides for same time of application 565

Between herbicides for different times of application . 606

Serra Between herbicides for same time of application. 418 643

Between herbicides for different times of application 479 729

Yolo Between herbicides for same time of application 497 564

Between herbicides for different times of application 514 609

Klasic Between herbicides for same time of application 474 549

Between herbicides for different times of application 640 765

In regard to injury symptoms, the 1992 results showed that grain heads of all three varieties were significantly affected from 2,4-D and dicamba plus MCPA when applied at the two-leaf stage. Dicamba alone caused injury to 20 percent of the Yolo Heads. In the case of 2,4-D and Yolo, research results show moderate to severe head injury from application at the two-leaf stage causes much greater yield loss compared to application at tillering. Tillering application had a greater number of heads affected to a much lesser degree, resulting in a significantly higher yield. Application of these herbicides at jointing in 1992 did not show any injury symptoms.

Bromoxynil applied at the three growth stages did not show any injury symptoms on the three grain varieties in 1992. In 1992, bromoxynil caused a significant yield reduction to Serra when applied at jointing; and in 1991, a significant yield reduction to Klasic.

Table 2. Significant and non-significant yield differences - herbicides x varieties x time.

1992		1991		1990	
Significant	Non-significant	Significant	Non-significant	Significant	Non-Significant
Time	Herbicide x Variety	Herbicides	Herbicide x Variety	Time	Herbicide x Variety
Herbicides		Herbicides x Time	Herbicide x Variety x Time	Varieties	Herbicide x Variety x Time
Herbicides x Time		Varieties	Variety x Time	Varieties x Time	
Varieties				Herbicides	
Variety x Time				Herbicides x Time	
Herbicide x Variety x Time					

CONCLUSIONS

In this 3 yr study, there was no interaction between herbicides and wheat varieties - Serra, Yolo, and Klasic (Table 2). Compared to other postemergence herbicide treatments, 2,4-D and dicamba plus MCPA can cause very significant yield reduction to wheat varieties when applied at the two-leaf and jointing stages, dependent upon the year by variety. Bromoxynil can cause yield loss when applied to Klasic and Serra at jointing stage. Dicamba can cause yield loss to Yolo when applied at the two-leaf stage and to Klasic when applied at jointing stage, dependent upon the year.

It is very evident that there are significant differences in yield between herbicides for the same time of application and significant differences between times of application for the same herbicide. Since there was never a significant difference in yield between the control and highest yielding herbicide treatments, it is not economically feasible to treat wheat fields for chickweed control. Grain that shows injury symptoms may not have a yield reduction compared to the yield loss from severe weed competition of highly competitive species.

Wheat stage of growth, herbicide rate, and herbicide are of prime importance when treating grain for vegetation management. To ensure maximum yields, tillered stage of growth is the appropriate time to make an application. Lower to mid-range label rates would ensure lower risk of injury to the grain; however, weed species, population, and size are important factors to consider when determining the correct herbicide and rate of application.

MANIPULATION OF SAFFLOWER ROW SPACING AND SEEDING RATE IMPROVES COMPETITION WITH GREEN FOXTAIL.

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Abstract. Agronomic production practices that promote rapid safflower canopy development may inhibit weed establishment and reduce the negative impact of weeds on crop yield. Field experiments were conducted in 1990 and 1991 at Lethbridge, Alberta to determine if narrower row spacings and increased seeding rates improved safflower's competitive ability with weeds.

A factorial set of treatments of safflower at two row spacings (11 and 22 cm) and six seeding rates (5, 20, 35, 50, 65, and 80 kg ha^{-1}) were grown weed-free or infested with green foxtail. Safflower emergence ranged from 70 to 85% in these tests. Plant counts determined that the resultant mean safflower densities at the above seeding rates were 10, 40, 70, 100, 130, and 160 plants m^{-2} in 1990, and 12, 48, 84, 120, 156, and 192 plants m^{-2} in 1991. Shoot dry weight of safflower and green foxtail was determined every two weeks throughout the growing season and seed yield of each species was taken at maturity. Photosynthetic active radiation (PAR) measurements were taken to determine the influence of row spacing and plant density on safflower canopy development over the growing season and to assess treatment effects on competition for light between safflower and green foxtail.

Decreasing safflower row spacing from 22 to 11 cm slightly improved competition with green foxtail but increasing safflower density had a much greater effect. Weed-free safflower biomass and seed yield plateaued at 35 kg ha^{-1} in both years (70 and 84 plants m^{-2} in 1990 and 1991, respectively). However, safflower infested with green foxtail (500 plants m^{-2}) increased in biomass and seed production with seeding rates up to 50 kg ha^{-1} (100 plants m^{-2}) in 1990 and 65 kg ha^{-1} (156 plants m^{-2}) in 1991. Increasing the density of safflower could not negate the suppressive effects of green foxtail but weedy safflower yields were 3- to 4-fold greater at high than low plant densities. Concurrently, increasing safflower density reduced green foxtail biomass (up to 72%) and seed yield (up to 85%). PAR measurements indicated that dense safflower stands developed a closed canopy earlier in the season and shaded green foxtail more effectively.

THE IMPACT OF pH AND COSURFACTANTS ON THE PERFORMANCE OF ORGANOSILICONE SURFACTANTS.

G. A. Policello, G. J. Murphy, and P. J. G. Stevens, Union Carbide Chemicals and Plastics Company Inc., Tarrytown, NY 10591, and Forest Research Institute, Rotorua, N.Z.

Abstract. Organosilicone surfactants have been shown to increase the uptake of chemicals into plant tissue through stomatal infiltration. Some of the key factors influencing uptake are related to the low aqueous surface tension (≈ 21 mN/m at 0.1 wt %) and the compact structure of the organosilicone. In addition, the performance of these unique surfactants is strongly influenced by pH. Aqueous solutions of the Silwet L-77® at pH 3 and pH 10 show a marked decrease in spreading relative to solutions buffered at pH 7 (1), which maintained spreading efficacy throughout the study. The organosilicone undergoes rapid hydrolysis at pH 3, and shows a total loss of spreading within five hours (2). This is further illustrated by measuring the uptake of ^{14}C tagged deoxyglucose (DOG) into bean (*Vicia faba*) (3) for solutions containing the organosilicone, under similar pH conditions. The uptake of DOG decreases with time for solutions at pH 3 (Figure). However, solutions buffered at pH 7 retain the ability to potentiate DOG uptake (uptake = 79 % ± 10.7 for > 20 d aging). Therefore, there is a correlation between the spreading ability of the organosilicone and the uptake of the DOG.

The organosilicone performance is also influenced by other surfactants contained in spray formulations (2). The spreading of solutions of organosilicones is severely inhibited by the presence of most conventional surfactants, such as alkylphenol ethoxylates (Table). However, some specialty surfactants, like acetylenic diol ethoxylates, prove to be favorable cosurfactants for organosilicones, without significantly interfering with spreading.

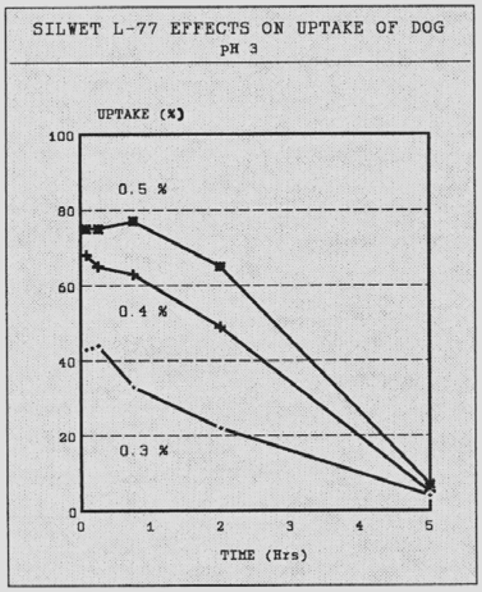

Figure. Effect of Silwet L-77® rate on deoxyglucose uptake into bean.

Table. Influence of cosurfactants on spreading[a].

Treatment	Rate	Alone	Spread area ratio[b] 0.05% Silwet L-77®
	- % -		
Silwet L-77®	0.05	77.0	N/A
Triton® X-100	0.15	4.4	9.0
AE-7[c]	0.15	6.6	8.2
PAO-50[d]	0.15	1.3	74.7
ADE-65[e]	0.15	1.7	90.2

[a] Spreading evaluated on polyester film, 3M IR 1175.
[b] Spread area ratio relative to water.
[c] Linear alcohol ethoxylate (7 EO).
[d] Polymeric surfactant of polyalkyleneoxide.
[e] Acetylenic diol ethoxylate (65% EO).

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ROTATIONAL CROP RESPONSE TO TWO ALS-INHIBITING HERBICIDES. G. P. Hoxworth, J. Schroeder, and E. Morris, Research Assistant, Assistant Professor, and Student Apprentice, Department of Entomology, Plant Pathology, and Weed Science, New Mexico State University, Las Cruces, NM 88003.

Abstract. Imazethapyr is an imidazolinone herbicide used in soybeans, peas, seedling and established alfalfa, clover, peanuts, and other leguminous crops. Imazethapyr has provided excellent weed control when applied from PPI to early postemergence. DPX-PE350 is a new herbicide that provides excellent control of many broadleaf weeds when applied to cotton from PPI to postemergence. The persistence and rotational crop sensitivity to these herbicides have not been determined for New Mexico soils and cropping systems. Therefore, greenhouse experiments were conducted to determine the sensitivity of several crops that might be planted following crops that had been treated with either imazethapyr or DPX-PE350. The crops evaluated included chile peppers, cotton, onion, lettuce, corn, grain sorghum, wheat, and peanut. Imazethapyr at 0, 0.0156, 0.031, 0.0625, or 0.125 ppmw or DPX-PE350 at 0, 0.031, 0.0625, 0.125, or 0.25 ppmw was uniformly incorporated into either a Belen clay loam soil (thermic, Vertic Torrifluvent, pH 7.0, 1% OM) or sand mix (1:1, sand:Belen clay loam) prior to planting ten seed of each crop. Experiments were established in a factorial arrangement of treatments in a randomized complete block design with four replications. The factors included two soils, two herbicides, and five rates of each herbicide. Crops were evaluated separately. The plants were harvested between 22 and 59 d after establishment, depending on the crop. The number of plants/cup were counted, the plants were visually rated for injury and top and root dry weight/cup were determined.

DPX-PE350 decreased root weight of all crops except peanut and cotton. Chile root weight was significantly reduced by 0.0625 ppmw and higher. The lowest rate of 0.031 ppmw reduced onion root weight by 98%. Lettuce root weight was reduced by 60% at the 0.0625 ppmw rate. Sorghum root weight was reduced by 79% at the lowest rate. Interactions between the rate of DPX-PE350 and the soil type were observed with wheat and corn. Wheat root weights were generally higher in the sandy soil than in the Belen, but increasing rates of DPX-PE350 caused more root weight reduction in the sandy soil than in the Belen. Corn root weights were reduced by DPX-PE350 in the sandy soil, but there was no reduction in root weight in the Belen soil. Imazethapyr reduced root weight of chile and lettuce at the lowest rate of 0.0156 ppmw. Cotton root weight was reduced by 34% at the 0.0625 rate. Corn and peanut were tolerant at all rates. There were interactions between rate and soil type with wheat, onion, and sorghum. Imazethapyr caused more reduction in root weights of these crops growing in sandy soil than in the Belen clay loam.

METOLACHLOR DISTRIBUTION IN THE SOIL PROFILE UNDER FURROW IRRIGATED NO-TILL AND CONVENTIONAL TILL MANAGEMENT. Ramona R. Parra, Jill Schroeder, Neal Christensen and Tim Jones, Senior Research Assistant, Assistant Professor, Assistant Professor and Assistant Professor, Department of Entomology, Plant Pathology and Weed Science, Agricultural Science Center at Clovis and Department of Agronomy and Horticulture, New Mexico State University, Las Cruces, NM 88003 and Clovis, NM 88101.

Abstract. The objective of this research is to monitor the movement and persistence of metolachlor as affected by furrow irrigation and tillage practice. Field research was conducted in 1989 and 1990 at New Mexico State University Agricultural Science Center near Clovis on a Pullman clay loam soil (pH 7.4, 1% organic matter). Conventional till and no-till plots were arranged in a randomized complete block design with four replications.

Metolachlor was applied at a rate of 5.6 kg/ha in 280 L water/ha as a broadcast preemergence treatment on Day 0. Irrigation water was applied after the metolachlor treatment on Day 0 and prior to the Day 35 and 85 samples in 1989 and the Day 72 samples in 1990. Soil samples were obtained on Days 0, 7, 14, 38, 85, and 360 in 1989 and on Days 0, 7, 15, 35, 72, and 365 in 1990 from the top of the raised plant bed and from the furrows between the raised plant beds to a depth of 0.6 m and divided into 7.5 cm segments. Metolachlor was extracted from 10 g soil samples by shaking with a water/methanol (80:20) solution. The extracts were evaporated to dryness, the residue dissolved in benzene and injected into a ^{63}Ni electron capture detector-equipped gas chromatograph. Recovery of metolachlor was greater than 90% for all the profile depths and the lower limit of detection was 0.05 µg/g soil.

In general, results of the soil analyses to date indicate decreasing levels of metolachlor over time and depth for the 0 to 7.5 cm profile with the no-till plots showing faster dissipation than the conventional till plots. The 7.5 to 15 cm profile shows an increase in metolachlor concentration between Days 7 and 38, particularly in the no-till plots. In 1989, the concentration of metolachlor peaked at 0.36 µg/g soil in the no-till furrow at a depth of 7.5 to 15 cm 14 d after treatment and prior to the second irrigation date. Samples obtained 38 d after treatment and after the second irrigation showed a similar concentration of metolachlor in the no-till bed at a depth of 7.5 to 15 cm. The pattern of metolachlor movement was similar in 1990, but not as pronounced due to the fact that the second irrigation was eliminated in 1990. Metolachlor concentration was non-detectable below 15 cm in the profile at all sampling dates and locations both years.

DIFFERENTIAL HERBICIDE TOLERANCE IN COTTON. William T. Molin, Associate Professor, Department of Plant Sciences, University of Arizona, Tucson, AZ 85721.

Abstract. The differential tolerance of upland (*Gossypium hirsutum* L.) and Pima (*G. barbadense* L.) cotton varieties to herbicides commonly used in the southwest is being examined. The tolerance of 18 cotton varieties to prometryn, metolachlor and fluometuron injury was determined in greenhouse tests. Preplant incorporated and postemergence applications of these herbicides at rates of 0.3 to 12 lb/A were used to select tolerant varieties. Acala 1517-75 and Pima S-6 and S-7 varieties were highly tolerant to prometryn with both methods of application whereas all other upland types tested, such as Delta Pine 5415, were highly susceptible to prometryn. There were no differences in varietal responses to metolachlor and fluometuron. We will now ascertain whether the tolerance is the result of differential uptake, translocation, metabolism, or binding of prometryn. Prometryn, a photosynthetic inhibitor, when used on soils that generally are coarse textured and low in organic matter, may cause injury as a result of leaching or volatilization. Understanding the mechanisms which afford tolerance to prometryn will allow us to identify targets for genetic manipulation in terms of enhancing herbicide tolerance and alleviating herbicide stress.

CONTROL OF THREE WINTER ANNUAL BROME GRASSES WITH SULFONYLUREA HERBICIDES. Dallas E. Peterson, Loren J. Moshier, and Chris T. Ebert, Assistant Professor, Associate Professor, and Undergraduate Research Assistant, Department of Agronomy, Kansas State University, Manhattan, KS 66506.

Abstract. Cheat, downy brome, and Japanese brome are three winter annual brome grasses, or "cheatgrasses", that commonly infest hard red winter wheat fields in Kansas. Cheatgrass in wheat commonly results in crop lodging, dockage, and reduced wheat yields. Cheatgrass can be managed through crop rotation, but is difficult to control in continuous wheat production. Several herbicides are approved for cheatgrass control or suppression in wheat, but the approved treatments are expensive and have provided inconsistent weed control. Triasulfuron, and metsulfuron plus chlorsulfuron are sulfonylurea herbicides used in wheat for broadleaf weed control and

cheatgrass suppression. Cheatgrass suppression with these treatments also has been inconsistent. Experiments were conducted in the greenhouse to evaluate triasulfuron and metsulfuron plus chlorsulfuron for control of cheat, downy brome, and Japanese brome. Metsulfuron plus chlorsulfuron applied preemergence at 22 g/ha plus 4 g/ha provided better control of all three cheatgrass species than triasulfuron applied preemergence at 29 g/ha. Both herbicide treatments reduced growth of Japanese brome more than cheat or downy brome. Japanese brome growth was not reduced by postemergence application of either herbicide treatment. Surface irrigation following preemergence application of the herbicides was essential for Japanese brome suppression.

TIMING AND RATE OF MON 13200 FOR DODDER CONTROL IN ALFALFA.

Mick Canevari and Ed Sieckert, Farm Advisor, University of California Cooperative Extension, San Joaquin County, Stockton, CA 95205, and Development Associate, Monsanto Agricultural Company, Lodi, CA 95242.

Abstract. Dodder is a parasitic weed that causes serious problems in California forage and seed alfalfa fields. A severe dodder infestation can reduce stand longevity, cause improper curing of hay, and lower both forage and seed yields. Current control measures which include trifluralin 10G provide control of germinating dodder for 90 d after treatment. Late season infestation of dodder with temperatures favorable to rapid growth and development also affects yields and adds to the seed pool in following years.

A 3-yr-old stand of alfalfa was divided into a randomized complete split block design with four replications and plots 50 by 50 ft. Mon 13200 was used at four rates in September 1991, followed by an irrigation. The second timing of application was applied in January 1992, with the same treatments and rainfall incorporated. The standard treatment for comparison was trifluralin 10G and hexazinone.

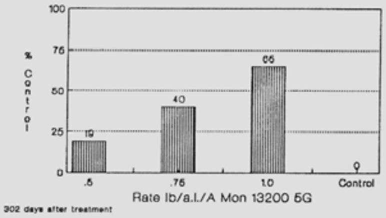
Table. Dodder ratings.

		No. colonies per plot (4 rep avg)	
		Rating date May 26, 1992	
Treatment	Rate	240 DAT Timing of application	120 DAT
	- lb/A -	September 1991	January 1992
13200	0.5	3.5	0
13200	0.75	1	0
13200	1.0	0.75	0
13200[a]	0.5 + 0.5		0
Hexazinone+trifluralin[a]	0.75 2 + 2	1.75	2.5
Check	--	2.25	9.25
		Rating date July 17, 1992	
		271 DAT	151 DAT
13200	0.5	7.5	0.5
13200	0.75	3.0	0
13200	1.0	0.5	0
13200[a]	0.5 + 0.5		0
Hexazinone+trifluralin[a]	0.75 2 + 2	5.5	3.75
Check	--	9.0	8.25
		Rating date August 18, 1992	
		302 DAT	182 DAT
13200	0.5	16.5	2.8
13200	0.75	12.5	1.8
13200	1.0	7.0	0.3
13200[a]	0.5 + 0.5		3.5
Hexazinone+trifluralin[a]	0.75 2 + 2	5.7	7.0
Check	--	20.3	17.0

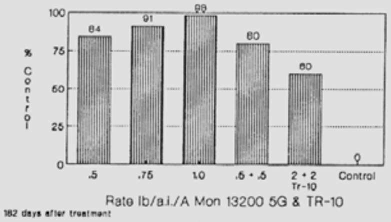
[a] Split applications made in January and April

There was a direct relationship to both rate and timing for full season control. The September timing treatments of 0.5 and 0.75 lb/A were unacceptable by the July evaluation and the 1 lb/A rate was beginning to break by the August evaluation. In the January treatments all rates of Mon 13200 provided excellent control through the July evaluation and the 1 lb/A rate control was excellent through August.

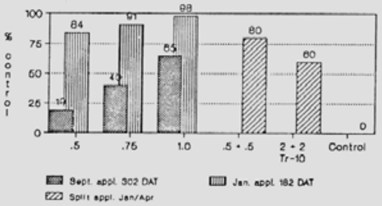
DODDER CONTROL
September Application
Evaluation date 8/18/92



DODDER CONTROL
January Application
Evaluation date 8/18/92



COMPARISON OF RATE AND TIMING
OF MON 13200
For Dodder Control in Alfalfa



WEEDS OF RANGE AND FOREST

CONTROL OF WHITE GINGER WITH METSULFURON. P. Motooka, K. Onuma and G. Nagai, Extension Specialist in Weed Science, University of Hawaii, Kealakekua, HI 96750, Noxious Weed Specialists, Hawaii Department of Agriculture, Captain Cook, HI 96704, and Hoolehua, HI 96729.

INTRODUCTION

White ginger is indigenous to south Asia and was introduced into Hawaii in the nineteenth century (4, 5). Since then, white ginger has become a favorite ornamental and its fragrant flowers are used to adorn women's hair. It is also of some economic importance because its flowers are used in making leis and perfume. Unfortunately, white ginger is well suited to wet zones in Hawaii. They invade roadsides, pastures and forests.

White ginger is a rhizomatous perennial herb, to 1 to 2 m tall, often forming a solid mat. It is deciduous, dying back between January and March, but resprouts almost immediately. Cattle do not graze ginger so it tends to slowly cover pastures. Conservationists are concerned about the disturbance of native forests by invading ginger. On roadsides, ginger tends to encroach towards the pavement, interfering with lines-of-sight.

Both white and yellow ginger were susceptible to picloram (2). However, current restrictions on picloram make its use difficult or impossible. Preliminary work by A. Arakaki of the University of Hawaii and E. Misaki of the Nature Conservancy indicated that metsulfuron was highly effective in controlling the closely related yellow ginger on Molokai (personal communication). Two trials were conducted on the Island of Hawaii to establish efficacious rates and to determine if the drizzle application method would be feasible for applying metsulfuron on white ginger. The drizzle application method was developed by S. Uyeda (3) of the McBryde Sugar Company of Eleele, Hawaii. Drizzle application is a low volume method. The droplets are large and sparsely distributed but its greatest advantage is that it is labor efficient since the applicator can reach up to 5 m for a swath of up to 10 m wide in one pass.

MATERIALS AND METHODS

The first of two trials was installed non-cropland at Ahualoa. Rainfall averaged 1900 mm annually, well distributed throughout the year. The standing ginger, originally 1 to 2 m tall, were slashed and allowed to regrow to 0.5 m. Plots, 2 by 5 m, in randomized complete blocks were blocked according to visually estimated ginger cover. Herbicide treatments (Table 1) were applied by a CO_2-powered sprayer at 207 kPa, with a four-nozzle boom with SS8003LP nozzle tips. A nonionic surfactant (nonylphenoxypolyethoxyethanol) was diluted in the herbicide solution to 0.5% v/v. The spray-volume rate applied was 320 L/ha. Visual control ratings (1) were made 6 months after treatment (MAT).

The second trial, to compare metsulfuron rates and drizzle application with conventional spraying was conducted in a pasture near Captain Cook, Hawaii. Rainfall there averaged 1900 mm annually. The ginger stood 1 m tall so no pre-treatment was necessary. Ginger cover was uniform. Plots, 2 by 5 m were arranged in randomized complete blocks, blocked by location. Conventional herbicide applications (Table 2) were made as in trial one. The drizzle application was made with a single-nozzle wand with the CO_2 - powered sprayer set at 207 kPa and with the strainer and nozzle replaced by a 100 mesh strainer and a disc with a 0.5 mm orifice. The spray volume of the drizzle application was 12 L/ha. A silicone surfactant, polyalkyleneoxide modified polydimethylsiloxane, was diluted in the herbicide solution to 0.2% v/v. Visual control ratings were made at 6 MAT.

RESULTS AND DISCUSSION

Trial 1. Initially, injury symptoms from triclopyr and picloram were identical: epinasty and rolling of the leaves. However the triclopyr treated plants had begun to recover by 6 MAT. The picloram plots did not recover. All of the metsulfuron treated plants turned chlorotic immediately and stopped growing. However, they were still standing at 3 MAT. At 6 MAT, the more severely injured plants had collapsed and, in some plots, were completely displaced by *Setaria palmifolia*. Regression of ginger control ratings on metsulfuron rates indicated that 16 or 32 g/ha was the optimum rate. The label maximum rate for pastures is 32 g/ha.

Trial 2. The lowest rate of metsulfuron used, 18 g/ha provided adequate control of ginger. Analysis of variance, check excluded, indicated no rate response but there was a response to method of application. The drizzle method was less effective overall but control was still good. Because of the low volume and reach of the drizzle method, it is particularly suited to weed control in forests especially in off-road sites. However, drizzle application does not conform to the label.

The results of two trials indicated that metsulfuron was effective for controlling white ginger at rates between 16 to 64 g/ha, depending on acceptable levels of control. The drizzle application method, though slightly less effective than conventional spraying shows promise in non-cropland ginger control because it offers low volume and a reach of 5 m, which provides portability in rough and remote terrain, and greater access to off-road stands.

Table 1. Control of white ginger by picloram, triclopyr and different rates of metsulfuron at 6 MAT.

Herbicide	Rate	Weed control
	g/ha	%
Check	0	0
Picloram	1000	87
Triclopyr	2000	22
Metsulfuron	8	69
Metsulfuron	16	85
Metsulfuron	32	91
Metsulfuron	63	99
Metsulfuron	126	99

Treatment F = 4.71**

Regression metsulfuron rates: Y = 36.2 + 24.2 log X, r = 0.96

Table 2. Control of white ginger by conventional and drizzle application of metsulfuron at 6 MAT.

	Weed control	
Rate	Conventional application	Drizzle application
g/ha	——— % ———	
18	93	80
35	89	89
52	94	80

Application method F = 7.25*

Untreated check: 64% control

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BIGLEAF MAPLE CONTROL: THINLINE BASAL APPLICATIONS USING TRICLOPYR AND TRICLOPYR PLUS PICLORAM. Paul F. Figueroa and Vanelle F. Carrithers, Weyerhaeuser Company, Centralia, WA 98531, and DowElanco, Mulino, OR 97042.

INTRODUCTION

Bigleaf maple is an important hardwood on the west side of the Cascades in the Pacific Northwest. It can be a major conifer competitor when it occurs in plantations in sufficient densities. Key factors that contribute to is competitiveness are its ability to resprout vigorously from stumps following cutting and its rapid juvenile growth (1, 3, 10). These growth attributes can result in significant reductions in Douglas-fir height growth and survival through overtopping and moisture depletion (7, 11).

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

The success of thinline treatments is based on several elements. Proper herbicide stem coverage, or the banding of every clump sprout is essential (3, 5, 8). Second, proper timing of the herbicide treatment is important. Wagner (12) studied triclopyr efficacy by time of application and reported that thinline applications made at center of the dormant season gave greater control levels than treatment in either the active growing season or the beginning of the fall dormancy season. A third element for success is delivering adequate herbicide dosage to the entire clump. The basic threshold for triclopyr has been defined by Wagner (12), and Figueroa (3), however, in both cases the lowest level of control had not be identified due to the study treatment designs limitations.

METHODS

A study was established to determine the minimum threshold level of herbicide needed to control bigleaf maple stump sprouts (LD 90) using triclopyr applied as a thinline basal application. Included, were application timings ranging from the beginning to the end of winter dormancy period. An additional treatment using a diluted pre-mix of triclopyr and picloram was included. The study design tested the control efficacy of diluted triclopyr as a thinline basal treatment. The test hypotheses compared time of application and herbicide efficacy.

The site was located in Cowlitz County in western Washington on Weyerhaeuser's Southwest Washington Mt. St. Helens Tree Farm. The soil on the test site is an Abernathy series. It is a deep, well-drained soil developing from siltstone and fine sandstone (2). Douglas-fir soil-site is estimated at 130 feet at breast height age 50. The elevation is 400 feet and the topography is level. The test area was logged with ground-based machinery in summer 1988 and broadcast burned during the winter. The study area was shovel-planted in April 1989 using 2+1 Douglas-fir seedlings grown at the Weyerhaeuser Mima Nursery. Across the 40-A site, bigleaf maple density averaged 10 clumps/A. Two years later, at the time of study installation the Douglas-fir plantation averaged 2.7 feet (range 0.9 to 4.3 ft.) in height while the bigleaf maple clumps averaged 9.6 feet in height (range 3.9 to 15.8 ft.) and had a mean crown width of 9.2 feet (range 4.6 to 16.1 ft.).

Treatment Application and Methodology

Treatment	Herbicide product concentration	Solution strength
	%	ai/gal
Check - No Treatment		
Triclopyr	75.0	3.00
Triclopyr	50.0	2.00
Triclopyr	25.0	1.00
Triclopyr	12.5	0.50
Triclopyr	6.0	0.24
Triclopyr + picloram	50.0	1.00+0.50

Application timing	
December 6, 1990	Early-winter bigleaf maple dormancy
February 6, 1991	Mid-winter dormancy
April 11, 1991	Later-winter (early-spring) dormancy
February 6, 1991	Triclopyr + picloram treatment

Bigleaf maple clumps were blocked according to their pre-treatment height and crown volume size classes. Treatments were randomly assigned within each clump size class. Ten clumps were treated with each herbicide concentration and timing. The untreated check and triclopyr plus picloram treatments had ten clumps each. Mor-Act was used as the diluent for all treatments. Mor-Act is a paraffin-base petroleum oil product that has been used extensively and effectively for basal bark applications in the Pacific Northwest. Applications were made by a certified pesticide applicator who had more than five years of operational thinline application experience.

Thinline treatments were applied using a Weed Systems HQ300 CO_2 spray applicator. Pressure was regulated at 30 psi at the tank head. A Spray Systems TP-00015 zero-degree nozzle tip was used and it had a 50 mesh screen. This system dispenses a solid straight stream of solution approximately 1 to 2 inches wide at a distance of 10 to 12 feet. Delivery volume averaged 0.31 oz/sec (SD 0.02). Agmark Agricultural Dye Marker (P2) basal bark dye was added to each treatment at 0.0025% v:v. Each clump was treated such that all stems were banded on at least two sides. Stems larger than 2 inches were banded to have complete 360 degree herbicide coverage. Mean clump application was 3.3 ounce and ranged between 0.9 and 9.2 oz/clump.

Measurements were made prior to thinline applications and at 1 and 2 yr after treatment. Clump height and crown widths were measured at each period. Total height was measured from the average ground line to the tallest live leaf. Crown width was the average measurement of the north-south and east-west crown widths. A clump was considered to be alive if any live foliage was present. A 425 tree sample of Douglas-fir was measured from a separate study within this same site. These Douglas-fir data were taken to compare their height and stand growth relative to treated and non-treated bigleaf maple clumps. Survival, vigor, and height were measured annually on these trees.

The experimental design for this study was a completely randomized design using an analysis of variance with equal sample sizes across all triclopyr treatments. The null hypothesis tested was that herbicide concentration level, timing of application, or interaction of level and timing has no impact on bigleaf maple height and percent crown volume. Treatment differences were analyzed using analysis of variance procedures. Hypotheses were tested at the 0.10 probability level. If F-values were significant at the 10% level, treatment differences were separated using the Bonferroni t-test (9).

RESULTS

Effects on bigleaf maple survival and height. Averaging all herbicide concentrations by timing, bigleaf maple survival was higher when triclopyr was applied in December compared to February or April (Table 1). Several apparently dead clumps resprouted across all timings, during the second year after treatment. Survival differences among application timings narrowed during the second year after treatment.

Survival differences among herbicide concentration, averaged across all application timings (Table 2). Resprouting during the second year occurred on all treatments except the triclopyr plus picloram treatment. The increase was greatest at the 12.5% triclopyr concentration. Observations made on live and resprouting clumps showed their vigor was high. This indicates those high vigor resprouts would continue to grow well and could develop into conifer competitors. The triclopyr plus picloram treated stumps had no resprouting and looked as though they would not sprout in the future. Figueroa and Nishimura (6) reported on bigleaf maple thinline treatments using triclopyr or imazapyr that bigleaf maple clumps that showed signs of rapid decomposition of either dead stems or the cut-stump, do not resprout.

Table 1. Effects of triclopyr timing on bigleaf maple survival, first- and second-year results averaged across all triclopyr concentrations.

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

Table 2. Effects of herbicide concentration level on bigleaf maple survival, first- and second-year results averaged across all timings.

Treatment	Herbicide[a] product concentration	Solution strength	Survival Year 1	Survival Year 2
	%	ai/gal	%	%
Check			100	100
Triclopyr	6.0	0.24	63	80
Triclopyr	12.5	0.50	23	63
Triclopyr	25.0	1.00	3	27
Triclopyr	50.0	2.00	0	13
Triclopyr	75.0	3.00	0	3
Triclopyr+picloram	50.0	1.00+0.50	0	0

[a] Triclopyr as Garlon 4 (4 lb), triclopyr + picloram as Access (2 lb + 1 lb).

Comparing clump height one year after treatment showed significant differences among triclopyr concentrations and timing (Table 3). Comparing clump height two years after treatment showed significant differences only among triclopyr concentrations and not for timings. These data show that differences among timings decreased substantially during the second growing season (Table 3). However, there were significant differences among herbicide concentrations (Table 4). Triclopyr concentrations of 25% and greater significantly reduced clump height in the second yr. The mean height of the bigleaf maple was reduced to a level below that of planted Douglas-fir mean height. The 6% herbicide level did not reduce the bigleaf maple height below that of the Douglas-fir.

Table 3. Effects of triclopyr timing on bigleaf maple total height, first- and second-year results averaged across all herbicide concentrations.

Treatment	Total height Year 1	Total height Year 2
	ft.	ft.
Check	11.9[a]	12.8[a]
December	1.8 a[b]	2.4 a[b]
February	1.2 ab	2.3 a
April	0.7 b	1.7 a

[a] The non-treated check plots and the triclopyr plus picloram were not tested against triclopyr only treatments since they were not replicated over timings.

[b] Treatments with same letter in a column are not significantly different at $p = 0.10$ using Bonferroni t-test.

Table 4. Effects of herbicide concentration levels on bigleaf maple total height, first- and second-year results averaged across all timings.

Treatment	Herbicide product concentration	Solution strength	Mean height Year 1	Mean height Year 2
	%	ai/gal	ft	ft
Check			11.9	12.8
Triclopyr	6.0	0.24	4.6 a	5.6 a
Triclopyr	12.5	0.50	1.3 b	3.3 b
Triclopyr	25.0	1.00	0.2 b	1.2 c
Triclopyr	50.0	2.00	0.0 b	0.4 c
Triclopyr	75.0	3.00	0.0 b	0.1 c
Triclopyr+picloram	50.0	1.00+0.50	0.0	0.0
Douglas-fir mean height			4.1	5.6

Effects of bigleaf maple crown volume change. Crown volume (or total crown mass) was calculated using crown width and total height assuming clump shape was a cylinder. Crown volume change was calculated as the percentage growth or loss relative to its pre-treatment crown volume. Significant treatment differences were shown for first-year crown volume change among triclopyr concentrations and timing. Second-year crown volume change had significant treatment differences among triclopyr concentrations only, and not due to timing, or the interaction. Differences among application timing months washed out two years after treatment (Table 5). Only the 6% concentration level was significantly different among the triclopyr levels (Table 6).

Table 5. Effects of triclopyr timing on bigleaf maple effective crown volume growth, first- and second-year results averaged across all herbicide concentrations.

Treatment	Crown volume growth	
	Year 1	Year 2
	%	%
Check	50.4 [a]	62.8
December	-97.9 a [b]	-96.2 a
February	-99.6 ab	-98.0 a
April	-99.9 b	-98.9 a

[a] The non-treated check plots and the triclopyr plus picloram were not tested against triclopyr only treatments since they were not replicated over timings.

[b] Treatments with same letter in a column are not significantly different at $p = 0.10$ using Bonferroni t-test.

[c] Triclopyr as Garlon 4 (4 lb), triclopyr + picloram as Access (2 lb + 1 lb).

Table 6. Effects of herbicide concentration level on bigleaf maple effective crown volume growth, first- and second-year results averaged across all timings.

Treatment	Herbicide[c] product concentration	Solution strength	Crown volume growth	
			Year 1	Year 2
	%	ai/gal	%	%
Check			50.4 [a]	62.8
Triclopyr	6.0	0.24	-95.8 a[b]	-91.4 a
Triclopyr	12.5	0.50	-99.9 b	-97.4 b
Triclopyr	25.0	1.00	-99.9 b	-99.8 b
Triclopyr	50.0	2.00	-100 b	-99.9 b
Triclopyr	75.0	3.00	-100 b	-99.9 b
Triclopyr+picloram	50.0	1.00+0.50	-100	-100

Triclopyr threshold of bigleaf maple control. An objective of this study was to develop the dosage/level triclopyr threshold required to control bigleaf maple. Wagner (12) developed a methodology to relate bigleaf maple control to triclopyr dosage when applied to variable clump sizes. He showed dormant application of 2 ml/m^2 triclopyr would give 95% or better first-year crown volume reduction. However, his data base did not include thinline levels below 2 ml/m^2. Figueroa (3) and Figueroa and Nishimura (6) showed there can be significant second-year resprouting, height and crown volume recovery using triclopyr or imazapyr. They concluded that curve construction using Wagner's (12) methodology to develop control thresholds should only done with second-year efficacy data.

Figure 1 is a plot of second-year crown volume reduction by application date plotted against ml/m^2 triclopyr (as Garlon 4) dosage per unit initial crown area. These lines represent the minimum crown volume reduction for any ml/m^2 application by timing. This data suggests the point where treated clumps would have 90% or better control is between 1.1 and 1.7 ml/m^2. This efficacy range can be used to estimate individualized triclopyr concentration levels for treatment of specific units.

DISCUSSION

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

At this time, a competition threshold between bigleaf maple and Douglas-fir has not been defined. Observations of how Douglas-fir growth is impacted by various bigleaf maple densities suggests there are levels where the overall conifer stand growth is not impacted. I have estimated the level where bigleaf maple does not economically impact Douglas-fir stand growth to be between 3 and 8 clumps/A. This is based on observations of bigleaf maple maximum crown occupancy of mature maple in second-growth Douglas-fir stands. It also assumes maple has the potential to achieve this occupancy on most sites. Site quality, age differential between Douglas-fir and bigleaf maple, site preparation methods, and pre- and post-harvest vigor of bigleaf maple potentially affect competitive impacts. Higher vigor bigleaf maple with lower site quality Douglas-fir would be impact with low maple density. Low vigor maple stands coupled with higher Douglas-fir site quality would require higher maple densities before impacts were noted. Big game browse can also play a large role in reduced maple vigor and growth. Selecting the level of herbicide used to reduce competition should take into account the risk of reducing the bigleaf maple below the estimated competition threshold.

Figure 2 is a hypothetical bigleaf maple density impact model patterned after work done by Figueroa et al. (4) for red alder. Additional growth impact data needs to be collected and analyzed to allow the users to determine where stand growth loss exceeds an economical threshold. This hypothetical model is only a two-dimensional version whereas the final model would have site quality as a third axis.

Bigleaf maple overtopping is the primary competition component that causes conifer growth or survival losses (7, 12). Table 7 is a model showing percent bigleaf maple clumps that could potentially overtop planted Douglas-fir following treatment. For example, a site that had twenty bigleaf maples per acre treated with a 25% triclopyr concentration would be estimated to have 4.6 surviving clumps overtopping planted Douglas-fir 4 yr after treatment. If 4.6 maple clumps/A was determined to be above the threshold of impact for Douglas-fir growth, then 25% concentration would not have been effective for that site. As a comparison, a site having ten clumps per acre, a 25% triclopyr concentration would be estimated to leave 2.3 clumps/A overtopping Douglas-fir 4 yr after treatment. This number of residual bigleaf maple would be below the expected competition impact threshold level thus making that herbicide prescription acceptable for that site.

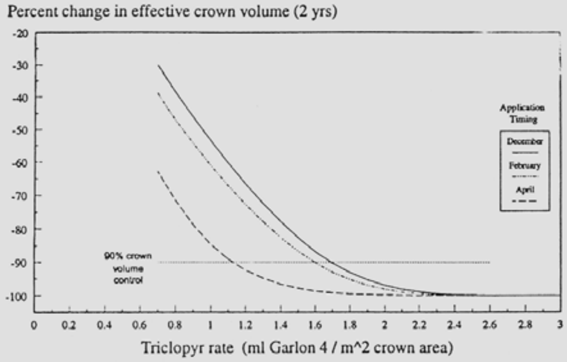

Figure 1. The relationship between the two-year post application change in bigleaf maple effective crown volume and timing of triclopyr application (Garlon 4). Treatments applied as a basal thin-line application.

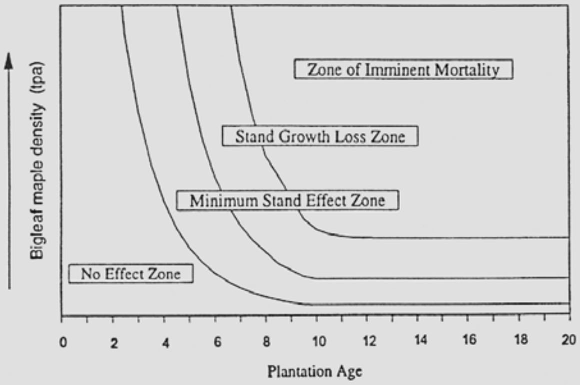

Figure 2. Hypothetical bigleaf maple competition impacts model: impacts of bigleaf maple density on Douglas-fir stand growth and survival by plantation age.

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

Treatment	Herbicide product concentration	Solution strength	Percent of initial BLM population overtopping Douglas-fir post-treatment			
			Year 1	Year 2	Year 3	Year 4
	%	ai/gal	%			
Check			100	100	100	100
Triclopyr	6.0	0.24	53	43	60	73
Triclopyr	12.5	0.50	17	27	33	43
Triclopyr	25.0	1.00	3	7	7	23
Triclopyr	50.0	2.00	0	0	3	10
Triclopyr	75.0	3.00	0	0	0	3
Triclopyr+picloram	50.0	1.00+0.50	0	0	0	0

Economic considerations for herbicide costs are equally important for treatment prescriptions. The potential economic benefits of selecting the proper level of triclopyr or triclopyr plus picloram are shown in Table 8. Depending on the objectives or risk accepted for control, the effective treatment costs could be as low as $0.30 per clump or as high as $1.48 (based on the average 3.3 oz. solution per clump for this study). We need to follow the long-term recovery of bigleaf maple to determine whether Douglas-fir can maintain its height dominance under various triclopyr concentrations. The triclopyr plus picloram treatment gave 100% control, but at a per clump cost of $1.62. This points out the need for additional data to develop the minimum control threshold for triclopyr plus picloram treatments.

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

Treatment	Herbicide[a] product concentration	Solution strength	Solution strength	Cost/[b] clump
	%	ai/gal	ai/clump	$
Triclopyr	6.0	0.24	0.0062	0.30
Triclopyr	12.5	0.50	0.0129	0.41
Triclopyr	25.0	1.00	0.0258	0.62
Triclopyr	50.0	2.00	0.0516	1.05
Triclopyr	75.0	3.00	0.0773	1.48
Triclopyr	100.0	4.00	0.1032	1.91
Triclopyr+picloram	50.0	1.00+0.50	0.0258+0.0129	1.62

[a] Triclopyr as Garlon 4 (4 lb), triclopyr + picloram as Access (2 lb + 1 lb).

[b] Based on the following 1993 herbicide costs: triclopyr (Garlon 4) $ 74 gal; triclopyr + picloram (Access) $118/gal Mor-Act $ 7.50 gal.

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

Wagner (12) showed increased bigleaf maple control when basal applications were applied in the dormant season (February) compared to either the late-summer (August) or active growing season (June). The dormant season appeared to begin in November while the end of the dormant season was in late-April at this test site. The treatments were designed to separate differences across the entire dormant season. While there were limited differences from the beginning of the dormant season to the end of the dormant season, it might be prudent to increase concentration rates slightly for early-dormant season treatments.

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A CHRONOLOGY OF LEAFY SPURGE RESEARCH. Russell J. Lorenz and Rodney G. Lym, Professor, Animal and Range Sciences Department and Associate Professor, Crop and Weed Sciences Department, North Dakota State University, Fargo, ND 58105.

INTRODUCTION

Leafy spurge is an exotic, noxious, perennial weed that has become widely distributed in North America. Starting from a few seeds in ship ballast and as a contaminant in seedstocks brought to North America from Eurasia in the early days of settlement, leafy spurge is now found in at least 26 states and six Canadian provinces. It is a serious problem on several million acres where it reduces the production of or use of desirable species. In addition, it impacts to a lesser degree tens of millions of acres of agricultural and grazing lands, recreational areas, highway and railroad rights of way and urban and city properties. Although leafy spurge is of little or no economic significance in Europe and Asia where it is native, its range extends from Siberia to the Mediterranean to northern Europe. It is kept under control in its native habitat by hundreds of species of insects and diseases, many of which are specific predators on leafy spurge. Some of these specific predators are now being processed for introduction and release in North America as part of a biological control program.

The date of introduction of leafy spurge to North America is not known, but a specimen preserved in the New York Botanical Garden Herbarium was collected at Newbury, Massachusetts in 1827. It is of interest that N. L. Britton titled a paper in 1921 *The Leafy Spurge Becoming a Pest* and that the first edition of *Gray's Manual of Botany* published in 1848 predicted that leafy spurge was likely to become a troublesome weed. Several other Botanists of the 1800s recognized leafy spurge in their writings and commented on finding it in places where it had not been previously reported. By the early 1900s, Dr. Gray's earlier prediction became fact when farmers in New York found leafy spurge to be "a menace to pastures" and were "taking measures for its reduction or eradication, ... but the task is not an easy one". An editorial comment to this effect appeared in the New York Herald on February 9, 1921.

In 1933, H. C. Hanson and V. E. Rudd published a 24 page North Dakota Agricultural Experiment Station Bulletin that is a classic report on what was known about leafy spurge at that time. Their description of the plant, its biology, distribution and culture served as the guide to research and control programs for the pre-World War II (WWII) period. The concluding statement in the summary of their bulletin explained the status of control technology in 1933: "Experiments are under way on the control of leafy spurge. The data accumulated so far indicates that it may be killed by means of sodium chlorate or by two seasons of frequent and careful cultivation. Since eradication is extremely difficult it is particularly important to find and destroy leafy spurge when it first appears."

Authors have described leafy spurge in many ways, depending upon what characteristics of the plant were important to the research or control strategy they reported. The following information is a generalization from many sources, and is provided here to acquaint the reader with leafy spurge in a general way. It is an extremely complex and interesting plant. In addition to being a long lived perennial, it is more drought tolerant than most species that it grows in association with, and can be found growing on a wide variety of sites and ecological types, from very wet to very dry, from level land to steep hillsides and banks, from deep bottomland soils to shallow, rocky ridgetops, in wooded areas and native grasslands to cropland, on heavy clays to sandy soils, on islands in rivers, in parks and recreation areas, in urban and city residential areas and industrial parks. The limits of its range of adaptation are unknown.

The plant is generally about 2 feet tall at flowering, but often grows to a height of 3 feet or more, has a woody crown below the soil surface, with an extensive root system, often more than ten feet into the soil, consisting of coarse and fine roots. Both the crown and root system have an unlimited number of vegetative buds capable of producing new stems rapidly and from great depths in the soil. Root segments 2 inches long can produce a well established plant in one growing season. Early spring growth gives leafy spurge a competitive advantage, and even seedlings have a remarkable capacity for vegetative reproduction.

Leafy spurge patches may contain more than 200 stems/yd^2 in sandy soils and higher densities occur in heavy clay soils. This density will crowd out or at least reduce the vigor of desirable plants by shading and competition for water and nutrients. All parts of the plant contain a milky latex. The latex serves as an aid in identification of leafy spurge, and that latex contains compounds responsible for limiting use of forage by cattle in even sparse stands. Cattle will not graze leafy spurge, sheep will generally graze it, and goats often prefer it to other forage. The nutritive value of leafy spurge as a feed for sheep and goats is very similar to that of alfalfa, but the plant can be toxic to cattle, causing skin irritation and/or digestive problems.

Identification of leafy spurge is enhanced by the following characteristics: bluish-green color that appears yellowish from a distance; milky sap (latex) in all parts of the plant; upright stems with linear-shaped leaves and a flat-topped cluster of yellowish-green bracts bearing the true flowers which produce pods containing three seeds each.

In North America, leafy spurge is commonly identified as *Euphorbia esula*, but many taxonomic variations occur. Leafy spurge was introduced to North America from various places in Eurasia at various times and in various ways. Introductions from widespread locations in Eurasia have become established in close proximity to each other in North America. The potential for the mixing and hybridization among the many closely related

Euphorbia species leads to taxonomic confusion. The genetic diversity of the species complex complicates control strategies, especially for biological control. Some consider leafy spurge to be a polymorphic complex. Others consider it to be a complex of many species and their hybrids. It could be something between these two extremes. Other species nomenclature appears in the literature, but for discussion purposes here, the weedy *Euphorbia* causing a problem in North America will be called leafy spurge.

CHRONOLOGY OF RESEARCH REPORTING

The second author of this paper has compiled and computer-indexed a collection of more than 830 journal and proceedings papers, book chapters, abstracts and research reports dealing with leafy spurge in North America. The collection covers the period of 1921 through 1992. In discussing the progression of research, the year of publication will be used even though the research was generally done as much as several years before the date of publication. We do not claim that this collection of papers is all inclusive, and we apologize for any omissions, but the collection is complete enough to show the trends in research on leafy spurge through the years.

The aggressiveness and persistence of leafy spurge, and its ability to take advantage of changes in agricultural management systems has shown it to be a survivor. As a survivor, it progressed from occurring in seaside wasteland and as a problem in cropland to being a major problem in grasslands, woodlands, roadsides and other permanently vegetated areas.

Pre-World War II. Most of the pre-WWII research was directed toward cultural and management practices for leafy spurge control on cropland. From 1921 to 1939, five journal papers, three Experiment Station Bulletins and two popular items were published. The journal papers were published in the *Journal of the New York Botanical Garden, Scientific Agriculture, Rhodora, Journal of American Society of Animal Production,* and *Science.* The Agricultural Experiment Station Bulletins were from Minnesota, Iowa and North Dakota. Several subjects were covered in each paper or bulletin. Subjects included history, anatomy, physiology, nutrient composition, morphology, drought tolerance, taxonomy, distribution, feed value for sheep and control by sheep, sodium chlorate, calcium chlorate, mowing and tillage.

During World War II. During WWII, agricultural research activity was greatly reduced, and leafy spurge apparently had a low priority. The collection contains only two papers published in the 1940s; one in the *North Dakota Bimonthly Bulletin* and one in the *American Midland Naturalist.* The North Dakota report dealt with control by grazing with sheep and the journal paper reviewed what was known about taxonomy, nomenclature and morphology of leafy spurge in North America.

Post World War II. Following the end of WWII, reinstatement of agricultural research and the availability of chemicals developed by chemical companies as spinoffs from those developed for the military led to a new era in weed control technology. The Canadian scientists led the way in leafy spurge research for the first 10 yr after WWII.

The 1950s. In the 1950s, five papers appeared in *Weeds*, three in *Canadian Journal of Agricultural Science*, two in *Canadian Journal of Botany*, and one in the Proceedings of the *North Central Weed Control Conference.* It was only the Proceedings paper that dealt with control methods. It included cultural (cultivation), chemical (chlorate, atlacide, 2,4-D) and biological (grazing with sheep). The post-WWII use of herbicides was beginning to appear in research reports and to be part of the leafy spurge control program. All of the journal articles dealt with some aspects of the biology of the plant, with an occasional reference to the research findings on herbicides and their relationship to cultural practices used to control leafy spurge. New subjects appearing in these papers included allelopathy, growth inhibitors, growth regulators, alkaloids and seed taxonomy, to list a few. During this period, scientists were again becoming interested in leafy spurge as a plant, and some realized the potential problems it could cause, but there was very little concern about leafy spurge among the landowners and land managers. During the post-WWII period, increased use of herbicides and more intensive tillage of cropland made possible by more powerful tractors, reduced the immediate threat of leafy spurge in cropland.

Complacency was common as leafy spurge patches began to appear in grasslands and recreational areas. The small areas occupied by leafy spurge caused no great loss in production, and no one believed the weed would be any more problem than were other weeds now that we were in the "chemical control" era.

The 1960s. During the 1960s, concern by land owners and public land managers gradually increased as leafy spurge continued to spread in spite of control efforts. But most people were still waiting for the herbicide that would conquer leafy spurge. Consequently funding research and control programs was low on the list of priorities. Researchers did begin to include leafy spurge in their programs, supported either by redirecting funds from some other weed, or through grants from chemical companies who needed the information for marketing their herbicides. During the 1960s there were 14 journal papers, 10 research reports (in North Central Weed Control Conference Proceedings) and John M. Kingsbury included leafy spurge in his 1964 book *Poisonous Plants of United States and Canada.* The journal papers included a four-part series in the *Canadian Journal of Botany,* titled *Developmental Studies on Euphorbia Esula L.*: (Morphology of the root system) (1963); (Apices of long and short roots) (1964); (Some effects of nitrogen supply on the growth and development of the seedling) (1967); (Apices of seedling and adventitious shoots) (1968). Papers in the *Journal of Range Management, Ecology, Advances in Botany* and *Ecological Monographics* covered research on cytotaxonomy, ecological relations, plant (root) dormancy, anatomical studies, plant physiology, regeneration from root segments, seed physiology, root buds, sheep grazing, burning, cultivation and cropping, and a series of chemicals including 2,4-D, sodium chlorate, monuron, diuron, fenuron, silvex, and various borate compounds. The 10 research reports all reported on chemical control research, 5 included picloram.

The first encouraging research results on chemical control occurred in the mid-1960s when picloram became available for testing. This led to an increase in activity among those doing research on leafy spurge control, but the general public was still waiting for the quick and easy chemical that would solve the rapidly expanding leafy spurge problem.

The 1970s. During the 1970s, 67 journal papers, research reports and proceedings papers were published. Of the 24 journal papers, all but five reported on some form of control technology, mostly chemical, including experimental chemicals, rates and times of application. Of the 43 research reports published in the 1970s, 15 were progress reports on chemical control. Among the new herbicides tested was glyphosate. Growth regulators for enhancing herbicide effectiveness and roller application techniques were also being evaluated. Other subjects in the research reports included more on sheep grazing, inter-specific competition for leafy spurge seedlings and competition from leafy spurge on grass yield. Five research reports discussed various aspects of leafy spurge seed production, dispersal, germination, survival in the soil and dormancy. Among the journal papers in the 1970s were six that reported on the possibility of using leafy spurge as a fuel source. None were very encouraging, but it is noteworthy that among the authors of these five papers was Dr. Melvin Calvin, a world renowned expert on photosyntheses who in his retired years explored world-wide for plants suitable for use as fuel sources. Leafy spurge and other *Euphoria* species were considered in his report.

In June of 1979, a Leafy Spurge Symposium was held in Bismarck, North Dakota. It brought together more than 100 people from the United States and Canada who were knowledgeable and concerned about leafy spurge. The Proceedings contains eight papers and the summaries of four workshop sessions. The Symposium brought together most of the information known about leafy spurge in North America up to 1979. It set in motion a series of meetings and conferences in 1980 and 1981, all of which provided the impetus for expanded programs in research, education and coordinated control programs on leafy spurge. The Great Plains Agricultural Council (GPAC) formed the Great Plains Committee on Leafy Spurge, (now the GPAC-Leafy Spurge Task Force) to facilitate and coordinate research, education, and control programs directed at leafy spurge. Primarily through priority setting and redirection of resources, State Agricultural Experiment Stations, USDA Agricultural Research Service and a few private institutions increased their effort on leafy spurge research.

The 1980s. The increased research effort in the late 1970s and early 1980s, resulted in the appearance of 526 journal papers, research reports and proceedings papers in the 1980s. Of these, 68 were journal articles, 23 were proceedings papers, two were book chapters and 433 were research reports. It is often difficult to distinguish between the proceedings and research reports categories because some organized committees call their annual report a proceedings even though most of the papers are reports of ongoing research. Other organizations publish proceedings that contain papers on completed research that may or may not be published in journal form. Much like the taxonomy of leafy spurge, the categorization of leafy spurge publications is often ambiguous.

The journal articles appeared in 23 different journals, an indication of the diversity among scientists doing research on leafy spurge. Leading the list for most frequent place to publish leafy spurge papers was *Weed Science* with 17 papers, followed by *Journal of Range Management* with six papers, and *Canadian Journal of Plant Science* and *Weed Technology* with five papers each. A few of the other 19 journals are listed here as an indication of the wide diversity of subject matter published about leafy spurge. Each had 1 or 2 papers published during the 1980s. The list of journals include *Phytochemistry*, *Economic Botany*, *Plant Physiology*, *Phytopathology*, *American Midland Naturalist*, *Bioscience*, *Journal of Agricultural and Food Chemistry*, and *Applied Animal Behavioral Science*.

More than 450 research reports and meeting proceedings papers were printed in the 1980s, an indication of the greatly accelerated research effort on leafy spurge after the symposium in 1979 and the subsequent coordination of activities in the early 1980s. Most of the research reports were presented at meetings and published in proceedings and research reports of the Western Society of Weed Science, Weed Science Society of America, North Central Weed Control Conference, Great Plains Agricultural Councils Leafy Spurge Task Force (formerly GPC-14), other GPAC committees, and the Annual Reports of USDA-ARS laboratories, especially the overseas oratories in Italy and France.

Subject matter of the journal papers and research reports expanded considerably during the 1980s. Basic research on the plant and the identification of physiological, chemical, anatomical and morphological characteristics that might lead to new approaches for chemical control, what the plant does with the herbicide applied to it and the relationship of all of this to taxonomy of what appears to be biotype or species differences. The interest in biological control greatly increased during the 1980s resulting in expanded overseas efforts by two USDA agencies, ARS and APHIS, to collect and screen insects and diseases as possible biological control agents. As the decade progressed and some control agents became available, increased research at several state Agricultural Experiment Stations and United States and Canadian federal research facilities began to provide technology for establishment of a biological control program on leafy spurge in North America. Research was also begun on integration of biological control with other control technology and with farming and ranching practices.

The 1990s. In the first 3 yr of the decade, 1990 to 1992, inclusive, 190 entries have been added to the collection of leafy spurge publications. Of these, 46 were journal papers, four were bulletins, three were book chapters and 137 were research reports and proceedings papers. A predominance of the reports dealt with biological control, particularly the use of imported insects, with some reports on the use of pathogens.

Other areas of reporting included use of leafy spurge as hay fed to cattle, use of leafy spurge pellets as fuel, genetic diversity of the plant and taxonomy as it relates to problems in control of the weed. Reports and bulletins on the economic impact of leafy spurge on the landowners as well as on the general public, and the use of combinations of control technology such as fire plus herbicide, biological control plus herbicides and sheep and goats in conjunction with cattle grazing. Integrated pest management systems are being studied emphasizing the concept that leafy spurge is here to stay and we need to learn how to manage it so we can live with it in a controlled situation.

In summary, the increased research effort following the 1979 Symposium is evident by the increased number of publications beginning in the 1980s (Table 1). Research since 1979 has added to the data base used to develop the technology for a long-term integrated management system for lands infested with leafy spurge, and for protecting uninfested lands from invasion by leafy spurge.

Although leafy spurge management and control technology is far from being perfected, accelerated control programs based on research aimed at integrated control methods is very encouraging. Continued strong support for research on leafy spurge control and for educational and extension programs to facilitate putting the technology to work on the land is essential to keep leafy spurge from getting a second wind.

Table 1. Summary of the chronology of reports and papers on leafy spurge - 1921 through 1992.[a]

Period or decade	Total	Number of journal papers, bulletins, book chapters	Abstracts, research reports, proceedings papers
Pre-WWII (1921-1939)	19	8	2
WWII Years (1940-1949)	10	1	1
Post WWII (1950-1992)	43	161	657
Total (1921-1992)	72	170	660
By decade			
1950s	10	10	1
1960s	10	15	10
1970s	10	24	43
1980s	10	70	457
1990-1992	3	42	146

[a] Based on a collection of leafy spurge papers assembled by Rodney G. Lym at North Dakota State University.

LEAFY SPURGE CONTROL WITH QUINCLORAC. Rodney G. Lym and Calvin G. Messersmith, Associate Professor and Professor, Crop and Weed Sciences Department, North Dakota State University, Fargo, ND 58105.

Abstract. Quinclorac is an auxin-type herbicide with moderate soil residual. Previous research at North Dakota State University has shown that quinclorac will reduce leafy spurge topgrowth density and may be more effective when applied in the fall than any other time of the growing season. The purpose of this research was to evaluate quinclorac applied alone and in combination with picloram or various spray adjuvants in the field and greenhouse for leafy spurge control.

Quinclorac at 1 lb/A fall-applied provided an average of 95% leafy spurge control 9 months after treatment (MAT) when applied with the adjuvant Scoil (a methylated seed oil) at 1 qt/A but only 50% control when applied alone. Control with quinclorac plus Scoil declined to 70% 12 MAT and was similar to picloram plus 2,4-D at 0.5 plus 1 lb/A, the most commonly used fall-applied treatment. Quinclorac applied with picloram provided similar control to picloram plus 2,4-D or quinclorac plus Scoil applied alone. Quinclorac plus Scoil at 1 lb plus 1 qt/A provided similar leafy spurge control to picloram plus 2,4-D at 0.5 plus 1 lb/A when applied annually in the fall. No grass injury was observed from any quinclorac treatment.

Quinclorac 0.68% granule formulation, soil-applied, provided better leafy spurge control than quinclorac spray applied at equivalent rates in greenhouse experiments. ^{14}C-quinclorac was rapidly absorbed by leafy spurge and averaged 40% of applied ^{14}C-quinclorac 24 h after treatment. Nearly 7% of applied ^{14}C translocated to the roots 24 h after treatment compared to only 1 to 2% of applied ^{14}C-picloram and 3% of applied ^{14}C-2,4-D.

Quinclorac provided good leafy spurge control both postemergence and soil applied and may be an alternative to picloram plus 2,4-D especially as a fall-applied treatment. The quinclorac granular formulation should be popular for control of leafy spurge in small patches. (Published with approval of the Agric. Exp. Stn., North Dakota State University, Fargo 58105).

INTEGRATED CONTROL OF LEAFY SPURGE (*Euphorbia esula*) WITH BOZOISKY RUSSIAN WILDRYE (*Psathyrostachys junce*) AND LUNA PUBESCENT WHEATGRASS (*Agropyron intermedium var. trichophorum*). M. A. Ferrell, T. D. Whitson, D. W. Koch, and A. E. Gade, Extension Pesticide Coordinator, Associate Professor, Professor, Department of Plant, Soil and Insect Sciences, University of Wyoming, Laramie, WY 82071, and Extension Agent, University of Wyoming Cooperative Extension Service, Sundance, WY 82729.

INTRODUCTION

Herbicide research to control leafy spurge in Wyoming began in 1952 with 2,4-D (6). Picloram which became available in 1963 has proven to be the most reliable and effective herbicide for control of leafy spurge with a single application. However, control can be maintained for only 3 to 5 yr. After this time a retreatment program must be implemented to maintain adequate leafy spurge control. Adequate control is when leafy spurge is controlled to a level where cattle can effectively utilize desirable forage growing in competition with leafy spurge. Hein found leafy spurge canopy cover exerted the greatest influence on grazing behavior and forage utilization by cattle (1). Leafy spurge canopy cover of 10% or less and shoot control of 90% or more were necessary to achieve 50% forage utilization by cattle in Montana. In North Dakota, moderate and high density leafy spurge infestations were avoided until early fall when the milky latex in the spurge disappeared (2). Cattle only used 2% of the available forage in leafy spurge densities of less than 20% cover.

Although herbicides play an important part in the control of leafy spurge alternative methods are available and may be used where persistent herbicides cannot be tolerated. One such method is plant competition. Grass competition has long been recognized as a method of leafy spurge control. Crested wheatgrass has been used successfully in Saskatchewan, Canada to decrease the rate of vegetative spread, limit density, reduce seed production and suppress top growth of leafy spurge. If 2,4-D is applied to such stands twice a year the hay may be safely removed for feed, and seed production will be prevented (5). Leafy spurge growth may also be suppressed by planting an early emerging crop such as crested wheatgrass, which will compete with it for early soil moisture (3). The purpose of this research was to determine the potential of perennial grass competition as an alternative to repetitive herbicide treatment for control of leafy spurge.

MATERIALS AND METHODS

A study was established near Devil's Tower in Crook County, Wyoming to determine the potential of Bozoisky Russian wildrye and Luna pubescent wheatgrass competition as an alternative to repetitive herbicide treatment for control of leafy spurge. Two applications of glyphosate at 1.1 and 0.75 lb/A were broadcast with a tractor mounted sprayer delivering 13.5 gpa at 20 psi before seeding grasses in 1989. The first application was May 18, 1989. (Temperature: air 72 F, soil surface, 80 F, 1 inch 80 F, 2 inch 65 F, 4 inch 65 F. Relative humidity: 48%. Wind: south at 10 mph) and the second application was July 19, 1989. (Temperature: air 75 F, soil surface, 108 F, 1 inch 100 F, 2 inch 81 F, 4 inch 80 F. Relative humidity: 55%, Wind: calm). Soils were classified as a slit loam (22% sand, 58% silt, 20% clay) with 1.8% organic matter and 6.3 pH. 2,4-D at 2 b/A was applied postemergent August 9, 1989 to control annual broadleaf weeds. An additional postemergent application of 0.06 oz/A metsulfuron plus 1 lb/A 2,4-D low volatile ester was made May 14, 1990 to control annual mustards. Plots (33 by 174 ft) were arranged in a randomized complete block design with two factors and four replications. One factor was grass variety and the other till versus notill. Plots were tilled with a rototiller and packed on August 7, 1989 and grasses with seeded with a Tye drill, with 0.25 inch depth bands, on August 8, 1989. Evaluations on percent grass stand, percent leafy spurge control, pounds of air dry grass/A, grass plants per 20 ft of row, and percent downy brome infestation were taken September 12 and 13, 1991 and July 8, 1992.

Grasses used in this study were selected on the basis of productivity, ability to establish in low moisture areas and ability to compete with leafy spurge. Grasses selected were pubescent wheatgrass (Luna), and Russian wildrye (Bozoisky). Luna was seeded at a rate of 11 lb of pure live seed/A and Bozoisky at a rate of 7 lb of pure live seed/A. Row spacing was 8 inches for both varieties.

RESULTS AND DISCUSSION

Grass stands in rototilled plots in 1991 were 94% and 93% for Luna and Bozoisky, respectively (Table 1). There was a slight increase in 1992 (Table 2). Grass stands in no-till plots were 86% and 69% for Luna and Bozoisky, respectively. There was a considerable increase in grass stand in 1992 for both Luna (95%) and Bozoisky (81%). The rototilled plots also had significantly more plants per 20 ft of row than the no-till plots for both grasses in 1991 (Table 1). In 1992 there was a considerable increase in plants in the Bozoisky plots (Table 2).

Leafy spurge control was excellent at 95% or better in both rototilled and no-till plots in 1991 and 1992 for both grasses (Table 1 and 2). Downy brome infestation was considerably greater in the no-till plots in 1991 (Table 1). Bozoisky had 21% infestation in the rototilled plots compared to 73% infestation in the no-till plots. Luna had 6% infestation in the rototilled plots compared to 20% infestation in the no-till plots. In 1992 the downy brome infestation was reduced considerably, with the Bozoisky no-till plots showing a serious infestation of 39% (Table 2).

Grass production for 1991 was very good for both the rototilled and no-till plots due to good early season moisture. In the rototilled plots Luna provided 3068 pounds of air dry forage per acre and 2181 pounds in the no-till plots (Table 1). Bozoisky production was 1463 pounds in the rototilled plots and 1046 pounds in the no-till plots. In 1992 forage production was also very good (Table 2). There were no differences between production in the rototilled versus the no-till plots in 1992.

Grass characteristics. Pubescent wheatgrass (Luna) is considered to be better adapted to droughty, infertile, and saline soils than intermediate wheatgrass. Luna was developed in New Mexico by the USDA/SCS (4). It had excellent grass stands in both the rototilled and no-till plots and excellent control of leafy spurge in the rototilled and no-till plots. Luna was also the top forage producer in both rototilled and no-till plots.

Russian wildrye is a cool-season perennial bunchgrass that has been widely used in the western U.S. and Canada. Once established, it has excellent drought and cold tolerance. The species is characterized by dense basal leaves that are high in nutritive value and palatable to grazing animals. Also, its nutritive value during the late summer and early fall is better than many other grasses, including crested and intermediate wheatgrass. 'Bozoisky', the cultivar used in this study was recently obtained from the USSR. It has been significantly more productive and easier to establish on semiarid range sites than other Russian wildryes (4). This grass looks excellent in the rototilled plots and fair in the no-till plots. Bozoisky also had excellent leafy spurge control in the rototilled and not-till plots. Based on their performance in this study Luna and Bozoisky appear to be good grasses for competition with leafy spurge.

Table 1. Pubescent wheatgrass (Luna) and Russian wildrye (Bozoisky) grass stand, leafy spurge control, number of grass plants, downy brome infestation and forage production, 1991 data.

	Grass stand[b]		Leafy spurge control		Number of grass plants		Downy brome infestation		Production of air dry grass	
Grass species (variety)[a]	Rototilled	No-till	Rototilled	No-till	Rototilled	No-till	Rototilled	No-till	Rototilled	No-till
	%				per 20 ft of row		%		lb/A	
Pubescent wheatgrass (Luna)	94	86	99	99	34	25	6	20	3068	2181
Russian wildrye (Bozoisky)	93	69	99	95	37	21	21	73	1463	1046
LSD (0.05)[c]	5	5	3	3	5	5	8	8	716	716

[a] Grasses seeded August 8, 1989.

[b] Evaluations - % Grass stand: % leafy spurge control: Grass plants per 20 ft of row: Percent downy brome infestation: September 13, 1991. Pounds of air dry grass per acre: September 12, 1991.

[c] Comparison of variety means is valid between rototilled and no-till.

Table 2. Pubescent wheatgrass (Luna) and Russian wildrye (Bozoisky) grass stand, leafy spurge control, number of grass plants, downy brome infestation and forage production, 1992 data.

Grass species (variety)[a]	Grass stand[b]		Leafy spurge control		Number of grass plants		Downy brome infestation		Production of air dry grass	
	Rototilled	No-till	Rototilled	No-till	Rototilled	No-till	Rototilled	No-till	Rototilled	No-till
	%				per 20 ft of row		%		lb/A	
Pubescent wheatgrass (Luna)	95	95	99	99	34	27	1	4	2121	2135
Russian wildrye (Bozoisky)	95	81	99	97	56	28	5	39	1383	1221
LSD (0.05)[c]	5	5	ns	ns	11	11	4	4	440	440

[a] Grasses seeded August 8, 1989.
[b] Evaluations July 8, 1992.
[c] Comparison of variety means is valid between rototilled and no-till.

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CONSEQUENCES OF RESTRICTIONS ON HERBICIDE USE ON U.S. FOREST SERVICE TIMBERLANDS IN CALIFORNIA. Duane A. Nelson, U.S.D.A. Forest Service, Placerville, CA 95667.

WHY MANAGE VEGETATION ON NATIONAL FOREST LANDS?

The U.S. Forest Service manages about 20 million acres of public wildland in California. About 6 million acres are capable, available and suitable for production of timber commodities (14), mostly softwood or conifer lumber. Using intensive management techniques, including the use of herbicides for control of competing plants, these lands have the potential to produce a sustainable annual yield of about 1.9 billion board feet (enough lumber to build about 130,000 typical three bedroom homes). Direct value of the standing trees is about $850 million. Reforestation, timber harvesting, manufacturing and indirect and induced employment associated with this level of timber harvest, generates about 29,000 jobs per year. This represents about $1.3 billion of employment generated income for the State of California (1).

Like any other crop, timber yields may be reduced by losses to insects, disease, vertebrate pests and competition with other vegetation. In California, management of competing plants in conifer plantations is the cornerstone for integrated pest management. The Forest Service (14), projects a 19% reduction in timber yields if conifer regeneration were managed without the use of herbicides and a 50% reduction in timber yields if no vegetation management were practiced on California's National Forests. This is not only a significant economic impact, but also affects all associated resources such as wildlife, watershed, biological diversity, and recreation, that are dependent upon effective reforestation of harvested and burned over lands.

RESTRICTION OF HERBICIDE USE ON NATIONAL FORESTS IN CALIFORNIA

Prior to 1983, herbicides were routinely used for site preparation and release from competition for the establishment of conifer plantations in California. Silviculturists relied on phenoxy herbicides for shrub control and soil active pre-emergent herbicides for control of grasses and forbs.

Herbicide use began to draw increasing public attention, triggered by growing environmental awareness, and concerns about safety and environmental impacts. By 1983, public concern about herbicide use on National Forests in California had peaked. Resistance to herbicide spraying was voiced by a small but vocal segment of the public. Opposition was expressed in appeals of decisions, litigation, public debate in the press, civil disobedience, isolated cases of violence, threats to Forest Service employees and destruction of spray equipment.

In 1983, the Chief of the Forest Service suspended the aerial application of phenoxy herbicides on National Forest lands, due to a U.S. District Court decision against two Bureau of Land Management (BLM) projects in Oregon. Shortly thereafter, the Regional Forester in California (Region 5) suspended all herbicide use on National Forest in California, due to an outdated environmental impact statement that did not adequately consider newly available information. Region 5 began the process of developing a new Environmental Impact Statement incorporating this new information and responding to significant public issues. In the interim, forest managers were restricted to non-herbicide methods for site preparation and release in conifer plantations.

On February 27, 1989, the Regional Forester signed a Record of Decision implementing a new programmatic Environmental Impact Statement for Vegetation Management for Reforestation covering National Forests in California. This document authorized the use of a specified list of herbicides as part of an integrated vegetation management program. Site specific environmental analysis is required for each individual project. The site specific analysis must consider a range of feasible treatments. Herbicides are only to be selected where essential to meet management objectives.

Though the new EIS authorized herbicide use on all National Forests in California, their use is still limited. Some Forest Supervisors and District Rangers have been unwilling to take on the public controversy associated with herbicide projects. On these Forests, non-herbicide methods are still used exclusively. Those Forests implementing herbicide projects have been reluctant to address aerial application, despite potential cost and effectiveness benefits. The choice has been to stay with ground based application methods, which are perceived to be lower in controversy and lower in risk.

COMPETING VEGETATION ON NATIONAL FORESTS IN CALIFORNIA

In the Mediterranean climate of California, grasses, forbs and brush compete with young conifer seedlings for nutrients, sunlight, soil moisture and growing space. Vegetation management is especially important, due to the protracted summer dry season in California.

Through natural selection over millions of yr, many weed species are superbly adapted to dominate newly disturbed areas. Herbaceous and woody weeds can remove enough soil water during the growing season to kill or reduce the growth of conifer seedlings (2). Soil heat transfer in the seedlings's microclimate is also adversely affected by water consumption of competing vegetation (7). Early maturing forbs and grasses are especially dangerous because they are widespread and remove water early in the growing season, thus denying water to seedlings later in the growing season when demand is greatest. Experience strongly indicates that reforestation will fail on droughty sites when competitors are present. Excessive moisture stress is the most frequent cause of mortality and insufficient growth in young conifers in California (14).

Woody shrubs pose a long-term threat to plantation establishment and survival. Seedlings and sprouts of broad-sclerophyll shrubs emphasize early and vigorous root development and have tremendous potential to fully occupy a site. After one growing season, heights of sprouts of Pacific madrone (*Arbutus menziesii* Pursh), tanoak (*Lithocarpus densiflorus* [H. & A.] Rehd.), chinkapin (*Castanopsis chrysophylla* [Dougl.] A. DC), California black oak (*Quercus kelloggii* Newb.); and shrubs such as Arctostaphylos and Ceonothus species will range from 1 to 5 feet. After three to ten growing seasons, height will range from 1 foot to more than 22 feet (5). This vegetation not only competes with conifers for soil moisture, sunlight and nutrients, but also adds tremendous amounts of highly flammable fuel to plantations that are vulnerable to wildfire. Increased moisture stress weakens the conifers and makes them more susceptible to damage from insects, disease and vertebrate pests.

How much competition is too much? From two long-term spacing studies, "the regression equations suggest that any amount of shrubs will restrict diameter growth," and beyond 30% crown cover, the shrubs dominate (6, 9). In a study in Sierra County, plotting pine height over shrub cover indicated that between 10 to 15% cover markedly reduced pine height on a harsh site (6). In general, crown cover is too much when it exceeds 10 to 20% on poor sites and 20 to 30% on good sites (McDonald and Fiddler 1989).

SINGLE TREE IMPLICATIONS OF COMPETITION AND RESTRICTION OF HERBICIDE USE

Competing vegetation has a profound effect on individual tree growth. In southwest Oregon, Douglas-fir seedlings were planted in treated and untreated areas where competing vegetation was primarily sprouts of canyon live oak (*Quercus chrysolepis* Liebm.) and greenleaf manzanita (*Arctostaphylos patula* Greene). After five growing seasons, excavation shows that seedlings in the control and lightly treated areas had retained the same shape and root system as when they were planted. Root biomass of essentially free to grow seedlings was 22 times that of seedlings planted among 3.3 foot tall sprouts in the untreated areas (13). In northern California, after the third growing season, reductions of 80 to 90% in ponderosa pine growth were noted from shrub cover of 50% or more (11).

In northern California, predawn moisture stress of ponderosa pine seedlings was lowest (5.7 atmospheres) on a plot treated with hexazinone, highest in the untreated control (12.7 atmospheres) and intermediate in other (manual) treatments (4). Maximum moisture stress was also lowest in the hexazinone treatment (16.5 atmospheres) and highest in the control (19.3 atmospheres). Maximum stress in the hexazinone treatment occurred late in the afternoon, but in the control took place at 10:10 a.m. By being under 15 atmospheres of stress for a longer period during the day, the seedlings in the treated plot probably achieved positive net photosynthesis for over 5 h, while seedlings in the control did so for about 1.5 h.

In this same study, stem caliper and tree height showed significant differences at age five. Average height of pines in the hexazinone treatment was significantly larger than counterparts where vegetation was grubbed in a 2 foot radius one time; grubbed in a 2 foot radius once and re-grubbed, after 3 yr, with the radius expanded to 4 feet; and grubbed in a 4 foot radius one time. Only where the vegetation was grubbed first to a 4 foot radius and regrubbed, after 3 yr, to a 6 foot radius were heights similar between the herbicide treatment and a hand method.

Herbicides have consistently been shown to be the most effective and least costly means to control competing vegetation in California conifer plantations. Good control can often be achieved in one or two treatments at a cost of $10 to $150/A (excluding the cost of herbicide) depending on the application, rate, and other factors (3).

McDonald and Helgerson (5) found mulches to generally be inferior to herbicides, primarily for economical, but also biological reasons. Mulches that are durable and large enough to allow growth at the potential of the site may cost between $2.40 and $6.00 per seedling treated. Repeated hand grubbing can produce adequate results if at least a five foot radius is cleared around each tree. Up to four treatments may be need to give results comparable to one herbicide release. Total costs may be as high as $1,100 to $1,400/A.

STAND LEVEL IMPLICATIONS OF RESTRICTED HERBICIDE USE

Silviculturists have traditionally used stand projections to select management strategies to meet product mix objectives. Vegetation management can also effect the time that a stand meets defined structural attributes that are suited for wildlife species of concern. Stand level projections of the effects of competition can be made using a stand simulator, SYSTUM-1 (12). The simulator projects height, diameter, and basal area of young stands of California conifers under varying conditions of site quality, tree spacing and competition (10).

Projections of a high site index, mixed conifer stand growing with bearclover, manzanita, Ribes spp., grasses and forbs indicates that control of competing vegetation can accelerate the development of suitable habitat for the California spotted owl by about 9 yr (8). Intensive management can produce the largest average tree size in the least time. With no treatment, bearclover and forbs would dominate the site, causing mortality and reduced conifer growth.

In summary, we may be able forge change through industry wide commitment to excellence in our vegetation management practices. We must make a determined effort to tell our story to the public. We must better prevent and manage the rare catastrophic events like the Dunsmuir Spill in California. We must better communicate our daily successes in safe and effective integrated pest management. We must gain the public trust and establish our role as stewards of the environment, as well as the producers of valuable commodities for society's consumption.

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WEEDS OF HORTICULTURAL CROPS

MULTIPLE HERBICIDE TREATMENTS FOR THE RESTORATION OF BERMUDAGRASS INFESTED COOL SEASON TURF. D. W. Cudney and C. L. Elmore, Extension Weed Scientists, University of California, Riverside, CA 92521 and Davis, CA 95616.

Abstract. Bermudagrass, although often used as a desirable turf species, is also an aggressive perennial weed. This is particularly true in warm temperate climates where bermudagrass is well adapted and can rapidly invade cool season turf swards. Bermudagrass invaded areas tend to have poorer color, particularly during the winter months. Current renovation procedures for the removal of bermudagrass infested areas are to fumigate and replant with cool season species (perennial ryegrass, tall fescue, or Kentucky bluegrass) or to treat with glyphosate and replant. Both methods require the loss of use of the turf area while the desirable cool season species are reestablished and reinvasion with bermudagrass usually can reoccur. The purpose of this research was to evaluate the use of postemergence herbicides, applied in sequential treatments to weaken and gradually reduce the bermudagrass allowing reseeding and reestablishment of the desirable cool season species. This would allow a gradual conversion of the bermudagrass infested swards back to desirable species without loss of use of the area.

Fenoxaprop (0.19 and 0.38 lb/A) and triclopyr (0.5 and 1 lb/A) were applied alone and in combination as single and as four sequential applications. Neither herbicide was effective as a single application but when applied as sequential treatments, they reduced bermudagrass and allowed reestablishment of the desirable cool season species. Combinations of these herbicides were also effective and controlled a broader spectrum of other weeds. Fenoxaprop reduced the vigor of young emerging perennial ryegrass at the University of California, Riverside but did not effect tall fescue at the University of California, Davis.

THE GLIDE HOE: AN INDISPENSABLE WEED CONTROL TOOL FOR THE SMALL FARM. R. D. Gibson, Extension Agent, Agriculture, Pinal County, Cooperative Extension, University of Arizona, 820 E. Cottonwood Lane, Building C, Casa Grande, AZ 85222.

INTRODUCTION

The small farm operator must, like all business people, be keenly aware of the bottom line. The cost of labor and materials as well as residue and labeling restrictions may limit the chemical control options. Additional limitations may come from the size of the farm, the diversity of plants being grown, and physical structures such as drip irrigation equipment, growth frames, and greenhouses. Tractor and small implement control methods may not be effective or indicated for all growing conditions. One inexpensive weed control option that has proven useful and effective in controlling many weeds under a variety of small farm field conditions is the glide hoe.

Sometimes called the push-pull hoe or the scuffle hoe, the implement works by gliding back and forth on the top of or just beneath the surface of the soil to cut weeds of all sizes. Glide hoes are excellent for fast removal of weed seedlings and mature weeds on level ground. Instead of chopping, the hoe is pushed forward and then pulled backward to destroy weeds with both strokes. (Flint, M. L., 1990, Pests of the Garden and Small Farm, University of California, page 186.)

The hoe is composed of a sturdy wooden handle, at least 5 feet long, and a hardened steel cutting blade, beveled on the top on all sides attached to the handle by a 0.44 inch steel shank formed to place the handle at an approximately 30 to 40 degree angle from the ground when the cutting blade is laid flat on the surface of the soil. The ideal angle would place the hoe handle 4 to 6 inches below the belt of the operator.

A small acreage wine grape vineyard manager east of Florence in central Arizona has been using the hoe exclusively to keep annual and perennial weeds under control in the row underneath the vines and the trellis mounted drip irrigation tubing. In the 2 yr he has been using the hoe, weeds have been effectively controlled without other inputs. He has noticed over time a general reduction in weed populations possibly due to a general reduction of weed seed in the soil. He uses a notched version of the hoe that he uses to hook woody perennial weeds and jerk them out. He also uses the notch to remove sucker growth from the vines. Seeing the success experienced by this manager, the question then was posed: How effective would the glide hoe be in other crops and would it be attractive to the trained hoe crew professional?

MATERIALS AND METHODS

Two forms of the glide hoe were field tested by three hoe crew professionals in two small farm field situations located at the Maricopa Agricultural Center. The professionals are employed by the Center. Also included in the test were a shovel and a standard hoe as a check. Each professional was asked to weed 50 feet of row and rate each tool on a scale of 1 to 10 as to the tool's effectiveness for the situation. A 10 was described to mean "excellent" and a 1 "poor". The dimensions of each implement are listed in Table 1. Two of the professionals were involved in both studies while Dan was replace by Joe in the second.

The first test was conducted in a fall sweet corn test planted in 40 inch rows with the plants spaced 4 to 6 inches apart in the rows. Major weeds included species of spurge, common lambsquarters, horse purslane, common purslane, summer annual grasses, and Palmer amaranth.

The second test involved a drip and sprinkler irrigated test of spring leaf lettuce planted on 5 foot beds separated by 6 inches between rows. Irrigation systems involved above ground drip irrigation using four lengths of T Tape spaced 14 inches apart on the beds; microjet sprinklers connected by thin tubing to a central tube running the length of and down the center of the bed; and a standard soaker hose also running down the center of the bed. Common weeds included seedling common lambsquarters, shepherdspurse, London rocket, little mallow, prickly lettuce, and winter annual grasses. Ratings and general comments by the participants were recorded. The ratings by each person are listed in Table 2.

Table 1. Description of implements involved in the study.

Implement	Description
Glide hoe #1	Blade, 8 by 3 inches, no notches; handle 5 feet long, 30 and 45 degree angle.
Glide hoe #2	Blade, 6 by 3 inches, no notches; handle 4 feet 4 inches long, 40 and 50 degree angle.
Standard hoe	Blade, 6 by 2 inches; handle 5 feet long.
Shovel	Standard digging spade; handle, 5 feet long, 20 degree angle.

RESULTS AND DISCUSSION

The hoe crew professionals did not prefer either of the glide hoes over the standard hoe. The shovel was the least preferred of all the implements. Part of their reluctance to adopt the glide hoe might be traced to their familiarity with the standard hoe and a reluctance to make changes. After the test was concluded, the author picked up one of the glide hoes and began to work along with them. He noticed that the professionals were watching him out of the corner of their eyes to see how the implement was working. Their stated reasons for not liking the hoe included: 1) the need to stoop over slightly to work the implement which over a day's work may lead to back strain, 2) a difficulty in controlling the tool around soft annual plants in the row, and 3) four sides of the implement to sharpen instead of one which could lead to longer down times which could slow them down and cost them money when they are paid by the row. All agreed that the shorter handle length of the second hoe was too short leading to a general reduction in preference over the first hoe. Those who had participated in the first test in the fall of 1992, tended to rate the glide hoes lower in the spring test.

Table 2. Individual ratings of each hoe crew professional evaluating each implement tested on a scale of 1 to 10 with 10 being "excellent" and 1 "poor".

	Field hand rating Sweet corn, 38 inch rows, November 1992			Field hand rating Leaf lettuce, 60 inch beds, February 1993		
	Manual	Terry	Dan	Manual	Terry	Dan
Glide Hoe #1	8	2	6	4	8	8
Glide Hoe #2	5	6	4	0	6	4
Standard chopping hoe	9	8	5	10	10	10
Shovel	4	4	3	4	8	6

Rejected by professionals, the glide hoe may be least useful in closely planted row crops such as cotton, sweet corn and lettuce. The implement has proven useful in situations where unrestricted movement of the implement was possible such as in tree and vine orchards, and widely spaced crops such as cucurbits and cole crops. It was especially useful in above ground irrigation systems where one careless stroke with a regular hoe could damage water delivery tubing. The glide hoe could be slipped under the drip tubing and worked back and forth to control weeds without harm to the irrigation structures.

In other situations, the glide hoe easily sliced through the roots of weeds of all sizes from three-inch Palmer amaranth to simple annual herbaceous weeds such as spurges, puncture vine, and common purslane. The implement buries itself under the surface of the soil as it works and cuts the weeds quickly and easily below the crown which discourages regrowth of cut annual weeds.

CONCLUSIONS

The glide hoe has proven to be a useful tool on flat surfaces in perennial woody crops, along fence rows, and around surface water delivery structures. Professional hoe crew members may not readily adopt the glide hoe because of the difficulty in controlling the tool around annual row crops, the need to stoop over somewhat to make the tool work efficiently, and because it involves a change from their tool of choice to which they have grown accustomed. Because professional crews usually do hand weeding on large farms, the major glide hoe niche at present may be the owner operated small farm. The angle and length of the handle and the shape and size of the blade are critical parameters in selecting a glide hoe.

ORCHARD AND VINEYARD WEED CONTROL WITH GLUFOSINATE. M. H. Ehlhardt and W. F. Strachan, Hoechst-Roussel Agri-Vet Co., Chico, CA 95928.

Abstract. Broad spectrum weed control in orchards and vineyards with glufosinate has been obtained with the use rates ranging from 0.75 to 1.5 lb/A. With the trend towards using low use rate herbicides or reduced rates of standard post-emergence herbicides, the activity of reduced rates of glufosinate on total weed control or control of individual species was investigated. Rates of 0.125, 0.25, 0.38, 0.5, and 0.63 lb/A of glufosinate were applied at 25 gpa to weeds with 6 inches of growth or less in 1991 and 1992, and 6 to 12 inches in 1991. Control ratings of 80% or greater, described as partial to complete control, was achieved on the following: 0.38 lb/A on fiddleneck and wild radish; 0.5 lb/A on giant foxtail, black mustard, fiddleneck, prickly lettuce, shepherdspurse, wild radish, wild oats, and large crabgrass; and 0.63 lb/A on the above species, plus downy brome and seedling Johnsongrass. The 0.25 lb/A rate did not provide activity at this level. Of the species over 6 inches in height, prickly lettuce and fiddleneck were sensitive to 0.5 lb/A. The 0.63 lb/A rate also controlled shepherdspurse. Species showing the greatest tolerance to reduced rates were annual ryegrass, wild mustard, redstem filaree, and field bindweed. Consistently the most sensitive species were fiddleneck wild radish and shepherdspurse. Results

from these tests indicate that broad spectrum activity with reduced rates will be dependent on the species present. An increase in the broad spectrum activity with the reduced rates was achieved when tank mixing 0.38 lb/A or more with 0.25 lb/A of oxyfluorfen. This mixture gave 80% or greater control of all winter annuals. An increase in the activity of the 0.5 lb/A rate on a summer weed spectrum was observed with a combination of 17 lb/100 gal of ammonium sulfate.

EFFECT OF TILLAGE LEVEL ON WEED CONTROL IN ASPARAGUS. Rick A. Boydston, Plant Physiologist, U.S. Department of Agriculture-Agricultural Research Service, Irrigated Agriculture Research and Extension Center, Prosser, WA 98930.

Abstract. Asparagus grown in Washington State is commonly tilled in early spring and often again in June after the final cutting. No till asparagus production may reduce soil erosion, conserve soil moisture, increase asparagus yields, and prevent damage to shallow crowns. This research was conducted to determine if weeds could be controlled adequately in no till asparagus production and whether no till asparagus production is feasible in Washington state.

The experiment was a split plot design with tillage as main plots and herbicides as subplots. Tillage treatments were: 1) no till; 2) rototilled once in the spring; and 3) rototilled once in the spring and again after the last cutting in June. Experiments were initiated in 1989 and repeated in 1990 and 1991.

Asparagus yield was reduced in 1989 by rototilling in early April. Asparagus yield was not reduced in 1990 or 1991 by rototilling earlier in March. Common groundsel and horseweed populations increased in no till asparagus when herbicides were not used. Volunteer asparagus increased in spring rototilled asparagus when herbicides were not used, but rototilling again at layby controlled volunteer seedlings. Hairy nightshade increased in plots that were rototilled in the spring and at layby when no herbicides were applied. Norflurazon plus metribuzin or diuron plus prodiamine split applied in the spring and at layby controlled annual weeds well under all tillage levels. Canada thistle and quackgrass were controlled in all tillage levels with spot treatment of clopyralid and fluazifop-P butyl, respectively. This data indicates that advantages of no till asparagus production, such as less erosion, less fuel, and water conservation, could be realized in Washington State without sacrificing asparagus yield and weed control.

EFFECTS OF ORCHARD FLOOR MANAGEMENT ON GROWTH AND PRODUCTIVITY OF 'MONTMORENCY' SOUR CHERRY TREES. J. LaMar Anderson and Thor E. Lindstrom, Professor and Senior Research Technician, Department of Plants, Soils and Biometeorology, Utah State University, Logan, UT 84322-4820.

INTRODUCTION

In the intermountain west, deciduous orchards are often planted on elevated sloping sites to allow cold dense air to drain away from the orchard. Such sites are less subject to late season freezing temperature damage. A permanent grass sod is generally established to reduce soil compaction by orchard equipment, to reduce soil erosion when orchards are under irrigation, to help control unwanted orchard floor vegetation and modify orchard temperatures.

Studies have shown that orchard floor vegetation will compete with fruit trees especially during the years immediately after orchard establishment or in time of drought (2). This study was set up in a continuing study of the effects of commonly-used orchard cover crops at various spacings and common orchard floor management practices on early growth and production of sour cherry trees grown on the two most common rootstocks.

MATERIALS AND METHODS

'Montmorency' sour cherry trees on mazzard and mahaleb rootstocks were planted 4 by 6 m apart, April 11, 1986, in a Draper gravelly loam soil at the Kaysville Farm of the Farmington, Utah Field Station. A trench dug between tree rows in an adjacent sour cherry orchard revealed a firm restrictive layer at about 40 cm depth. A solid-set mini-sprinkler system was installed in May, 1986. The system was engineered to deliver comparable volumes of water to each single tree plot.

Orchard floor management systems included clean cultivation, chemical fallow where plots were kept vegetation-free by repeat glyphosate treatment, and permanent 'Elka' perennial ryegrass or 'Ensylva' creeping red fescue sod plots. Grasses were planted in June, 1986. Grass-cover treatments were subdivided into solid sod, 1 m vegetation-free square around tree trunks, and 1 m vegetation-free strips along the tree rows. Two single-tree plots of each treatment were included in each block and blocks were replicated six times.

Clean-cultivated plots were cultivated with a rotary hoe to a depth of 8 to 10 cm three times annually. Chemical fallow plots and vegetation-free squares and strips in the sod plots were sprayed with 1.1 kg/ha glyphosate three times annually.

Trunk diameters were measured at a height 10 cm above the soil surface annually in November. Canopy height, canopy width and leaf area index were calculated for each tree. Trees were hand-harvested in 1991 and 1992. Production in 1992 was unusually heavy. Net fruit weight from individual trees was recorded and yield efficiency (kg of fruit per cm^2 of trunk cross-sectional area) calculated.

RESULTS AND DISCUSSION

In many areas where cherries are grown, mazzard [wild sweet cherry (*Prunus avium* L.)] is the rootstock of choice. On irrigated arid sites in Utah, cherry trees on mahaleb (*P. mahaleb* L.) rootstock are generally more vigorous and fruitful than comparable trees on mazzard rootstock (1). Mazzard rootstocks are generally considered to be shallow rooted, whereas, mahaleb had a deep tap root with relatively fewer branch roots. Consequently, mazzard has been the recommended rootstock for soils with a high water table while mahaleb has been recommended for deep sandy soils. Mazzard root injury has been associated with deep cultivation (5).

When averaged across all orchard floor management treatments, trees on mahaleb rootstock generally had larger trunk diameters after seven growing seasons, yielded heavier, and had a higher yield efficiency (Table). The only exception being that trees on mazzard rootstock in the chemical fallow plots had larger trunk diameters than comparable trees on mahaleb. Under the conditions of this study, grass sod competition or denying root development in the top 8 to 10 cm of soil by repeated cultivation was more restrictive to growth and production of sour cherry trees on mazzard rootstock than on mahaleb rootstock. Only when these stresses were eliminated, in this case by chemical fallow, did trees on mazzard rootstock out-perform trees on mahaleb in any of the parameters tested.

Growth and production of trees in the ryegrass plots was not significantly different from those values of trees in the fescue plots. For simplicity, only data from the ryegrass sod plots is listed (Table).

Tree growth was generally proportional to the amount of area kept vegetation-free per tree. Trees in the chemical fallow plots were larger than trees in the cultivated plots as measured by trunk diameter (Table) or canopy volume (data not shown). Fruit yields corresponded to tree size. Trees in the chemical fallow plots out-yielded trees in any of the other orchard floor management treatments. No evidence of glyphosate toxicity was observed in any of the treatments throughout the course of the study.

Yield efficiency in all plots except those with a complete sod cover was similar indicating that tree size was generally the limiting factor in fruit production. Trees in plots having a complete sod cover had significantly lower yield efficiency ratings (Table).

Table. Sour cherry growth and yield responses to orchard floor management.

Rootstock	Treatment	Trunk diameter	1992 yield	Yield efficiency
		cm	kg/tree	kg/cm^2
Mazzard	Complete sod[a]	7.97	17.8	0.34
	m square[a]	9.15	30.5	0.46
	m strip[a]	10.02	33.2	0.42
	Chem fallow	14.13	63.1	0.42
	Cultivated	11.05	41.8	0.44
Mahaleb	Complete sod[a]	8.93	20.9	0.33
	m square[a]	9.54	31.1	0.43
	m strip[a]	10.50	40.7	0.46
	Chem fallow	12.95	63.9	0.49
	Cultivated	10.85	44.6	0.50
LSD (0.05)		1.10	6.9	0.09

[a] 'Elka' ryegrass as a complete sod, with a 1 m grass-free square or with a 1 m grass-free strip.

A transpiration-yield model (CRPSM) was used in conjunction with a weather data collection network to predict orchard transpiration, dry matter production and fruit yield (4). CRPSM calculated potential evapotranspiration using a modified Penman equation. Actual transpiration was estimated using separate crop coefficients for trees and grass. Output of the model was compared to neutron probe data taken throughout the season. The CRPSM model indicated a greater reduction in transpiration in plots with a complete grass sod cover (3). Water stress, induced at least in part by the sod cover, is thought to be the primary factor in reduced yield efficiency of sour cherry trees in the complete grass sod plots and is likely a major factor in the reduced growth and yield of trees in all the sod plots.

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RESEARCH ON 2,4-D TRIETHYLAMINE SALT UTILITY, OFF-TARGET DRIFT AND VOLATILITY IN ALMONDS.

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INTRODUCTION

Envy is an aqueous formulation of triethylamine 2,4-D which conventional wisdom considers to be the lowest volatility of all 2,4-D formulations. It has been marketed for many years in northern California and the Northwest in orchards and leafed-out vineyards with ground application equipment. Bivert, a deposition and retention agent, is often marketed for drift control. The objective of this field research was to verify 2,4-D safety to almonds in Kern County in the hottest part of the summer but more importantly, its safety to adjacent 2,4-D sensitive crops. Other small plot studies were done to evaluate its safety and efficacy on problem weeds in grapes but are note reported here.

A review of past results with 2,4-D formulations and in-field use was made with contacts to Harry Agamalian, Monterey County Farm Advisor *Emeritus*, Salinas, CA; Dr. Art Lange, UC Extension Weed Scientist *Emeritus*, Parlier, CA; Dr. Robert Parker, Washington State Weed Specialist, Prosser, WA; and Dr. Alex Ogg, USDA Weed Scientist, Pullman, WA. 2,4-D has been used by orchardists and vineyardists in Washington and in the Sacramento, Monterey and upper San Joaquin Valleys of California. In grapes concern for adjacent crops occurs when temperatures reach the century mark. Ground application has been used sparingly with Ag Commissioner approval of this restricted material, in some San Joaquin Valley counties in the recent past and spot-treatment of field bindweed and other perennial broadleaf weeds by ground has been permitted for many years. Problems with 2,4-D has usually been with aerial applications in low volumes and in oil on cereals with concurrent windy conditions, which encourages air mass contamination and movement for several miles. Grapes and cotton are the usual crops showing damage. In California 407,000 A of almonds are grown, 854,000 A of grapes and 1.3 million A of cotton. Most of these are grown in the Mediterranean climate of the San Joaquin Valley.

Test protocols were designed to measure crop safety, weed control efficacy, off-target drift and volatility to adjacent bioassay indicator plants, cotton and beans during the hottest part of the summer: a worst case scenario. The studies were approved the Kern County Ag Commissioner (CAC) staff, George Montrose of Wilbur-Ellis and Bob Ver Burg of Lilly-Miller staff, and were coordinated with three veteran orchardists, Paramjt Dosanjh of Tejon Farming Company [Site A], Mettler; Skip Tyler of Belridge Farms [Site B], Lost Hills, and Jean Hudgins of Paramount Farming Company, [Site C] McFarland.

MATERIALS AND METHODS

Details of the applications of each site sprayed are in Table 2, and the treatments of each site as applied appear in Table 3. Each of four non-replicated plots were about one acre with almond middles sprayed from trunk-to-trunk using grower equipment. One mistake was made on site A where treatment 3 was applied at twice the scheduled rate. In all cases the spray mixtures were made up for the lower rate and then addition of concentrate was calculated to make up the higher rate. Also, in all cases, the Bivert was added to the 2,4-D concentrate and stirred vigorously before adding it to water in the grower spray unit, as directed on the label. No evidence of incompatibility existed with the addition of glyphosate. All calibrations were made to 20 gpa. Sprays were absent of fines except at site C, where the flat fans at 30 psi, which covered vegetation very well, were observed to produce fines moving laterally when standing behind the spray rig. One could detect the Bivert aroma in the air as well.

All applications were made in order from treatments 1 to 4, beginning in the morning at 9:00 or 10:00 AM and concluding at 2:00, 3:00 and 1:00 respectively at sites A, B and C. Wind and temperatures were: A-none until the last treatment when they were 0-3 NW; B-0-3 E in the morning; variable in the afternoon in direction and speed; C-4 N/NW with more sustained wind movement during all applications. Wind is also recorded below, supplied from private (at site A) or UC CIMIS sources. Note that air movement in the orchard is always less than from such weather station sources in the open.

Temperature and wind maximums and minimums, are recorded, from CIMIS reports at Lost Hills and McFarland. Wind at site A was provided from ranch records. Additionally, temperatures were obtained in the shade and in the sun by laying a thermometer on the soil surface. Temperatures were about 15-30 F greater in the sun than in the shade. They were: A: shade, wet soil 87 F; sunny, wet soil 102; sunny, dry soil 107;
B: shade, dry soil shade 90; sunny dry soil 122; C: shade dry soil shade 102; sunny dry soil 128.

Relative humidity at McFarland near Site C ranged from 25 to 76% during the test period. Solar radiation was from 642 to 686. No precipitation occurred during any tests. Other detailed data is available from the CIMIS Project records. Each orchard was irrigated differently as noted in Table 2. In each the tree rows (about 8 feet wide) were essentially free of vegetation. As a result of irrigation system differences at A, the 12 inch vegetation covered 90% of the middles and was moist until flailed 5 DAT (days after treatment); B, previously sprayed with glyphosate and recently mowed and irrigated; about 2 to 25% plant cover; C, very recently mowed but with a dry surface; about 50% plant cover.

Table 1. Application and daily wind and temperature maximum/ minimums recorded near each site during the bioassay test period.

Site A			Site B			Site C		
Date	Wind	Temp*	Date	Wind	Temp	Date	Wind	Temp
July 15	0	67 to 96	July 22	3.8 to 4.9	62 to 91	July 28	4.5 to 6.3	69 to 102
July 16	0	67 to 99	July 23	1.2 to 6.2	60 to 89	July 29	1.7 to 6.3	67 to 101
July 17	0	68 to 101	July 24	1.2 to 7.6	61 to 94	July 30	1.7 to 6.9	65 to 99
July 18	0	64 to 98	July 25	1.5 to 5.0	61 to 97	July 31	1.7 to 7.1	60 to 98
July 19	6	63 to 98	July 26	1.0 to 5.6	62 to 98	August 1	2.1 to 7.5	62 to 98
July 20	3	59 to 91	July 27	1.2 to 6.3	63 to 100	August 2	1.7 to 8.0	65 to 100
July 21	0	62 to 94	July 28	1.0 to 6.4	63 to 103	August 3	1.5 to 8.2	63 to 98
July 22	4	62 to 91	July 29	1.6 to 6.2	65 to 102	August 4	0.4 to 7.0	63 to 98
July 23	4	60 to 89	July 30	1.5 to 6.6	67 to 101	August 5	0.8 to 6.9	62 to 97
July 24	3	61 to 94	July 31	1.0 to 6.3	59 to 99	August 6	0.3 to 6.7	62 to 97
July 25	3	60 to 94				August 7	1.3 to 7.0	63 to 9

*Data from Lost Hills Station, 40 miles northwest of Tejon.

Bioassay indicator plants were planted at three different times (June 19, 22 and 26) in advance of the in-field bioassay. One gallon pots of soil were planted with five seeds of Acala 4- 42 cotton and Broadbent beans and placed in a lathe house under automatic daily sprinkler irrigation for 10 to 14 min as deemed optimum. Emergence of cotton was good and beans fair, and most pots were thinned to three cotton plants per pot. An early infestation of cotton aphid occurred and was sprayed with *Safer Soap* which failed; then sprayed with *Diazinon* on July 15 and later with *Danitrol*, both of which worked well. The aphid damage distorted the new cotton leaves and made the earliest 2,4-D symptom evaluation on August 2 more difficult. After that cotton leaves were normal and symptoms could be easily ascertained after new leaves were over one inch long. It took about 3 to 4 wk to see all symptoms, though when severe-as in the Paramount application evaluation-symptoms were obvious after 1 wk. Beans, which are about 10 times less sensitive to 2,4-D, showed no aphid symptoms or in nearly all cases no 2,4-D symptoms.

Three exposure periods to orchard applications were evaluated. 1) During application, with four pots placed one orchard row and three orchard rows downwind from the application [See tables 7, 8, 9]; 2) An initial volatility exposure period of two days in length placed soon after application, with four pots placed on each edge of the six-middles (trunk-to-trunk) spray plot of about 1 A [See tables 10, 11, 12]; and 3) A second volatility exposure period of 4 d, placed 5 or 6 DAT at the edge of each plot. In the volatility periods, pots were placed in food trays which held water to avoid drying out of plants, which was replaced once in the middle of the 4-d exposure period. After these periods, pots were returned to the lathe house for growing until symptoms had a chance to be manifested. Bioassay pots (36) were transported in the trunk of a car. Except for the first application bioassay at Site A, all included a control set of four pots, which were placed in the field about 0.25 to 0.5 mile upwind of the almond test sites. These were included to check for possible contamination which might occur during transport, handling of pots or in the lathe house. These controls occasionally showed symptoms on less than 30% of the plants and may have been due to handling. Results of treatments, however, were conclusive despite this happening.

Data from the observations on each bioassay indicator species from each site appear in Tables 7 to 15. Tables 7, 8, and 9 show off-target drift effects, Tables 10, 11, and 12 show initial volatility effects from two days of exposure after application, and Table 6 shows secondary volatility effects from four days of exposure when placed in the field 5-6 DAT. In addition to the bioassay evaluations ratings were taken soon after application for effects on resident weeds (Table 4, 5, 6) and after irrigation following harvest to measure any shift in weed regrowth (Table 16, 17, 18).

RESULTS

Table 2. Field and application data.

	Site A	Site B	Site C
Almond orchard age:	10 to 15 y	8 y	22 y
Location:	Tejon Farms	Belridge Farms	Paramount Farms
Soil type:	sandy loam 1% OM	heavy sandy loam 1% OM	sandy loam 1% OM
Plot size:	6 middles by 12 trees	6 middles by 12 trees	6 middles by 10 trees
Pre-application:	sprinkled 24 h before	sprinkled	sprinkled
Application date:	July 15, 1992	July 22, 1992	July 28, 1992
Application method:	Grower sprayer	Randall sprayer	Trailer sprayer
Nozzles:	5 110 10 LP, OC8 at ends	5 TK-4	14 110154, 11003 at end
Trt conditions:	95F, 0 to 3 mph wind, moist	88F, 0 to 3 mph wind, dry/moist	104F, 0 to 5 mph dry/moist
Post-application:	moist July 15, July 16	final irrigation before harvest	no further irrigation
Irrigation method:	solid set sprinklers	drag line with 3 heads	

Table 3. Treatment data.

Treatment	Site A	Site B	Site C
1 2,4-D : Bivert	2 pts: 0.5 pts	2 pts: 0.5 pts	2 pts: 0.5 pts
2 2,4-D : Bivert	3 pts: 0.75 pt	3 pts: 0.75 pts	3 pts: 0.75 pts
3 2,4-D : Bivert + glyphosate	4 pts: 1.0 pt + 4.0 pts	3 pts: 0.75 pt + 2.0 pts	2 pts: 0.5 pt + 2.0 pts
4 2,4-D : Bivert + glyphosate	3 pts: 0.75 pts + 3.0 pts	3 pts: 0.75 pts + 3.0 pts	3 pts: 0.75 + 3.0 pts

Table 4. Site A: Ratings on resident weeds.

	Crabgrass		Prostrate spurge		Dandelion		Shepherdspurse	
Treatment	N	S	N	S	N	S	N	S
1	0	0	7	5	7	8	7	6
Control	0	0	0	0	0	0	0	0
2	0	0	6	7	7	8	8	8
Control	0	0	0	0	0	0	0	0
3	6	6	8	7	8	8	8	8
Control	0	0	0	0	0	0	0	0
4	6	6	7	6	8	7	8	6
Control	0	0	0	0	0	0	0	0

Rated in treated plots (0 to 10: 0=no injury, 10=kill) compared to adjacent control in north and south middles. (No drift apparent on these weeds). Rated 3 days after treatment. Symptoms on occasional plants were rated: redstem filaree, 7-8; Australian brass buttons, 7; Common sowthistle, 7; clover, 7.

Table 6. Site C: Ratings on resident weeds.

Treatment	Dandelion	Prostrate spurge	Clover	Yellow nutsedge	Cupgrass
1	4	3	4	0	0
Control	0	0	0	0	0
2	5	5	5	0	0
Control	0	0	0	0	0
3	3	4	3	0	3
Control	0	0	0	0	0
4	4	5	5	2	4
Control	0	0	0	0	0

Rated July 30, 1992, 2 days after treatment, within plots and adjacent control middles to east and west (0 to 10; 0=no injury, 10=kill). Dandelion was mowed.

Table 5. Site B: Ratings on resident weeds.

Treatment	Prostrate spurge	Cupgrass	Clover
			- % -
1	4	0	2 to 10
Control	0	0	2 to 25
2	5	0	0 to 5
Control	0	0	2 to 25
3	7	6	0 to 5
Control	0	0	2 to 10
4	8	9	0 to 5
Control	0	0	2 to 10

Treated July 22, 1992; rated on July 31, 1992 within plots and in adjacent control middles to east and west (0-10 rating: 0=no injury, 10=kill). Rated 9 days after treatment. Prostrate spurge was variable, 6 to 18 inches in diameter with half of the plants dead from previous glyphosate application and the others recovered. Cupgrass was 6 inches and widely scattered.

Table 7. Site A: Application off-target drift on bioassay indicators (July 15, 1992.)

		Cotton with symptoms		Beans with symptoms	
Treatment	Distance downwind	Aug. 19	Aug. 7	Aug. 19	Aug. 7
1	24 ft	0/13	0/10	0/5	0/2
	72 ft	0/13	0/12	0/11	0/10
2	24 ft	2/13	1/12	0/3	0/5
	72 ft	0/10	0/13	0/5	0/8
3	24 ft	1/14	1/11	0/5	0/6
	72 ft	1/9	0/12	0/8	0/9
4	24 ft	4/12	6/13	0/6	0/8
	72 ft	4/12	2/12	0/7	0/10

Applied July 15, 1992.

Table 8. Site B: Application off-target drift on bioassay indicators (July 22, 1992.)

Treatment	Distance downwind	Cotton with symptoms		Beans with symptoms	
		Aug. 19	Aug. 11	Aug. 19	Aug. 11
1	20 ft	9/12	3/12	0/3	0/3
	60 ft	0/14	0/11	0/2	0/2
2	20 ft	8/11	3/13	0/5	0/5
	60 ft	1/10	0/11	0/1	0/3
3	20 ft	2/13	5/15	0/3	0/4
	60 ft	1/13	0/13	0/5	0/3
4	20 ft	12/14	11/15	1/2	1/4
	60 ft	6/13	4/15	0/2	0/4
Control		3/13	3/14	0/4	0/3

Applied July 22, 1992.

Table 10. Site A: Initial volatility evaluation on bioassay indicators (July 16 to July 18).

Treatment		Cotton with symptoms		Beans with symptoms	
		Aug. 19	Aug. 7	Aug. 19	Aug. 7
1	North edge	0/13	0/12	0/6	0/5
	South edge	1/13	1/14	0/4	0/4
2	North edge	0/13	0/13	0/2	0/3
	South edge	1/11	0/12	0/1	0/1
3	North edge	0/10	0/13	0/6	0/6
	South edge	3/9	3/7	0/3	0/4
4	North edge	0/12	0/12	0/3	0/4
	South edge	0/15	0/14	0/3	0/3
Control		1/5	1/5	0/2	0/2

Applied July 15, 1992.

Table 12. Site C: Initial volatility evaluation on bioassay indicators (July 28 to July 30).

Treatment		Cotton with symptoms	Beans with symptoms
		Aug. 19	Aug. 19
1	E	4/8	0/1
	W	10/11	0/7
2	E	13/13	0/6
	W	10/11	0/7
3	E	10/11	0/6
	W	12/12	0/6
4	E	11/11	3/8
	W	8/12	2/7
Control		-	-

Applied July 28, 1992 AM; pots placed at 4 PM.

Table 9. Site C: Application off-target drift evaluation on resident weeds (July 28, 1992).

Treatment	Distance downwind	Cotton with symptoms	Beans with symptoms
		Aug. 19	Aug. 19
1	27 ft	11/11	3/5
	72 ft	11/13	0/3
2	27 ft	12/13	0/3
	72 ft	8/10	1/4
3	27 ft	11/11	2/3
	72 ft	12/13	0/3
4	27 ft	12/12	2/2
	72 ft	13/13	6/6
Control		4/11	0/6

Applied July 28, 1992, AM.

Table 11. Site B: Initial volatility evaluation on bioassay indicators (July 22 to July 24).

Treatment		Cotton with symptoms		Beans with symptoms	
		Aug. 19	Aug. 11	Aug. 19	Aug. 11
1	E	6/14	4/13	0/3	0/3
	W	7/9	6/13	0/1	0/2
2	E	4/11	3/11	0/4	0/5
	W	11/11	7/14	0/2	0/2
3	E	5/14	5/14	0/4	0/3
	W	11/13	9/12	0/2	0/3
4	E	9/16	8/17	0/3	0/3
	W	12/12	12/13	0/2	0/3
Control		0/7		0/1	

Applied July 22, 1992 AM, pots placed in field at 4 PM.

Table 13. Site A: Secondary volatility evaluation on bioassay indicators (July 21 to July 25).

Treatment		Cotton with symptoms		Beans with symptoms	
		Aug. 19	Aug. 11	Aug. 19	Aug. 11
1	North edge	0/14	0/14	0	0/3
	South edge	0/16	0/14	0	0/5
2	North edge	0/16	0/14	0	0/2
	South edge	0/14	0/16	0	0/2
3	North edge	0/14	0/13	0	0/2
	South edge	0/11	0/14	0	0/2
4	North edge	0/12	0/12	0	0/2
	South edge	0/11	0/12	0	0/3
Control		0/10	0/13	0	0/5

Applied July 15, 1992.

Table 14. Site B. Secondary volatility evaluation on bioassay indicators (July 27 to July 31).

Treatment		Cotton with symptoms	Beans with symptoms
		Aug. 26	Aug. 26
1	E	0/12	0/4
	W	0/12	0/5
2	E	1/13	0/2
	W	4/13	0/2
3	E	1/15	0/2
	W	3/13	0/4
4	E	2/13	0/3
	W	4/13	0/3
Control		0/12	0/4

Applied July 22, 1992.

Table 15. Site C: Secondary volatility evaluation on bioassay indicators (August 3 to August 7).

Treatment		Cotton with symptoms		Beans with symptoms	
		Aug. 28	Aug. 26	Aug. 28	Aug. 26
1	E	0/9	0/7	0	0/5
	W	2/6	2/6	0	0/4
2	E	3/7	0/7	0	0/5
	W	2/10	0/10	0	0/2
3	E	7/15	5/15	0	0/3
	W	2/9	2/9	0	0/5
4	E	2/7	3/10	0	0/3
	W	5/8	3/8	0	0/5
Control		0/6	0/9	0	0/4

Applied July 28, 1992.

Table 16. Site A: Effects of 2,4-D and glyphosate on almond middles vegetation after irrigation following harvest.

Treatment	Cover	Shpu	Rsfi	Anbg	Ckwe	Begr	Yens	Grgr	Prsp
	%								
1	100	34	10	35	0	10	4	5	0
Control	100	40	5	34	0	5	4	5	0
2	95	20	25	30	10	7	2	2	0
Control	95	20	25	25	10	10	2	1	5
3	95	10	30	25	25	0	1	1[a]	2
Control	95	10	25	25	30	2	1	1	3
4	95	30	30	20	10	0	2	1[a]	1
Control	95	30	5	30	19	5	1	1	3

[a] New seedling crabgrass.

Table 17. Site B: Effects of 2,4-D and glyphosate on almond middles vegetation after irrigation following harvest. Lost Hills, CA.

Treatment	Cover	Shpu	Rsfi	Anbg	Soth	Begr	Prsp
	%						
1	75	60	2	3	2	0	7
Control	80	67	2	5	1	+	5
2	85	76	2	3	1	+	+
Control	80	66	2	7	1	+	4
3	85	69	2	3	1	+	10
Control	85	68	1	5	1	-	10
4	85	73	0	5	1	1	5
Control	85	53	1	5	1	-	25

Table 18. Site C: Effects of 2,4-D and glyphosate on almond middles vegetation after irrigation following harvest. McFarland, CA.

Treatment	Cover	Rsfi	Anbg	Ckwe	Dadl	Bucl	Cugr	Yens	Prsp
	%								
1	40	16	3	10	1	2	3	2	3
Control	40	17	3	4	2	3	7	1	2
2	50	18	3	18	1	3	3	3	1
Control	50	18	5	14	2	4	3	2	2
3	50	20	5	5	s	1	15	2	2
Control	50	17	5	5	2	3	12	2	4
4	40	22	1	0	s	1	14	2	0
Control	45	18	3	1	3	2	12	2	4

RESULTS AND DISCUSSION

The data clearly defines that at these high temperatures and low winds there is yet a risk of off-target drift. However, they show that it is probably limited to the adjacent 25 to 75 feet unless nozzles allow fines and winds are above 5 mph. That could be controllable. Using flat-fan nozzles with 30 psi pressure at Site C (to apply the 20 gpa standardized in all sites) certainly increased drift, though slightly more wind was also a contributing factor. The 11010 LP (low pressure) nozzles with outside (Off- Center) OC-8s at Tejon and the TK-4 flood nozzles at Belridge produced visibly larger droplets.

The data also clearly defines that volatility is occurring at these high temperatures. The indicator plants were placed on the edge of the sprayed plots to gauge if directional volatility occurred. Had none shown, one could second guess that it might have occurred but wouldn't show under this methodology. But since it did and with Belridge data suggesting possible impact of drift on volatility, one might speculate that slightly more would occur in field usage than indicated here in these one-acre tests. The conclusions comes only from data with the highly sensitive cotton plants, showing that these emissions from the soils or vegetation were small. Further, emissions from the secondary delayed exposure period of 4 d, showed that marked reductions in cotton plants having symptoms occurred in each trial, compared to primary initial volatility exposure for 2 d: A 0% from 5%; B 15% from 72%; C 32% from 88%.

Volatility was greater in the B and C sites, where less vegetation was present, thus more ground surface was exposed. Previous research reports suggest that the amine formulation of 2,4-D can be converted to a calcium or sodium ion which is considered more volatile. In both these locations, the soil surface remained dry throughout the evaluation period. Temperatures do not seem to be a factor in this, based on when the periods of exposure were. The vegetation at Site A was moist all day long until it was mowed 5 DAT, which might have reduced volatility losses for some reason.

No almond tree symptoms or tree injury was noted during observations when managing bioassay plants in the orchards. Weed control data from the plot areas after irrigating back following harvest of the nuts are in Table 7 at each site. Data showed that glyphosate controlled emerged summer annual grasses, bermudagrass and reduced or controlled prostrate spurge.

WEEDS OF AGRONOMIC CROPS

CEREAL RESIDUE AND MULCH EFFECTS ON WEEDS AND VEGETABLE CROPS. R. Edward Peachey, Ray D. William, Edgar Chongwe, and Ivoline de Sousa, Graduate Research Assistant and Extension Horticulturist, Department of Horticulture, Oregon State University, Corvallis, OR 97331, Extension Coordinator of Horticulture, Ministry of Agriculture, PO Box 30134, Lilongwe, Malawi, and Research Assistant, Rua Estudantes 90/301, 36570 Vicosa-Minas Gerais, Brazil.

INTRODUCTION

Weed suppression with cereal residues has received considerable attention in light of the increased use of conservation tillage systems in the midwest and the allelopathic nature of certain cereal cultivars (1, 3, 9, 10). Cereal residues suppress weeds by modifying the light, temperature, chemical, and moisture environment of germinating seeds (2, 13). Residues from cereal cover crops reduced weed density by 80% early in the season compared to plots without cereal residue; residues had little effect on late season weed suppression, however (17). A dead mulch of rye improved the efficiency of atrazine and metolachlor in sweet corn and improved weed control more than no-till without residues for a full season (6).

Cereal mulches or residues in no-till systems introduce other challenges include interference with cultivation, lower soil temperature in the spring, and aggravation of pest problems such as slugs (15). The latter two are of particular prominence in the maritime climate in the Willamette Valley of Oregon (8). Another difficulty is the lack of equipment to direct-seed vegetable crops through cereal mulches. Cucurbit crops are less affected by no-till and mulched conditions than beans and peas (15).

This report summarizes research of the past 3 yr on the effects of cereal residues or mulches on weed suppression and vegetable crops. Two general systems were examined. Cereals were planted in the fall as a cover crop, or in the spring, 2 to 8 wk before vegetable seeding. Objectives included: evaluate the extent and nature of weed suppression with residues of fall-sown cereals in a no-till system; investigate factors that influence crop responses to cereal mulches, particularly the role of soil temperature; evaluate weed suppression and crop effects of immature spring-sown cereals desiccated with herbicide; and determine the effect of cereal mulches on symphylans, a serious soil pest in the Pacific Northwest.

MATERIALS AND METHODS

Fall-planted cereals: weed suppression. Four field and one controlled environment experiment were designed to define the weed suppression potential of cereal cover crop residues and effects on crops and crop yields. 'Micah' barley was planted on a 'Chehalis' silt clay loam soil in October, 1989 and killed with glyphosate (1.1 kg ha^{-1}) on April 10, 1990. Tomatoes were transplanted on May 26 while lettuce and cucumber were direct seeded on June 20 into three residue treatments: plots with soil fully covered by residue, and plots with residue concentrated in 30 cm or 60 cm strips over the row. Weed density was determined 6 wk after crop establishment.

In the second field experiment, spring barley (vars. Galt, Micah, and Steptoe), winter rye (var. Wheeler) and winter wheat (var. Stevens) were sown in October, 1991. Two treatments remained unseeded and fallow during the winter for the conventional-tillage and winter fallow no-till treatments. Glyphosate (2.2 kg ha^{-1}) was applied to barley on March 21, to rye on April 2, and to wheat and one winter fallow treatment on April 30, 1992. The conventional tillage plots were mowed on April 1 and rototilled before cucumber planting.

Cucumbers (var. Pioneer) were seeded with a cross-slot seeder[1] on May 16, 1992 in rows spaced 1.8 m and perpendicular to the length of the cereal residue plots. A strip plot design was used with 1.8 m by 3 m subplots. Main effects were 'residue' and herbicide 'level'. 'Level 1' was treated with glyphosate (1.12 kg ha^{-1}) just before cucumber emergence, sethoxydim (0.31 kg ha^{-1}) at 6 wk after planting (WAP), and a light hoeing to destroy the largest in row weeds at 6 WAP. 'Level 2' had no additional weed control other than the herbicide that killed the cereal. The conventionally managed plot in 'level 1' was cultivated 18 d after planting (DAP) and 6 (WAP).

Weed suppression was visually evaluated 35 DAP. Effects of the cereal residue only (excluding in-row disturbance effects) on weed density and biomass were measured at 6 WAP. Weed density and biomass were assessed again at cucumber harvest, approximately 12 WAP, from both between rows and within rows. Cucumber emergence was counted 18 DAP, then seedlings thinned to equal densities within each plot. Percent reduction in growth of the cucumber plants in relation to the conventional tillage treatment was visually assessed at 35 DAP. Cucumbers were harvested, graded and weighed from 1.5 m of row six times at intervals of 3 to 4 d.

Fall-planted cereals: crop growth. A growth chamber bioassay with cold water extracts of several cereal varieties was initiated September, 1990. Barley (vars. Micah and Bowers), oats (var. Cayuse), wheat (var. Yecole Rojo) and common rye were planted in pots in a greenhouse. After 6 wk the cereals were killed with glyphosate (1% v/v), and 60 g samples of each cereal placed in distilled water overnight. The extracts were filtered and 4 ml applied to 50 seeds of lettuce, tomato, cabbage and cucumber. Seed germination and radicle length were recorded 4 and 8 d after the extract was applied.

The effect of cereal cover crop residues on cucumber growth was quantified in a third field experiment. A mulch was established from 'Galt' barley as described above in the 1992 fall-planted experiment. Treatments were assigned to plots in a completely randomized design, except for the no-till treatment without cereal, which was planted to an area in the center of the main plot that was not seeded to barley. Drymatter weight of the cereal residue on June 6 was approximately 3800 kg ha^{-1}. Cucumber seeds (var. Pioneer) were hand-planted on May 19, 1992. The cereal mulch was maintained undisturbed except in plots that did not require a mulch.

Populous excelsior wood shavings (PE) were used as a control for the mulch effect of barley residue. However, equal dry weights of barley residue and PE did not result in the same soil temperature. An additional 37% of PE was needed to equilibrate the soil temperatures to the barley residue plots. Activated charcoal and soil (2% w/w) were mixed and positioned around the cucumber seeds for the charcoal treatment, and cucumber seeds were treated with metalaxyl (0.63 g kg^{-1} of seed) for the fungicide treatments. Plots were maintained weed free. Cucumber seedling emergence and plant drymatter were measured at 5 WAP.

Spring planted cereals. Weed suppression and crop growth were quantified in a spring-planted cereal system. Treatments represented modifications of a stale seed-bed system (Table 5). Soil was cultivated on May 7, 1992, except for final tillage. Cereal seeds of barley or rye were spread with a Gandy fertilizer spreader at 484 seeds m^{-2} on designated cereal planting dates. A tractor mounted rototiller followed by a roller incorporated the cereal seed and fertilizer into the top 5 cm of soil. Glyphosate (1.1 kg ha^{-1}) or sethoxydim (0.31 kg ha^{-1}) was applied to kill the cereal crops according to treatment schedule (Table 5).

Cucumbers were seeded on June 5 with the cross-slot planter at a 1.8 m row spacing. Cucumber seedlings were thinned to an in row spacing of 13 cm at 17 DAP and row lengths within each plot reduced to 1.5 m at 38 DAP. Weed biomass and density were measured 5 WAP, after which all plots were hand-weeded, cultivated, and kept weed-free until the last harvest. Cucumbers were harvested 9 times from 1.5 m of row and the fruit weighed and graded.

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[1] Planter provided by Keith Saxton of USDA-ARS, Pullman, WA through collaborative research effort.

A second experiment with spring-planted cereals assessed the effect of cereal residues on symphylans, snap bean yield, and weed suppression. Spring barley (vars. Micah and Hesk) were planted on May 3, 1991 and killed by flailing or herbicide when 60 cm tall. Dyfonate was soil incorporated in plots without cereals as a control. Snap beans (var. Oregon 91) were planted on June 1991. Symphylans were counted from 8000 ml samples at bean flowering. Bean pods and weeds were harvested and weighed.

RESULTS AND DISCUSSION

Cover crop residues: weed suppression. In 1990, cereal residues of 9000 kg ha^{-1} from a fall seeded 'Micah' barley cover crop reduced weed density between rows by approximately 80% compared to unmulched, un-tilled plots. Weed pressure was very low however, as demonstrated by the control (Table 1). In 1992, cereal cover-crop residues reduced between-row weed density an average of 65% 6 WAP compared to the untilled treatment with no cereal residue and the conventionally tilled (unweeded) treatment (Table 2). However, cereal residues tended to increase weed biomass unless the residue density was greater than 4800 kg ha^{-1}. At 12 WAP, residue treatments reduced weed density by 67% but weed biomass by only 20% compared to the unweeded, conventional tillage treatment.

Table 1. Effect of cereal residues on weed density and crop yield, 1990.

Treatment	Weed density	Vegetable yield		
		Tomato	Lettuce	Cucumber
	- No. plot^{-1} -	t ha^{-1}		
No cover	5.3 a[a]	77.5	16.3	46.3
30 cm strip	0.8 b	86.3	13.0	36.9
60 cm strip	0.6 b	70.2	12.5	27.6
Full cover	1.1 b	73.9	12.6	40.9
		NS	NS	NS

[a] Figures in the same column followed by the same letter are not significantly different (P=0.05).

Table 2. Effect of cereal residues on weeds in conservation tillage system at 6 wk after cucumber seeding, 1992.

Cereal and planting date	Weed density[a]		Weed biomass		Cereal residue[b]
	Level 1[c]	Level 2	Level 1	Level 2	
	No. m^{-2}		gm^{-2}		- kg ha^{-1} -
Galt barley (Oct 1)	91*	111*	13.7	164*	3700
Galt barley (Oct 18)	110*	81*	13.4	171*	3200
Galt and clover (Oct 18)	120*	153*	13.4	242*	4000
Micah barley (Oct 1)	60	193*	16.3*	218*	3900
Steptoe barley (Oct 1)	114*	73*	23.6*	119*	4800
Wheeler rye (Oct 18)	94*	71	11.2	28*	6900
Stevens wheat (Oct 18)	61*	100*	5.5	30*	8800
No-till, no residue	456*	323*	22.0*	103*	800
Conventional tillage	33	335*	7.8	65*	0

[a] Values in these two columns followed by (*) differ from the conventional control (underlined) at P<0.05 according to Is means comparison procedures of SAS.

[b] Residue biomass at cucumber seeding.

[c] Level 1= glyphosate 5 DAP; sethoxydim 6 WAP.
Level 2= glyphosate only used to kill cereal.

The results of 1990 are comparable to reports by Shilling (11) and Teasdale (13). However, weed suppression in 1992 was somewhat less than expected. Because of a warm winter, barley matured and was killed in mid-march, and nearly 2 months elapsed before cucumbers were seeded, allowing more weeds to emerge.

Applying glyphosate over cereal residues just before cucumber emergence (level 1) reduced weed biomass an average of 92% but weed density by only 16% 6 WAP (Table 2). Several of the treatments in 'level 1' compared favorably with the cultivated, conventional tillage treatment at 6 WAP on a weed biomass basis. These included 'Steptoe' barley, 'Wheeler' rye and 'Stevens' wheat. At 12 WAP, all residue treatments except 'Steptoe' barley with glyphosate had a greater weed density than the cultivated, conventional tillage treatment. But even this treatment had nearly five times the weed biomass of the conventional tillage control (Table 3).

Soil disturbance increases the number of weed seeds that emerge (5, 14). Although the cross slot planter minimized mulch and soil disturbance, average in-row weed density and biomass in mulched plots were 77 and 112% greater, respectively than weed density and biomass between rows (Table 3).

Table 3. Weed density and biomass at 12 wk after cucumber seeding in fall-planted cereal, conservation tillage system, 1992.

	Weed density				Weed biomass			
	Between rows[a]		Within rows		Between rows		Within rows	
Cereal and planting date	Lvl 1[b]	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2	Lvl 1	Lvl 2
	No. m^{-2}				g m^{-2}			
Galt barley (Oct 1)	42*	41*	63	153*	600*	351*	673	1605
Galt barley (Oct 18)	36*	36*	63	101	522*	700*	673	1375
Galt and clover (Oct 1)	37*	47*	37	134	440*	700*	740	1230
Micah barley (Oct 1)	23*	33*	23	91	291*	510*	240	1702
Steptoe barley (Oct 1)	13	17	53	48	221*	416*	801	904
Wheeler rye (Oct 18)	18*	32*	39	101	535*	758*	1212	2548*
Stevens wheat (Oct 18)	26*	22*	63	57	328*	323*	1908*	2827*
No-till, no-residue	22*	35*	53	43	192*	526*	259	971
Conventional till	12	108*	39	87	47	664*	64	721

[a] Values in these two columns followed by (*) differ from the conventional control (underlined) at $P<0.05$ according to ls means comparison procedures of SAS.

[b] Level 1: glyphosate 5 DAP; sethoxydim 6 WAP.
Level 2: glyphosate only used to kill cereal.

Cover crop residues: crop effect. In 1990, vegetable crop yields were reduced slightly by cereal residues, although differences were statistically insignificant (Table 1). Possible causes for the trend include reduced soil temperature and allelotoxins. Evidence for allelopathy was presented by a growth chamber bioassay that found cold water extracts of cereals suppressed seed germination of tomato and lettuce and radicle elongation of tomato, lettuce and cucumber (Table 4). It is unlikely that soil temperature was a factor as these crops were seeded late in the season.

In 1992, cucumber seedling emergence was greatly restricted by mulch levels that exceeded 6500 kg ha^{-1} (Table 6). Crop growth at 5 WAP was less than the conventional tillage treatment for all treatments including no-till without residue. This indicates that cucumber growth reduction was either due to the interaction of multiple factors or the no-till soil environment. The most severe crop reduction was noted in 'Wheeler' rye, but

Table 4. Effect of cold water cereal extracts on seed germination and radicle elongation.

Cereal variety	Seed germination				Radicle length (after 8 days)			
	Tomato	Lettuce	Cabbage	Cucumber	Tomato	Lettuce	Cabbage	Cucumber
	%				mm			
Distilled water	75^{a}	87a	93a	85a	10.6a	13.1a	17.0a	9.1a^{1}
Y.Rojo wheat	3b	33b	32b	40a	1.3b	0.9b	0.3b	2.4b
Micah barley	2b	19b	11b	28a	0.5b	0.8b	0.03b	1.7b
Bawers barley	2b	48a	37a	48a	1.2b	0.8b	0.8b	2.2b
Cayuse oats	5b	30b	23b	73a	1.3b	0.8b	0	2.1b
Common rye	0	21b	0	39a	0	0.4b	0	2.6b

[a] Figures in a column followed by the same letter are not statistically different (P=0.05) by Duncan's Multiple Range Test.

this was primarily a factor of the difficult seeding conditions encountered with rye residue. Rye formed a very compact mat even though its density was less than other cereals. The mat of rye residue restricted moisture loss, causing the coulter of the cross-slot planter to drag rather than cleanly cut through the mulch. Cucumber yield was significantly less for all treatments with residue compared to the conventional tillage treatment, but was largely a factor of weed competition.

Table 5. Emergence, growth and yield of cucumbers planted in cereal cover crop residues in a conservation tillage system.

Cereal and planting date	Crop emergence (18 DAP)^{a}	Reduction in plant growth (5 WAP)^{b}	Cucumber harvest				
			Cucumber fruit		Cucumber weight		Mulch biomass
			Level 1^{c}	Level 2	Level 1	Level 2	
	- No.m^{-1} -	- % -	No. m$^{-1\ d}$		t ha$^{-1\ d}$		t ha$^{-1\ e}$
Galt barley (Oct 1)	93*^{f}	13^{f}	34*	12	14.5*	4.9*	3.7
Galt barley (Oct 18)	66	10	35*	17	15.9*	5.5*	3.2
Galt and clover (Oct 1)	79	10	36*	14	15.6*	4.8*	4.0
Micah barley (Oct 1)	69	10	56*	18	22.5*	7.3*	3.9
Steptoe barley (Oct 1)	69	10	40*	19	17.6*	7.9*	4.8
Wheeler rye (Oct 18)	36*	58*	40^{g}	11^{g}	13.8^{g}	3.7^{g}	6.9
Stevens Wheat (Oct 18)	38*	45*	48^{g}	27^{g}	19.3^{g}	9.3^{g}	8.8
No-till, no residue	88	10	63*	39*	25.8*	18.4*	0.8
Conventional tillage	72	0	84	18	34.3	7.6*	0

[a] Average emergence of Level 1 and level 2.

[b] Level 1 only.

[c] Level 1= glyphosate 5 DAP; sethoxydim 6 WAP.
Level 2= glyphosate only used to kill cereal. Figures in this column followed by (*) differ from the conventionally managed plot (P<0.05)

[d] Values in these two columns followed by (*) differ from the conventional control (underlined) at P<0.05 according to ls means comparison procedures of SAS.

[e] Residue biomass at cucumber seeding.

[f] Figure in this column followed by (*) differ from the conventional control using Fishers Protected LSD (P=0.05).

[g] Insufficient data to make comparison.

Table 6. Effect of temperature, activated charcoal, Populous excelsior (PE), and metalaxyl on cucumber emergence and growth in cereal residues, 1992.

		Plant drymatter yield		
Residue and rate	Emergence	Total weight	Avg plant weight	Avg soil temp at 2.5 cm
	No. plot^{-1}	- g plot^{-1} -	- g -	- C -
1. Barley (1X)	7.25	19.95	2.73	21.3
2. PE (adjusted)	8.25	32.92	4.12	21.5
3. Bar + PE	6.50	24.17	3.89	21.3
4. No residue no-till	11.50	30.76	2.70	24.8
5. Barley(1X) + charcoal	8.50	19.05	2.15	21.2
6. Barley (1X) + fungicide	7.25	17.68	2.44	21.7
7. No residue, tilled	11.00	38.99	3.54	25.0
8. No residue, tillage, or roots	10.50	17.91	1.69	25.9
LSD (P=0.05)	3.41	12.53	0.77	1.2

The third experiment tested the hypothesis that soil temperature is the predominant limiting factor of early season cucumber growth in cereal residues of conservation tillage systems. The temperature difference between barley residue and PE plots was nearly zero according to data from the temperature chronometer and soil temperature point monitoring (Table 7). Still, a 65 and 50% increase in total plant weight (TPW) and average plant weight (APW), respectively were found in plots where PE had been substituted for barley residue. Two explanations are plausible. First, an undefined property of the residue such as allelotoxins or disease organisms were responsible for the reduced growth. The alternative hypothesis is that PE improved seed-microenvironment parameters such as light penetration, soil boundary layer conditions, and soil moisture evaporation, thus improving growth in plots with PE. The PE mulch was slightly thicker than the cereal residue and a lighter color early in the season. The second alternative also is supported by the results of the treatment with both barley residue and PE, which increased TPW and APW (difference was statistically significant only with APW). These results challenge the assertion that PE is an inert mulch under field conditions (1).

Tillage increased APW compared to the no-till treatments but not the PE treatment. Cucumber emergence was greatest in the conventional tillage and no-till treatments. However, no-till decreased TPW and APT by 21 and 23% respectively compared to the conventional tillage treatment. The natural level of barley residue decreased emergence by 37% compared to the bare no-till treatment, but APW was the same. Activated charcoal and the fungicide metalaxyl had no effect on emergence, TPW, or APW. Activated charcoal has been used in studies of allelopathic interactions to determine the nature of toxins extracted from plants (12). Metalaxyl is a fungicide commonly used to improve stand establishment of several vegetable crops in the Pacific Northwest, particularly in cold and wet soils.

Spring cereals. Barley planted 4 wk before cucumber seeding and killed with glyphosate 4 DAP reduced weed biomass by 91% compared to the same stale-seedbed treatment without barley. Four wk old barley residue also outperformed the weed suppression of all the other treatments with cereal (Table 8). On average, sowing barley decreased weed biomass by 85%. Weed density however, was unaffected by the addition of barley except in treatment 7. Weed biomass reduction was the same for barley and rye. Barley is very competitive (7) and apparently reduced weed growth but not emergence, thereby increasing the efficacy of glyphosate.

Table 7. Effect of spring-planted cereal residues on weeds and cucumber yield.

Treatment description				Weed suppression (5 WAP)		Cucumber harvest	
Cereal	Cereal planting date[a]	Herbicide application date[b]	Herb.[c]	Weed drymatter	Weed density	Fruit	Weight
				- $g\ m^{-2}$ -	- No. m^{-2} -	No. 1.5 m^{-1}	kg ha^{-1}
1. Barley (var.Galt)	28	4	G	0.05d[d]	66.9	254	21800
2. Barley (var.Galt)	28	-2	G	0.36cd	75.0	233	19000
3. Barley (var.Galt)	14	12	S	0.15cd	78.3	127	10200
4. Barley (var.Galt)	0	21	S	0.21d	62.0	105	8500
5. Rye (var.wheeler)	14	12	S	0.13cd	96.2	83	6200
6. None	28	4	G	0.58bc	66.9	234	21100
7. None	28	-2	G	1.09abc	128.8	202	18100
8. None	14	12	S	1.79abc	73.4	100	8500
9. None	0	21	S	1.91abc	65.2	199	17400
10. None weedfree	0	0	-	0.01e	4.1	338	31000
11. None unweeded	0	0	-	0.76abc	63.6	87	13000
LSD (P=.05)				LT[e]	45.2	57	4800

[a] Days cereal was seeded before cucumbers were planted (or last tillage).

[b] Days after cucumber seeding that herbicide was applied; a negative number indicates days before cucumber seeding.

[c] Herbicide applied: G=glyphosate, S=sethoxydim.

[d] Values in the same column followed by the same letter are not significantly different (FPLSD, P=0.05).

[e] LT = natural log transformed.

Table 8. Effect of spring planted cereals on symphylans and weeds.

Treatment	Symphylan density	Weed fresh weight	Bean pod yield
	No. 8 l^{-1}	- $g\ m^{-2}$ -	- g -
Control	15 ab[a]	6.9	15
Control-dyfonate	12 abc	7.0	12
Hesk Flailed	17 a	5.6	10
Glyphosate	12 abc	5.6	10
Micah Flailed	4 bc	5.2	9
Glyphosate	3 c	4.7	7

[a] Figures in a column followed by the same letter do not differ (Tukey, P=0.05).

Cucumber yield was very large for the conventional weed free plot at 69000 kg ha^{-1}, probably due to minimal soil disturbance during weed removal and weed-free growing conditions. The addition of barley to the treatments made little difference in cucumber yield except in treatment 4. Cucumber yield declined proportional to the length of time that the cereal was present with the cucumbers, indicating that the cereals were effectively competing with the cucumber crop. Rye was particularly competitive and produced the lowest yield. The best treatment considering both weed control and cucumber yield was barley planted 4 wk in advance of cucumber seeding and killed at 4 days after seeding cucumbers. Though weed control of other treatments with cereals (2, 3, and 4) compared to this treatment (1), cucumber yields were greatly reduced.

Symphylans. Symphylans are a centipede-like, soil arthropod that cause considerable damage to vegetable crops in the Pacific Northwest by feeding on roots. In a spring-planted cereal system, symphylan density in the soil was reduced 75% in 'Micah' barley plots compared to the controls of Dyfonate or untreated soil (Table 7). 'Hesk' barley had no effect on symphylans. In addition, weed biomass in plots with barley residue was reduced by 25% at bean harvest compared to the controls with no cereal. Again, 'Micah' barley suppressed weeds more than 'Hesk' barley and bean yield was slightly reduced in the residue plots.

One hypothesis for the reduction of symphylans in the 'Micah' barley treatment is that allelochemicals present in the barley residue may be affecting the symphylans. Allelotoxins have been isolated from cereal residues with wide ranging effects on a number of organisms (16). Two cyclic hydroxamic acids isolated from rye, 2,3-benzoxazolinone (BOA) and 2,2'-oxo-1,1'-azobenzene (AZOB), have been found to reduce seed germination, and radical and shoot elongation for a number of weed species (2, 3). BOA is formed from glucosides within a cell during cell disruption (16), and AZOB is a microbially transformed compound formed from BOA (4). While these compounds have not been isolated from barley (18), barley contains compounds identified as germination and growth inhibitors (7). In a laboratory study, purified extracts of BOA and AZOB reduced symphylan density in proportion to the concentration of the extract. BOA was more effective than AZOB in killing symphylans. The LD_{50} for BOA (100 ppm) was significantly less than the LD_{50} for AZOB (280ppm).

Table 9. Effect of concentrations of BOA and AZOB on symphylans with 24 and 48 hour contact.

		Symphylan contact	
Treatment	Concentration	24 h	48 h
	- ppm -	- No.[a] -	- No. -
BOA	50	2.5 a[b]	2.0 b
BOA	100	2.2 ab	1.7 bc
BOA	200	1.7 ab	1.0 c
BOA	500	1.0 b	0.0 d
AZOB	50	2.7 a	2.5 ab
AZOB	100	2.7 a	1.7 bc
AZOB	200	2.5 a	1.7 bc
AZOB	500	1.7 ab	1.0 c
Distilled water	-	3.0 a	3.0 a

[a] Number of symphylans surviving after 24 and 48 hours.

[b] Figures in the same column followed by the same letter are statistically equal (Tukey's HSD, P=0.05).

CONCLUSIONS

Cereal residues from fall planted cover crops suppressed weeds for at least 6 wk in treatments with sufficient residue. In the fall-planted system, applying glyphosate over the crop before emergence greatly increased the effectiveness of the mulch, particularly if the time from cereal desiccation to crop seeding was more than 4 wk, and if the cereal residue on the soil was less than 4800 kg ha^{-1}. The limiting factor in this system was the inability to cultivate with conventional cultivation equipment during the 6 wk period after cucumber seeding. However, given appropriate equipment adapted to no-till conditions, these weeds could have been controlled, particularly in residues less than 4800 kg ha^{-1}. However, weeds that emerged in the row from soil disturbance present a more difficult problem. Banded herbicides may be necessary to control these weeds, for it is difficult to envision another planter causing less disturbance than the cross-slot seeder. The mechanisms that reduced crop growth and yield are poorly understood. Evidence from these experiments indicate that reduced soil temperature, allelopathy, and the no-till environment are important factors. PE mulch was not a good control treatment for temperature and other factors under field conditions.

Spring planted cereals adapted to a stale-seedbed system and a single application of a broad spectrum herbicide (glyphosate) effectively controlled weeds for 5 wk after crop seeding and had minimal impact on crop yield. Seeding difficulties were less than in the conservation tillage system with the additional advantage that conventional cultivation was easily accomplished within 3 to 4 wk after the cereal was killed. This system is especially suited to crops that do not have registered preemergence herbicides available or for areas that have high winds. Symphylan density also was reduced by the presence of barley residue.

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WINTER WHEAT RESPONSE TO CLOMAZONE WITH OR WITHOUT PHORATE.

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INTRODUCTION

Weed control programs for winter wheat fallow include the introduction of improved equipment and replacement of some tillage operations with herbicides. This has resulted in increased efficiency of water storage, and reduced loss of soil by wind and water erosion. The change in winter wheat fallow systems has influenced the introduction of hard to control winter annual grass weeds such as downy brome. Currently there is no established method for selectively controlling these grass weeds in winter wheat. Clomazone is registered for use in fallow and provides control of downy brome when applied in the fall before germination (3). This has lead to the interest in developing clomazone for fall application in winter wheat. However, winter wheat is susceptible to the chlorosis effects of clomazone (1). These effects are a result of clomazone disrupting the synthesis of carotenoid and chlorophyll (4). The chlorosis effects of clomazone can be reduced with the soil applied insecticide phorate (2, 5). Phorate is an organic phosphate insecticide that is applied in furrow at planting time and used for grasshopper control in winter wheat. Phorate can also be used to control the Russian wheat aphid which has become a concern in winter wheat production. Phorate has the potential to reduce chlorosis caused by clomazone, while acting as an insecticide. Elimination of the clomazone caused chlorosis results in a herbicide that can be applied in winter wheat for the selective control of winter annual grass weeds. The objectives of this research were to determine the effectiveness of phorate to reduce the phytotoxic effects of clomazone on winter wheat and the response of winter wheat to preplant and preemergence applications of clomazone with and without in furrow applications of phorate.

MATERIALS AND METHODS

Greenhouse experiment. A study was established in the greenhouse to evaluate the influence of several rates of phorate on wheat injury with clomazone. The experiment was conducted with a 14 h photoperiod with temperature of approximately 24 C during day light and 21 C during the dark period. High pressure sodium lamps, delivering 60 to 400 W m^{-2} of photosynthetically active radiation, were used to maintain the continual 14 h photoperiod. Radiation was maximum in center of the study area (400 W m^{-2}) and a minimum at the edge (60 W m^{-2}). The pots were rotated two times weekly, maintaining each replication in the original block, to achieve an even distribution of light for all treatments. The treatments were a factorial combination of three clomazone rates (0, 0.14 and 0.28 kg ha^{-1}) and five phorate rates (0, 0.12, 0.25, 0.49 and 0.74 g m^{-1}). Plastic pots (15 cm square and 15 cm deep) were filled to a depth of 11.5 cm with a greenhouse soil mix (78% sand, 12% silt and 10% clay) with a pH of 7.7 and 2% organic matter. Ten winter wheat seeds (var. Buckskin) were arranged on the soil surface and phorate added with the seed. Clomazone was applied to 2.5 cm of soil in separate flats with a moving nozzle pot sprayer delivering 187 L ha^{-1} at 276 kPa. The treated soil was thoroughly mixed then placed over the seeds. The experiment was a factorial arrangement of a randomized complete block design with four replications and was conducted twice. Emergence and visual injury was evaluated 14 d after treatment and plants were harvested 28 d after treatment.

Field studies. A study was initiated in 1991 to evaluate downy brome control and winter wheat tolerance with preplant and preemergence applications of clomazone with and without in furrow applications of phorate (study 1). This study was repeated in 1992 under weed free conditions at two locations (study 2). Visual injury, stand reduction, and wheat yield were evaluated in both studies. Downy brome control was also evaluated in study 1.

Study 1. Plots were established under dryland conditions at the Research and Extension Center, Archer, WY to evaluate winter wheat tolerance with preplant and preemergence applications of clomazone with and without in furrow applications of phorate. Plots were 2.7 by 9.1 m with three replications arranged in a factorial design. Herbicide treatments were applied broadcast with a CO_2 pressurized knapsack sprayer delivering 187 L ha^{-1} at 276 kPa. Phorate treatments were applied in furrow at the time of planting with a Gandy applicator mounted on the drill. Preplant treatments were applied, winter wheat (var. Buckskin) seeded and preemergence treatments applied September 6, 1990 (air temperature 25 C, relative humidity 40%, wind calm, sky partly cloudy, and soil temperature at 0 cm 29 C, 5 cm 22 C and 10 cm 20 C). The soil was a loam (49% sand, 27% silt and 24% clay) with a pH of 7.4 and 1.5% organic matter.

Study 2. Plots were established under dryland conditions at both the Archer and Torrington Research and Extension Centers to evaluate winter wheat tolerance with preplant and preemergence applications of clomazone with and without in furrow applications of phorate. Plots were 2.7 by 7.6 m at Archer, WY and 1.5 by 7.6 m at Torrington, WY with three replications arranged in a split plot design at both locations. Herbicide treatments were applied broadcast with a CO_2 pressurized knapsack sprayer delivering 187 L ha^{-1} at 276 kPa. Phorate treatments were applied in furrow at the time of planting with a Gandy applicator mounted on the drill. The preplant treatments were applied, winter wheat (var. Buckskin) seeded and preemergence treatments applied at both locations. The study was established at Archer September 5, 1991 (air temperature 27 C, relative humidity 36%, wind S at 12.9 km h^{-1} , sky clear, and soil temperature at 0 cm 32 C, 5 cm 23 C and 10 cm 21 C) and at Torrington September 25, 1991 (air temperature 29 C, relative humidity 22%, wind calm, sky clear, and soil temperature at 0 cm 38 C, 5 cm 20 C and 10 cm 17 C). The soil was a loam (49% sand, 27% silt and 24% clay) with 1.5% organic matter and pH 7.4 at Archer and a sandy loam soil (78% sand, 13% silt and 9% clay) with 1.2% organic matter and pH 7.5 at Torrington. The plots were maintained weed-free throughout the growing season at both locations by hand weeding.

RESULTS AND DISCUSSION

Greenhouse experiment. Clomazone had no effect on wheat emergence (data not reported). Visual injury with clomazone increased as rate increased and was reflected in the dry weight (Table 1). Phorate at rates as low as 0.12 g m^{-1} effectively reduced winter wheat injury from 59 to 19% with 0.14 kg ha^{-1} clomazone. However, at the higher clomazone rate phorate was not as effective in reducing winter wheat injury. Phorate at 0.49 g m^{-1} was required at the higher rate of clomazone to achieve the same dry weight of 1 g as 0.12 g m^{-1} phorate with 0.14 kg ha^{-1} clomazone. The results from this experiment were used in establishing the rates of phorate for the field studies. The rates of phorate that were included in the field studies were 0.74 g m^{-1}, since it was the lowest rate that reduced the effect of clomazone on wheat dry weight, and the half rate 0.37 g m^{-1}.

Table 1. Winter wheat response to clomazone with several rates of phorate (values presented are an average of two runs conducted August 24, 1991 and December 12, 1991).

Clomazone	Phorate	Injury[a]	Dry weight[b]
kg ha^{-1}	g m^{-1}	%	g
0	0	0	1.2
0	0.12	6	1.3
0	0.25	10	1.2
0	0.49	7	1.4
0	0.74	9	1.2
0.14	0	59	0.7
0.14	0.12	19	1.0
0.14	0.25	18	1.1
0.14	0.49	14	1.2
0.14	0.74	11	1.1
0.28	0	69	0.5
0.28	0.12	47	0.8
0.28	0.25	43	0.9
0.28	0.49	41	1.0
0.28	0.74	31	1.1
LSD (0.05)		9.3	0.22

[a] Injury evaluated 14 days after treatment.

[b] Plants harvested 28 days after treatment and dried.

Field studies. Phorate at both 0.37 and 0.74 g m^{-1} reduced winter wheat injury from clomazone by 10 and 11% respectively (Table 2). Winter wheat tolerance to clomazone was greater with preplant (PP) than preemergence (PE) applications (Table 3). Preemergence applications of clomazone greatly reduced wheat stands 22 and 33% as compared to preplant applications of only 4 and 10%. Winter wheat injury from preplant applications of clomazone were 3 and 8%, while preemergence applications were severe at 32 and 56%. Yields were 414 to 555 kg ha^{-1} lower with preemergence compared to preplant applications of clomazone. However, where downy brome was not controlled in the check plots the wheat yields were lowest at an average of 1027 kg ha^{-1} because of the competition from downy brome. Downy brome control ranged from 88 to 94% and was similar with preplant or preemergence applications of clomazone. Downy brome control was not influenced by phorate (data not reported). The 1992 field studies reflected the tolerance of winter wheat to application method of clomazone that was observed in the 1991 study (Table 4). However, phorate did not reduce damage from clomazone (data not reported). The limited precipitation during the 1992 growing season possibly reduced the effect of phorate on winter wheat injury from clomazone.

Table 2. Phorate effect on winter wheat injury from clomazone Archer, WY 1991 (values are an average of clomazone rates).

Phorate	Injury[a]
g m^{-1}	%
0	27
0.37	17
0.74	16
LSD (0.05)	6.4

[a]Wheat visually evaluated April 29, 1991.

Table 3. Winter wheat response to clomazone and downy brome control at Archer, WY 1991 (values are an average of phorate rates).

		Wheat[a]			
Clomazone	Application	Stand reduction	Injury	Yield	Downy brome[b] control
kg ha^{-1}		%	%	kg ha^{-1}	%
0		1	2	1027	0
0.14	PP	4	3	1892	88
0.28	PP	10	8	1898	94
0.14	PE	22	32	1478	91
0.28	PE	33	56	1343	93
LSD (0.05)		10.3	8.1	361	2.6

[a]Wheat stand reduction and injury visually evaluated April 29 and plots harvested July 29, 1991.
[b]Downy brome control visually evaluated April 29, 1991.

Table 4. Winter wheat response to clomazone at Torrington and Archer, WY 1992 (values presented are an average of phorate rates).

Location	Clomazone	Application	Stand reduction[a]	Injury[a]	Yield[b]
	kg ha^{-1}		%	%	kg ha^{-1}
Torrington	0		0	0	4203
	0.28	PP	12	25	3839
	0.28	PE	76	86	2177
Archer	0	PP	0	0	1584
	0.28	PE	28	37	1442
	0.28		50	85	948
LSD (0.05)			11.4	9.4	420

[a]Wheat stand reduction and injury visually evaluated March 20 at Torrington and April 2, 1992 at Archer.
[b]Plots harvested July 8 at Torrington and June 22, 1992 at Archer.

SUMMARY

Phorate effectively reduced the chlorosis and possible yield reduction from clomazone. The levels of protection with the preemergence applications of clomazone were not sufficient. However, acceptable levels were achieved with preplant applications of clomazone. Phorate was not as effective in reducing winter wheat injury from clomazone when precipitation was limited during the growing season. More information is needed on environmental conditions and herbicide activity in order to recommend the use of clomazone with phorate in winter wheat. Clomazone provides good to excellent control of downy brome at the rates used but there needs to be more research on the control of other winter annual grassy weeds.

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SWEET CORN INBRED TOLERANCE AND WILD-PROSO MILLET CONTROL USING NICOSULFURON.

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Abstract. Hybrid sweet corn seed production is very important in southwestern Idaho. Wild-proso millet is a serious threat to sweet corn seed production. Inbreds used for seed production are considered non-competitive. There are very few herbicides that can be used in corn that provide adequate season-long control of wild-proso millet. Nicosulfuron has recently been registered for use in field corn, but not for sweet corn. Sweet corn inbred tolerance to nicosulfuron has not been widely investigated, nor has the ability of nicosulfuron to control wild-proso millet under southern Idaho environmental conditions. Nicosulfuron was applied to 28 sweet corn inbreds in 1991 at the Parma Research and Extension Center, and 32 inbreds in 1992 at the Kimberly Research and Extension Center. Rates used were, 35 (1X) and 70 (2X) g/ha. Injury was evaluated visually, followed by plant growth measurements and aerial biomass samples were harvested. Results of the inbred studies indicate good tolerance of most inbreds to nicosulfuron, however injury seems to be very specific and serious to some inbreds. Injury does not appear to be genotypically related. In 1991 and 1992, 75 and 88% of the inbreds tested respectively, were injured less than 5%. Only 6 to 11% of the inbreds were injured more than 25% in both yr. Injury levels at 2X rate were very similar to 1X rate. Individual inbreds were injured from 0 to 100%. In 1992 studies were established near Nampa, to investigate wild-proso millet control under two environments using nicosulfuron compared to other registered herbicides. Nicosulfuron controlled wild-proso millet 36% and 89% in the two environments. Standard germination tests of the seed of treated plants indicate no significant difference among treatments. Inbreds investigated demonstrated high tolerance to nicosulfuron and wild-proso millet control was variable in the two environments.

BIODIVERSITY ASSOCIATED WITH VARIOUS TEBUTHIURON APPLICATION RATES IN SELECTED NORTHCENTRAL WYOMING SAGEBRUSH COMMUNITIES: PRELIMINARY REPORT. K. H. Johnson, R. A. Olson, T. D. Whitson, and R. J. Swearingen, Research Assistant and Assistant Professor, Department of Range Management, and Associate Professor and Research Assistant, Department of Plant, Soil, and Insect Sciences, University of Wyoming, Laramie, WY 82070.

INTRODUCTION

Big sagebrush is the dominant shrub on more than 40 million hectares of North American rangeland (15, 18), including 20.9 million hectares in Wyoming (1). The primary commercial use of the big sagebrush ecosystem is cattle grazing (15). Historical evidence suggests that prior to European settlement, big sagebrush was an important component of the rangeland across which it is dominant today (15). However, intensive grazing during the 1800's and early 1900's and fire suppression are suspected of facilitating an increase in the within-stand dominance of big sagebrush in these areas (11, 12). Because big sagebrush has little forage value to cattle and competes with desirable herbaceous species, the suspected increase of its foothold on rangelands has led to its classification as a weedy species by commercial range managers and to development of sagebrush control programs (7, 14, 15).

Traditionally, sagebrush control projects have involved mechanical and nonselective chemical (2,4-D) treatments aimed at total control (2, 3, 10, 13, 14, 16, 20). Conversions of sagebrush stands to grassland monocultures result in decreased wildlife populations and biodiversity (6, 13, 14, 20). Such wildlife community responses reflect the importance of sagebrush as habitat and forage for wildlife (6).

Of all wild vertebrates, small mammals are particularly sensitive to habitat alterations (7, 20) and can be especially useful as indicators of ecological conditions. Small mammals may also have positive economic significance to commercial rangeland managers. The importance of small mammals to seed dispersal in seral big sagebrush stands has been documented (9). Frischknecht and Baker (7) reported that voles at high population densities effectively controlled long-term sagebrush canopy development, enhancing production of herbaceous understory vegetation preferred by cattle. Due to their environmental sensitivity, small mammal communities may be used as barometers of overall biodiversity for an area.

Tebuthiuron, a root-absorbed pelleted herbicide, has been identified as a promising, highly selective sagebrush treatment option with thinning capabilities (18, 19). Low application rates of tebuthiuron aimed at partial control of big sagebrush may elicit unique responses from wildlife communities.

Our research goals were to characterize the plant communities associated with various tebuthiuron application rates, and to describe the small mammal communities associated with those habitats, at a site in Northcentral Wyoming 13 yr posttreatment. Because of increasing concern for biodiversity on rangelands (17) particularly with regard to the implications of sagebrush conversion projects (6), assessment of diversity in the plant and small mammal communities was our primary objective.

STUDY AREA AND METHODS

Tebuthiuron was applied at 0.94, 0.67, and 0.31 kg/ha to single, 10 ha plots in a homogenous big sagebrush habitat near Ten Sleep, Wyoming in 1978. Buffer strips of 30 m were maintained between spray plots. In 1992, a control plot was established 150 m from the treatments. Site soil composition includes 32% sand, 43% silt, 26% clay, and 2.3% organic matter, with a pH of 8.1. Average annual precipitation is 29 to 38 cm.

Four 70 m vegetation sampling transects were randomly located in each plot. Ten 0.25 m^2 hoop quadrats were sampled at even intervals along the length of each transect. In addition to determining density and estimating cover, double-sampling (4) was used to determine biomass production for each species in each quadrat. The weighted average of the relative values for density, frequency, cover, and biomass production was calculated. This value represents the importance of a species as a percent of the overall community. Percent control of sagebrush (based on differences in importance values between treatments and the control) relative to tebuthiuron application rate was analyzed through regression.

Small mammal populations were sampled via mark-and-recapture procedures. A 10- by 10-station grid, 10 m between stations, with 1 aluminum livetrap per station, was established in each plot. Trapping was conducted for 5 consecutive 24 hr periods in July. Captured individuals received unique toe-clip codes for positive identification. Mark-and-recapture data were analyzed via the Schnabel estimator, an appropriate model for closed populations (8):

$$\hat{N} = \frac{\sum (C_t M_t)}{\sum R_t}$$

where $\hat{N}$ = Population estimate
C_t = Total captures in sample t
R_t = Number of recaptures in sample t
M_t = Number already marked prior to sample t

Importance values for plant species and Schnabel estimates of abundance for small mammal species were used to calculate Shannon-Wiener diversity (8) for those communities in each plot:

$$H' = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where H' = Index of diversity
s = Number of species
p_i = proportion of sample belonging to *i*th species

Regression analysis was used to evaluate the relationship between plant community diversity and small mammal community diversity.

RESULTS AND DISCUSSION

Table 1 shows the importance of dominant plants to each community. Big sagebrush comprised 35.47% of the plant community in the untreated area. Importance of big sagebrush decreased with progressively heavier tebuthiuron application rates. Figure 1 shows that big sagebrush control was a linear function of application rate ($r=0.97$). The slope of the regression line in Figure 1 is significantly positive at the $\alpha=0.05$ level ($p=0.017$), showing that the increase in big sagebrush control with application rate is significant. Plant species richness (the total number of species present) was lowest in the untreated plot (Table 1).

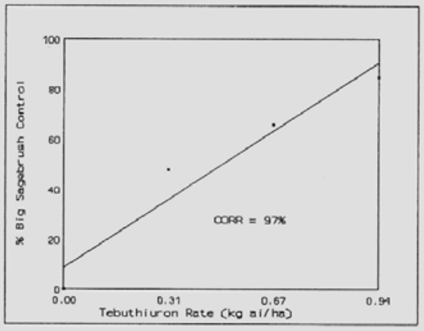

Figure 1. Big sagebrush control with tebuthiuron application rates, Ten Sleep, Wyoming, 1992.

Table 1. Plant community composition by dominant species for sagebrush plots treated in 1979 with various tebuthiuron application rates, Ten Sleep, Wyoming, 1992.

	Plant community composition[a] for dominant species[b]			
	Plot 1 (0.94 kg/ha)	Plot 2 0.67 kg/ha)	Plot 3 (0.31 kg/ha)	Plot 4 (untreated)
Species	%			
Western wheatgrass *Pascopyrum smithii* (Rydb.) A. Love	64.17	50.90	39.26	22.86
Sandberg bluegrass *Poa secunda* Presi	8.82	6.67	8.81	5.69
Prairie junegrass *Koeleria pyramidata* Lam.) Beauv.	6.68	9.34	7.21	10.62
Woolly loco *Astragolis mollissimus* Torr.	2.06	3.78	6.05	4.03
Big sagebrush *Artemesia tridentata* Nutt	5.27	11.89	18.27	35.47
Number of species present	23	23	24	20

[a] Based on Curtis-McIntosh importance values (weighted averages of relative values for cover, density, frequency, and biomass production).

[b] A dominant species is one with an importance value > 5.00 for any plot.

Table 2. Schnabel estimates of 1992[a] small mammal species abundance ($\hat{N}$) for sagebrush plots treated in 1979 with various tebuthiuron application rates, Ten Sleep, Wyoming.

	$\hat{N}$/ha			
	Plot 1 (0.94 kg/ha)	Plot 2 (0.67 kg/ha)	Plot 3 (0.31 kg/ha)	Plot 4 (untreated)
Species	%			
Richardson's ground squirrel *Spermophilus richardsoni*	66	63	59	29
White-footed deer mouse *Peromyscus maniculatus*	9	18	13	16
Northern grasshopper mouse *Onochomys leucogaster*	3	5	13	0.62

[a] Mark-and-recapture sampling was performed for 5 consecutive 24 h periods in July.

Table 3. Percent sagebrush control and biodiversity associated with tebuthiruon application rates, Ten Sleep, Wyoming, 1992.

		Shannon-Wiener Diversity Value ($\hat{H}'$)[a]	
Tebuthiuron rate	Sagebrush control	Plants $\hat{H}'$	Small mammals $\hat{H}'$
kg/ha	%		
0.94	85	2.22	0.74
0.67	66	2.75	1.04
0.31	48	3.09	1.19
Untreated	--	2.41	0.94

[a] Large values for H indicate high diversity.

Schnabel estimates of small mammal populations from mark-and-recapture data are presented in Table 2. Abundance of Richardson's ground squirrel (*Spermophilus richardsonii*) was lowest in the untreated plot. Species richness was also lowest in the untreated plot, as the northern grasshopper mouse (*Onychomys leucogaster*) was absent only in this area. The white-footed deer mouse (*Peromyscus maniculatus*) was present in all plots and was least abundant in the heavy treatment (0.94 kg/ha) area.

Shannon-Wiener diversity values associated with different levels of big sagebrush control achieved with the various tebuthiuron application rates are presented in Table 3. Plant community diversity was lowest in the heavy treatment and highest in the thinned plots. The 0.31 kg/ha treatment, resulting in 48% control of big sagebrush, yielded the highest plant community diversity value. Small mammal community diversity varied with plant community diversity.

The strength of the linear association between plant community diversity and small mammal community diversity ($r=0.97$) is displayed in Figure 2. The increase in small mammal community diversity with habitat (plant community) diversity, indicated by the positive slope of the regression line, is significant at the $\alpha=0.05$ level ($p=0.015$).

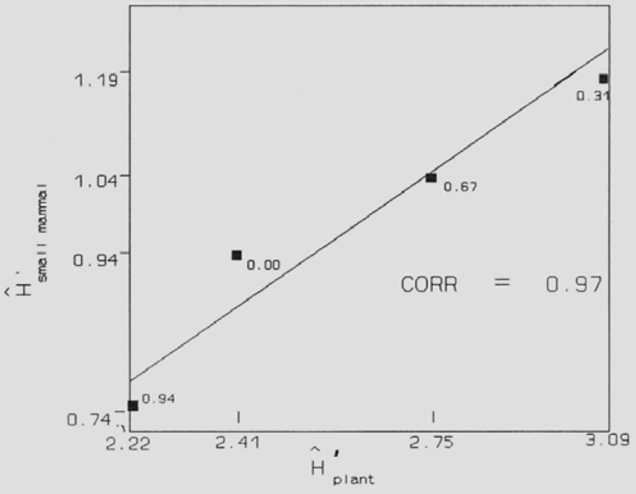

Figure 2. Relationship of diversity of plant and small mammal communities in sagebrush plots treated with various tebuthiuron rates (kg/ha), Ten Sleep, Wyoming, 1992.

These results show that thinning big sagebrush with tebuthiuron can increase production of preferred cattle forage while increasing proximal biodiversity. The increase in dominance of western wheatgrass, the primary cattle forage species at the site, as big sagebrush dominance decreased (Table 1) supports the suggestions by Vale (15) and Frischknecht and Baker (7) that sagebrush competes with cattle-preferred herbaceous species, and big sagebrush control improves desirable forage production. The strength of the association of plant and small mammal communities regarding diversity at Ten Sleep (Figure 2) portrays the potential importance of habitat composition to wildlife community heterogeneity. That lowest Ĥ' characterized the heavy treatment plot, wherein big sagebrush control was 85% (Table 3), supports Franklin's (6) contention that eradication of sagebrush can sabotage biodiversity. However, the higher Ĥ' values associated with the plots in which big sagebrush was thinned (0.67 and 0.31 kg/ha) compared to the untreated area suggest that thinning big sagebrush with tebuthiuron offers promising potential as a management option to biodiversity-conscious rangeland managers.

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EFFECTS OF HERBICIDES AND BURNING ON MEDUSAHEAD CONTROL AND ESTABLISHMENT OF DESIRABLE FORAGES ON RANGELANDS. John M. Squire and S. A. Dewey, Graduate Research Assistant and Professor, Plants, Soils, and Biometeorology Department, Utah State University, Logan, UT 84322-4820.

Abstract. Medusahead is a non-native winter annual grass which dominates millions of hectares in the western United States. The weed is avoided by grazing livestock and reduces carrying capacity up to 70 and 80%. Medusahead causes physical damage to livestock, and also creates a fire hazard in the summer. It is adapted to many downy brome sites and can out-compete and dominate these sites. Recently, medusahead was discovered in Utah and currently inhabits less than 800 hectares. However, it could potentially infest much of the state.

Research was conducted to formulate a management scheme for medusahead control on rangelands. Two experiments (referred to as studies) were executed in a split-split-plot design with four replications. A residue management was the whole plot treatment, herbicides the sub-plot treatment, and competition from seeded perennials was the sub-sub-plot treatment. Sections of both sites were burned in late Aug, 1991. Selected plots on study A received a fall or spring tank mix application of glyphosate and metsulfuron at a rate of 841 and 4.2 g ha^{-1}, respectively. Other chemical treatments included glyphosate applied alone in the spring at 841 g ha^{-1}, and no herbicides. Competition levels included: none, HyCrest crested wheatgrass, and Luna pubescent wheatgrass [seeded on a PLS (Pure Live Seed) basis at 0, 12, and 5 kg ha^{-1} respectively]. Study B was treated with fall or spring applications of glyphosate at the above rate, no chemicals, or with paraquat applied in the spring at a rate of 525 g ha^{-1}. Competition levels for this site were: none, HyCrest plus alfalfa mix, and HyCrest plus forage kochia mix (seeded on a PLS basis at 0, 14+6, and 18+2.7 kg ha^{-1} respectively). Treatments were evaluated to determine plant biomass, and percent medusahead control.

Burning alone on study A caused a 14% increase in medusahead biomass. Whereas, burning alone increased medusahead biomass by 66% on study B. The best treatment for the reduction of this weed on study A was the combination of burning and glyphosate plus metsulfuron applied in the spring. This reduced medusahead biomass by 91% when compared to burning and no herbicides. On study B the best treatment was burning combined with a fall application of glyphosate which decreased medusahead biomass by 81% when compared to burning and no herbicides. When medusahead was eliminated, broadleaf weeds invaded the opening. A heavier rate of metsulfuron would be recommended to control these weeds. More time is needed to determine the level of competition provided by improved perennials.

RUSSIAN KNAPWEED CONTROL WITH HERBICIDES APPLIED DURING EARLY FALL DORMANCY.

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Abstract. Various herbicides and herbicide combinations were applied at the onset of fall dormancy for Russian knapweed control. Three experiments were initiated in 1989 near Shoshoni, Wyoming on an abandoned corn field with a loamy sand soil containing 89% sand, 4% silt and 7% clay with 1.1% organic matter and a pH of 8.0. Treatments were applied after knapweed plants were defoliated by frost. Comparisons were made to treatments applied during bloom and rosette stages of growth. A fourth experiment was initiated near Manderson, Wyoming in 1991 to study the efficacy of treatments applied at early dormancy on a silt loam soil containing 13% sand, 62% silt and 25% clay with 4% organic matter and a pH of 8.0.

Picloram at rates of 0.25 lb/A and above, had greater than 92% control at all application timings and locations. The largest difference in percent control among application timings was found with dicamba. When applied at the rosette and bloom stages, control was less than 10% but when applied at early dormancy dicamba at 2 lb/A provided 62% control at Shoshoni and when applied at 1 lb/A provided 49% control at Manderson. When the combined treatment of dicamba at 0.5 lb/A and picloram at 0.125 lb/A was applied at the Shoshoni location a consistently higher percent control was obtained than dicamba alone. Dicamba at 1 lb/A combined with picloram at 0.25 lb/A controlled 96% when applied at early dormancy at the Manderson location. At Shoshoni, clopyralid at 0.25 lb/A and the combination of clopyralid at 0.25 lb/A plus 2,4-D at 1.33 lb/A provided a 26 and 22% increase in control, respectively when applied at the bloom stage compared to the rosette stage. At the Shoshoni location 2,4-D at 2 lb/A failed to adequately control Russian knapweed regardless of time of application.

Table. Russian knapweed control with herbicides applied at various growth stages.

Herbicide	Rate	Shoshoni[a] Rosette	Shoshoni[a] Bloom	Shoshoni[a] Early dormancy	Manderson[b] Early dormancy
	- lb/A -	%			
Picloram	0.25	..	..	..	93
Picloram	0.375	96	99	99	..
Dicamba	1				49
Dicamba	2	9	3	62	..
Dicamba + picloram	0.5 + 0.125	75	93	83	..
Dicamba + picloram	1 + 0.25	..	..	..	96
Clopyralid	0.25	70	96	94	85
Clopyralid + 2,4-D	0.25 + 1.33	55	77	89	90
2,4-D	2	0	5	1	..
LSD (0.05)		29	32	23	23

[a] Herbicides were applied May 18, July 7, and October 8, 1989. Evaluations were made August 5, 1992. Average annual precipitation is 5 to 9 inches.

[b] Herbicides were applied October 9, 1991. Evaluations were made August 5, 1992. Average annual precipitation is 6 to 9 inches.

A NOVEL METHOD FOR STUDYING PREEMERGENCE HERBICIDE DISSIPATION PRIOR TO WATER ACTIVATION: A CASE STUDY WITH UCC-C4243.

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Abstract. UCC-C4243 is an experimental herbicide from the Uniroyal Chemical Company that has shown promise for the preemergence control of a wide spectrum of broadleaf weeds in wheat. However, in previous field trials, weed control efficacy was reduced when no rainfall was received for 2 to 3 wk following herbicide

application. A novel method was developed to determine the loss of herbicide activity as a function of herbicide rate, time after preemergence application before water activation, and level of water applied. UCC-C4243 was applied preemergence to soft white spring wheat (var. 'Edwall'), spring lentils (var. 'Brewer'), common lambsquarters, and field pennycress at the Palouse Conservation Field Station, Pullman, WA. Plant species were hand planted into miniplots (0.5 by 1.2 m) the day of spraying. The herbicide was applied at 0, 0.07, and 0.14 kg/ha at 1, 6, 14, and 21 d before 0.5 and 2 cm of water were applied by sprinkler irrigation to activate the herbicide. Field plots were protected from natural rainfall during the 3 wk period by temporary, removable rain shelters. Soil samples (0 to 3 cm) were taken immediately before irrigation from all plots and remaining herbicide activity determined by bioassay with sugarbeets in the greenhouse. Weather conditions during the study were warm, dry, and sunny. The experimental design was a randomized complete block with a triple split-plot arrangement. Four replications constituted the blocks. The first split was the level of irrigation for herbicide activation. The second split consisted of a completely randomized factorial arrangement of herbicide rate by time of application treatments applied to each of the miniplots. The final split was by plant species which were arranged randomly within miniplots.

UCC-C4243 at 0.14 kg/ha controlled common lambsquarters and field pennycress greater than 90% versus nontreated controls for both irrigation levels if water was received within 14 d. Weed control was reduced with a longer time before water activation. The 0.07 kg/ha treatment did not control the two weed species as well as the 0.14 kg/ha treatment. Weed control with the low rate of herbicide was acceptable (>80%) at the 2 cm water activation level for up to 8 and 9 days (by interpolation) before irrigation for field pennycress and common lambsquarters, respectively. The 0.07 kg/ha rate did not control weeds consistently at the 0.5 cm water activation level but weed control was improved with 2 cm irrigation. Wheat tolerated UCC-C4243; however, spring lentils were only marginally tolerant to both levels of herbicide. Bioassay results indicate UCC-C4243 has a soil surface half-life of approximately 18.5 d under warm, dry, and sunny conditions.

These results show that UCC-C4243 will lose a significant amount of activity if overhead water is not received within 8 d after 0.07 kg/ha is applied or 14 d after 0.14 kg/ha is applied. The method described can be used for evaluating the amount and rate of dissipation of activity for other herbicides applied preemergence.

CONTROL OF ALS RESISTANT AND SUSCEPTIBLE KOCHIA BIOTYPES WITH PRE-EMERGENCE TREATMENTS OF DICAMBA AND METSULFURON.

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Abstract. A field experiment was conducted to evaluate soil application of herbicides for kochia control. Eight kochia biotypes (4 resistant and 4 susceptible to ALS inhibitor herbicides) with different germination rates were seeded in rows at 30 cm intervals and individual rows were 30 cm apart. Herbicides were applied perpendicularly to the rows immediately after planting. Kochia was planted on April 13 and April 21, 1992. Dicamba was applied at 0.07, 0.10 and 0.14 kg/ha alone and in combination with metsulfuron methyl at 0.007 kg/ha. The experimental area was irrigated to activate herbicides and to promote seed germination.

Metsulfuron effectively controlled susceptible kochia biotypes but had little effect on resistant ones. Effectiveness of the dicamba treatments was highly rate dependent. Control ranged from 20 to 36%, 56 to 66%, and 75 to 94% for treatments at 0.08, 0.10 and 0.14 kg/ha, respectively. Crop competition would likely increase overall control at lower herbicide rates. Kochia biotypes responded similarly to dicamba at all rates. Dicamba at higher rates displayed good soil residual and suppressed other broadleaf weeds for most of the growing season. These results show that pre-emergent dicamba treatments can be an effective management strategy for control of ALS resistant kochia when moisture for herbicide activation is present.

FREQUENCY OF TRIALLATE RESISTANCE IN MONTANA. W. E. Malchow, B. D. Maxwell, P. K. Fay, and W. E. Dyer, Graduate Student, Assistant Professor, Professor, and Assistant Professor, Department of Plant and Soil Science, Montana State University, Bozeman, MT 59717.

Abstract. Wild oat resistance to triallate has been reported in Montana. The purpose of this research was to confirm the existence of resistance in the greenhouse and under field conditions, to test for cross resistance, and to determine the frequency and distribution of triallate resistance on the Fairfield Bench of Montana. In 1991, wild oat seeds were collected from 67 fields by Monsanto personnel in response to triallate performance complaints. These samples were screened for resistance in the greenhouse using greenhouse soil treated with triallate at 1.1 kg/ha. Fifty-one percent of the samples were resistant. A survey of growers owning sampled fields was conducted to find correlations between resistance and farming practices. Number of years of triallate use and seeding date appeared to be related to resistance. In 1992, 23 of the 67 samples were randomly selected and seeded into single rows in the field. Triallate, trifluralin, triallate and trifluralin, diclofop methyl, imazamethabenz, and difenzoquat were applied at the appropriate growth stage at labelled field rates to each sample. Visual injury ratings were taken several times during the growing season. Field results confirmed greenhouse results. Twenty-one of the 23 samples that were resistant to triallate were also resistant to difenzoquat.

In 1992, seed samples were gathered from a 70 mile square irrigated malt barley production area (Fairfield Bench) where resistance had been identified in 1991. Four randomly selected fields were sampled per square mile. Samples were also gathered from roadsides of the same area. Samples were screened in the greenhouse using greenhouse triallate treated soil at 1.1 kg/ha. Approximately 61% of the field samples contained resistant wild oat seed. Resistance appears to be randomly distributed in the malt barley area. Only one of the roadside samples contained resistant seed, indicating that resistant seed has not yet moved from fields or resistant types may not be able to survive along the roads.

A SURVEY OF TRIALLATE TOLERANT WILD OATS IN THE UNITED STATES. J. A. Mills, D. K. Ryerson, and J. D. Colyer, Monsanto Company, 800 North Lindbergh, St. Louis, MO 63167.

Abstract. Triallate has been used successfully as a wild oat herbicide in cereal production areas of the United States since 1972. In 1991, wild oats tolerant to commercial rates of triallate were discovered in a small area of Montana. A survey was initiated in 1992 to determine if wild oats tolerant to commercial use rates of triallate were wide spread in Montana and parts of Idaho and North Dakota. Over 200 seed samples were collected and tested. Results indicate that triallate tolerance is primarily isolated to the Fairfield Bench in Teton county, Montana where high rates of triallate have been used year after year in continuous barley production. Wild oats tolerant to triallate were not found in cereal-fallow rotations even when triallate was used consistently in years of cereal production.

THE FREQUENCY OF SULFONYLUREA HERBICIDE RESISTANT KOCHIA (Kochia scoparia L. Schrad) IN COLORADO, IDAHO, AND MONTANA. J. L. Wright*, C. A. Mallory-Smith#, P. K. Fay*, D. C. Thill#, P. Westra, and P. A. Trunkle*, Research Associate, Post-doctoral Associate, Professor, Professor, Associate Professor and Student, Department of Plant and Soil Science*, Montana State University, Bozeman, MT 59717; Plant, Soil, and Entomological Sciences Department#, University of Idaho, Moscow, ID 83843; and Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

Abstract. Resistance to the sulfonylurea (SU) herbicides first became apparent in several states in the mid-1980's following frequent use of the persistent herbicide chlorsulfuron. SU resist kochia is very common. A survey was conducted in 1991 to determine the degree of resistance to chlorsulfuron in field collected kochia

seed in Colorado, Idaho, and Montana. Seed samples were collected from 30 plants per cell (a randomly selected area ranging from 36 square miles in Idaho to 64 square miles in Montana). There were 128, 183, and 300 composite samples from Idaho, Montana, and Colorado respectively. Composite samples containing seed from each plant in a cell were sent to Montana State University for greenhouse screening to determine the frequency of resistance to chlorsulfuron.

Approximately 500 seeds from a composite sample were planted in a small flat. There were two replications. Two weeks after planting, seedlings were thinned to approximately 250 seedlings per flat, and sprayed with chlorsulfuron at a rate of 0.5 oz/A with 0.25% v/v nonionic surfactant. One week later the plants were sprayed again with the same rate of herbicide. Visual injury ratings were taken 2 and 4 wk after the second herbicide application.

Approximately 75% of the composites (137 of 183) from Montana contained plants resistant to chlorsulfuron. The percent injury ranged quite uniformly from 0 to 100%. Approximately 50% of the lines from Idaho showed some resistance to chlorsulfuron. Only one composite from Colorado had 70% injury or more, indicating no resistance was detected in the samples collected. SU resistant kochia is commonplace in Montana and frequent in Idaho. No resistance was found in Colorado.

RESISTANCE OF CALIFORNIA ARROWHEAD AND SMALLFLOWER UMBRELLA SEDGE TO SULFONYLUREA HERBICIDES. T. Pappas-Fader, J. F. Cook, T. Butler, P. J. Lana, E.I. DuPont de Nemours and Company, Stine-Haskell Research Center, Newark, DE 19714 and J. Hare, Pest Control Advisor, The John Taylor Fertilizer Company, 900 N. George Washington St. Yuba City, CA 95993.

Abstract. During the fourth season of bensulfuron methyl use in monoculture rice in California, biotypes of two aquatic weed species resistant to bensulfuron methyl were discovered on four rice farms in the Sacramento Valley. The apparent resistance in the field of biotypes of California arrowhead, an annual broadleaf and smallflower umbrella sedge, an annual sedge has been confirmed by laboratory and greenhouse studies.

In greenhouse tests, the two resistant arrowhead biotypes required use rates of 600 to 670 g/ha of bensulfuron methyl for 50% growth reduction, whereas the susceptible biotype exhibited 50% growth reduction at 1 g/ha. Acetolactate synthase (ALS), the target site of bensulfuron methyl, was isolated from the arrowhead biotypes and assayed for sensitivity to bensulfuron methyl. Results show that resistance in the two biotypes is due to insensitivity at the target site. Both resistant biotypes of arrowhead exhibit cross-insensitivity at the enzyme level to the ALS inhibitors chlorsulfuron, metsulfuron methyl, chlorimuron ethyl, NC311, CGA-142464, and TH-913.

In greenhouse studies, resistant smallflower umbrella sedge biotypes required use rates of 31 to 310 g/ha of bensulfuron methyl for 50% growth reduction while the susceptible biotypes exhibited 50% growth reduction at less than 1 g/ha. Both resistant biotypes of smallflower umbrella sedge were also cross resistant at the whole plant level to NC311, CGA-142464, and TH-913. Results show that resistance in the two biotypes is due to insensitivity at the target site. Both resistant biotypes exhibit cross-insensitivity at the enzyme level to the ALS inhibitors chlorimuron ethyl, sulfometuron methyl, metsulfuron methyl, and chlorsulfuron. Cross-insensitivity at the enzyme level to NC311, CGA-142464, and TH-913 is under investigation. These biotypes of California arrowhead and smallflower umbrella sedge are the first documented cases of resistance to ALS inhibitors among aquatic weeds. Resistant weed management strategies will be implemented and monitored in 1993 to ensure the continued effective use of bensulfuron methyl in California agriculture.

A BIOECONOMIC MODEL FOR DETERMINING LONG-TERM ECONOMIC OPTIMUM WILD OAT MANAGEMENT STRATEGIES IN BARLEY.

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INTRODUCTION

Wild oat is the most costly and wide spread weed in spring-sown small grain production in Montana. The main focus of weed control in barley and wheat is on wild oats. Increased resistance to wild oat herbicides as well as a growing interest in reducing pesticide inputs, have produced a need for research on non-chemical and reduced herbicide weed management practices.

The corner stone of approaches to reduce herbicide inputs in agricultural systems is the identification and implication of weed thresholds. The pest density at which the value of the crop loss equals treatment cost (economic injury level) and the pest density at which control measures should be taken to prevent an increasing pest population from reaching the economic injury level (economic threshold) are definitions of thresholds that are best suited for weed management situations. Managing weeds by the threshold concept typically means identifying the density of weeds in the crop before a control practice is used and by knowing the effect of different weed densities on crop yield, the price of the crop and management costs, the farmer can determine if the cost of controlling the weed population will be greater than the economic benefit from the control.

MATERIALS AND METHODS

A set of equations were combined in a computer program to determine hypothetical wild oat density thresholds in small grain production in Montana. The equations and data were generated from experiments in central Alberta and Idaho over a number of years. Where applicable, data from the 1990 Montana Agricultural Statistics manual (3) were used. Analysis of the program output allows one to determine wild oat economic injury levels (EILs) for current weed control strategies, and to determine the relative importance of the equation parameters in determining the EIL's. The EIL is defined in this analysis as the weed density where lost profit from yield loss is equal to the weed control cost. So it is assumed that it is profitable to do weed control with a chosen practice if the wild oat density is above the EIL, but the farmer loses money by controlling weeds with the practice method if the weed density is below the EIL.

In addition the model has been expanded with the incorporation of wild oat population process subroutines to determine the profit maximizing wild oat control strategy over a three year time horizon for continuous small grain production. The economic threshold (ET) for the first yr can then be identified including the risk of future (following 2 yr) weed problems as a result of leaving weeds in the system the first yr.

The yield loss function was developed by Cousens et al. (1) to model the percent yield loss (YL) of small grains in response to wild oat density (D) which accounts for differences in wild oat and crop emergence times:

$$YL = b * D/(e^{cT} + b * D/a) \qquad [1]$$

where a, b and c are parameters fit with non-linear regression to a range of crop yields in response to a range of wild oat densities. Cousens et al. (1) using data from O'Donovan et al. (2) found average values for a number of yr experiments with non-irrigated spring barley. The parameter T is the difference in emergence time (days) between the wild oats and the crop. The yield loss has an asymptotic response to increasing wild oat density where maximum yield loss is near 40% when the emergence times for wild oats and barley coincided, and near 20% when emergence of the wild oats was 7 d behind the barley (1).

In order to calculate the economic injury level for wild oats in a crop the wild oat density must be related to net profit.

$$NP = [Y * (P - ccd)] - (H + W + S) \qquad [2]$$

Where Y is the crop yield/A calculated from the expected weed free yield (Y_{wf}).

$$Y = Y_{wf}(1 - YL/100) \qquad [3]$$

P is the price received per bu. of grain. P is decreased by $0.045/bu (ccd) when wild oats are present in the grain according to standard docking procedures. H_{tot} is the total cash expenses per acre of production for barley and wheat in 1988 in Montana adjusted for irrigated barley production by subtracting purchased irrigation water costs. H in eqn. 2 is H_{tot} minus the cost associated with wild oat control and the cost of crop seed (S) to be planted. The parameter W includes the cost of the wild oat herbicide (hp) for a given strategy (herbicide brand and rate) plus application costs (apc). The wild oat weed control cost is made a function of the herbicide rate relative to the labeled rate (pc).

$$W = hp * pc + apc \qquad [4]$$

The relative herbicide rate (pc) is also related to the density through a weed density reduction function (dose response curve).

$$DR = \boldsymbol{\beta}_1/(1 + \boldsymbol{\beta}_2 * pc^{\boldsymbol{\beta}_3}) \qquad [5]$$

Where DR is the percent wild oat density reduction and $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$ and $\boldsymbol{\beta}_3$ are herbicide specific coefficients fit with non-linear regression.

The wild oat density reduction is then used to adjust the density in eqn. [1] to calculate the yield loss and subsequent NP based on the herbicide rate.

$$D = D_0 * (1 - DR/100) \qquad [6]$$

Where D_0 is the original weed density in the field before weed control occurs. Thus by inputing the desired herbicide for wild oat control, the rate of the herbicide relative to the labeled rate, the wild oat density, and the d between emergence of the wild oats and the crop, the NP can be calculated from the equations in the sequence: 4, 5, 6, 1, 3, 2. The threshold density or economic injury level (EIL) for each weed control treatment (relative herbicide rates: 1.0X, 0.75X, 0.5X and 0.25X) for a single growing season is determined by finding the wild oat density that corresponds to the intersection of the NP response at the 0 weed control rate and another treatment rate.

RESULTS AND DISCUSSION

Using the above data and equations the NP was calculated for a range of wild oat densities in dryland barley using triallate, diclofop and difenzoquat to control the wild oats and the crop and the weed set to emerge at the same time. The NP values were plotted against the wild oat densities for 4 herbicide rates (1.0X = labeled rate, 0.75X, 0.5X, 0.25X and 0 = no herbicide used). The EIL was determined for each herbicide over a range of rates when the crop price (P) was set at $2.19/bu (the 10 yr mean price for feed barley in Montana from 1981 to 1991) and the relative emergence time (T) was held at 0 and 2.

The results of simulations with the model indicate that in dryland barley with a crop price of $2.19/bu., there is no current yr economic advantage in controlling wild oats with triallate at any herbicide rate. Under the same conditions, however, the model indicates an economic advantage in treating wild oats with diclofop at one quarter of the label rate (0.25X) when the wild oat density is greater than 19 plants/m^2. Similarly, net profit could be maximized using difenzoquat applied at the 0.25X rate when wild oat densities ranged between 17 and approximately 80 plants/m^2 and using the half rate (0.50X) at higher densities. When the crop price (P) was increased in the model the EIL's decreased, but the reverse trend occured when the emergence time of the wild oats was delayed relative to the barley (i.e. T > 0).

Table 1. Economic injury level (P =$2.19/bu).

Herbicide	Herbicide rate relative to label rate			
	1.0X	0.75X	0.50X	0.25X
Triallate	no[a]	no	no	no
Diclofop	no	no	84	19
Difenzoquat	no	81	41	17

[a] no = no threshold was determined or no herbicide use had a higher NP than any of the herbicide rates across the weed density range that was tested.

Table 2. The influence of relative emergence time (T) on the current year EIL when diclofop is applied for wild oat control.

T	Diclofop EIL (P = $3.00/bu)			
	Herbicide rate relative to the label rate			
	1.0X	0.75X	0.50X	0.25X
0	154	58	31	12
1	no	104	41	16
2	no	157	56	21
3	no	no	108	28
4	no	no	165	68
5	no	no	no	99

There is a need to characterize the variance in wild oat density reduction associated with chemical and non-chemical weed control practices so that the risk associated with each practice can be assessed. The variance in the yield loss function as well as prices and costs are also associated with risk and should be assessed.

Further research is being conducted to determine the long-term economic thresholds where the impact of weeds left in the system at the EIL will be assessed. The wild oat population dynamics as influenced by wild oat and barley population densities and the relative emergence time of wild oats relative to barley are factors that will be included to determine economic optimum wild oat management strategies.

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HERBICIDE RATE REDUCTION AND OFF-TARGET HERBICIDE MOVEMENT WITH AN AIR SPRAYER. Joan M. Lish and D. C. Thill, Research Associate and Professor, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83843.

Abstract. This research was initiated to compare an air-assist sprayer to a conventional sprayer. Initial testing in 1991 indicated that herbicide efficacy with the air sprayer was better than or equal to a conventional sprayer and that drift was not more serious with an air sprayer than a conventional sprayer. Postemergence wild oat herbicides were evaluated in winter wheat and spring barley in 1992. Wild oat control was better with the air sprayer (75%) than the conventional sprayer (61%) when averaged over diclofop rates. Wild oat control with difenzoquat and imazamethabenz was better with conventional application than with air spray application. Soil was dry and the air created a large amount of dust. This may have inactivated some of the herbicide. Barley test weight was better with conventional applications (726 g/L) than with air-assist applications (720 g/L) when averaged over difenzoquat rates. Barley grain yield was not affected. Wheat yield and test weight were not affected by sprayer application method of imazamethabenz. Thifensulfuron plus tribenuron (19 g/ha) were applied to 4 to 5 node 'Columbian' peas on June 2, 1992 to evaluate drift. Pea plants were sampled at full bloom at 0, 2, 3, 5, 6, 8 9, 11, 12, 15, 18, 21, 24, 30, 37, and 49 m downwind of the spray swath. Drift was less from the air assist spray system than the conventional applications.

Two experiments, one each in wheat and pea, established spring 1992 will determine the effects of reduced herbicide rate in winter wheat-spring pea rotations. Weed control in wheat was better with all rates than the check. Field pennycress and prickly lettuce control was less with 0.3X rate than 0.7X or 1X rate. Weed control in pea was better with all rates compared to the check, but there was no difference among rates. Wheat yield, test weight, and pea yield did not differ among any rates including the untreated check.

SYNERGISM BETWEEN PHENMEDIPHAM PLUS DESMEDIPHAM AND ETHOFUMESATE FOR COMMON KNOTWEED CONTROL IN SUGARBEETS. R. F. Norris, Associate Professor, Section of Botany, University of California, Davis, CA 95616.

Abstract. Common knotweed is a serious weed in some areas of sugarbeet production in California. Uncontrolled knotweed caused between 50 and 70% yield loss. Applications of between 1.1 and 1.6 kg ha^{-1} of phenmedipham, desmedipham, or the commercial mixture of phenmedipham plus desmedipham typically controlled less than 60% of the weed when applied at sugarbeet growth stages indicated on the label. Split applications did not consistently improve control when applied to sugarbeets at the two true-leaf stage of growth, but split applications so that treatment was started when sugarbeets were at a late cotyledon growth stages did improve weed control. Postemergence application of ethofumesate, at up to 1.7 kg ha^{-1}, also only provided partial control, which typically did not exceed 60%. Splitting application of ethofumesate did not improve weed control; any delay in application resulted in decreased efficacy. Tank mixtures of the herbicides typically controlled 80 to 95% of the weed. A typical field result was 75% common knotweed control on a count basis when 0.7 kg ha^{-1} of phenmedipham plus desmedipham was applied, 66% control with ethofumesate at 0.8 kg ha^{-1}, and 94% when the two herbicides were applied tank mixed. Results of evaluation under greenhouse conditions were similar. Phenmedipham plus desmedipham at 1.1 kg ha^{-1} controlled 50% of common knotweed (dry weight basis); 1.1 kg ha^{-1} of ethofumesate controlled 59%, and the tank mixture controlled 87%. Analysis of the results of field and greenhouse trials using Colby's formula indicated that the interaction between the herbicides was synergistic, with increases ranging from +3.0% to greater than +40%.

SIMULATED DRIFT OF POSTEMERGENCE HERBICIDES ON SUGARBEETS. R. W. Downard and D. W. Morishita, Research Associate and Assistant Professor, Department of Plant, Soil and Entomological Sciences, University of Idaho, Twin Falls, ID 83303.

Abstract. Foliage injury from drift ranged from slight to complete death and the longevity of injury did affect yield and sugar content. Postemergence herbicides were sprayed over sugarbeets at below labeled rates (0.5X, 0.1X, and 0.01X) to stimulate drift from adjacent or nearby fields. Crop injury was examined in terms of foliage injury, yields, sugar content, nitrates and conductivity. All treatments showed moderate to severe foliage injury 11 days after treatment (DAT). All 0.01X rate treatments showed a decrease in foliage injury symptoms 19 and 31 DAT. These treatments were also the highest yielding and were not significantly lower than the untreated check. Rate had an effect on sugar content with 0.1X and 0.5X significantly lowering sugar content from that of the untreated check. There were no significant differences in nitrates and conductivity. Simulated drift from herbicide rates at 0.01X indicate initial injury to foliage is moderate but the sugarbeets tend to overcome these effects with no lasting injury to root yields or sugar content.

WEED CONTROL IN FALL-SEEDED ALFALFA WITH IMAZETHAPYR ALONE OR AS A SEQUENTIAL TREATMENT. R. N. Arnold, E. J. Gregory, and M. W. Murray, Pest Management Specialist, Professor of Agronomy, and Research Assistant, Agricultural Science Center, New Mexico State University, Farmington, NM 87499.

Abstract. Imazethapyr is a member of a new herbicide family called imidazolinones. Imazethapyr is used to control a wide range of grass and broadleaf weeds in dormant and fall-seeded alfalfa, edible beans, snap and Lima beans, peas, and lentils throughout the United States. In the fall of 1989 through 1992, at the New Mexico State University Agricultural Science Center at Farmington, NM, imazethapyr was applied postemergence alone or as a sequential treatment for grass and broadleaf weed control in fall-seeded alfalfa. Redroot and prostrate pigweed control was good to excellent with all treatments except bromoxynil and 2,4-DB applied at 0.25 and 0.5 lb/A. Barnyardgrass and green foxtail control was excellent with all treatments except postemergence applications of imazethapyr at 0.047 and 0.063 lb/A, bromoxynil at 0.25 and 0.38 lb/A, and 2,4-DB at 0.5 and 0.75 lb/A. For the first cuttings yields ranged from 1.9 to 2.3 T/A and protein content from 16.8% to 24% in all treatments including the check. Crop injury was measured and recorded as the number of live plants/m^2. Pendimethalin and trifluralin applied preplant incorporated at 1 and 0.75 lb/A alone or with a sequential postemergence treatment of imazethapyr applied at 0.063 lb/A had the least plants/m^2 of any treatment. Stand counts ranged from 7 to 26 plants/m^2.

THE EFFECT OF TIMING ON THE INCORPORATION OF TRIFLURALIN AND EPTC GRANULES WITH IRRIGATION.

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Abstract. Granular formulations of trifluralin and EPTC have gained widespread usage because of improved weed control and greater application efficiency and accuracy. Product labels recommend incorporation soon after application. Both herbicides are commonly incorporated with irrigation water when used on alfalfa. Timely incorporation with irrigation water may not always be possible. Large field size and acreage may require one or more days to irrigate. Several days may also be required between ordering irrigation or pesticide applications and the time they occur. EPTC is one of the most volatile of all herbicides. Microbial breakdown is normally described as the main mechanism by which EPTC is lost although in the irrigated Southwest it is most commonly lost by contact with irrigation water. It is readily volatilized from the water of wet soil or leached deep into the soil profile where organic matter is low, as it is in much of this region. Trifluralin, on the other hand, is strongly absorbed on soil and slows negligible leaching with the irrigation water. Trifluralin is slightly volatile and can be lost from degradation by microorganisms in the soil or by photodecomposition where it is left on the soil surface. A test was conducted to determine the effect of timing on the incorporation of trifluralin and EPTC granules with irrigation.

This test was conducted at the University of Arizona Yuma Mesa Agriculture Center on Superstition sand soil. Trileaf 2 pearl millet was used as an indicator crop to simulate the effect of EPTC and trifluralin granules on similar summer annual grasses. The millet was planted in rows 6 inches apart and 0.25 inches deep. The herbicides were applied over the top of the millet and incorporated with an overhead lateral move sprinkler system. The treatments included in this test were EPTC 10% granules at 1 and 3 lb/A and trifluralin 10% granules at 0.5 and 2 lb/A. Each treatment was incorporated with between 1.3 and 1.5 inches of water applied either 12 h, 1, 3, 5, 7, or 14 d after application for a total of 24 treatments and an untreated check. There were three replications of each treatment. The plots measuring 30 by 2 ft were planted and treated on April 9, 1992. After the initial irrigation, approximately 0.3 inches of water was applied every 2 d until evaluation counts were made on May 4, 1992. Evaluation consisted of counting the number of emerged millet seedlings per 3 ft in the center of the three planted rows.

The rates of both trifluralin and EPTC represented a rate lower than that normally used and a normal to high use rate. The seedling counts made on May 4, 1992, 25 d after planting and treatment, indicated that trifluralin at the 2 lb/A rate remained stable and effective even when incorporated 14 d after application. The lower rate of 0.5 lb/A started to break when exposed for 7 d before incorporation but still was very effective after 14 d of exposure. The high rate of EPTC was effective when incorporated 12 h after application but was marginally effective when exposed for 3 d before incorporation. EPTC remained marginal at the high rate after 3 d of exposure and until the end of the test. The low rate of EPTC was marginal when exposed for 12 h and ineffective after 5 d of exposure.

Table. The effect of timing on the efficacy of trifluralin and EPTC in controlling pearl millet.

Time between application & incorporation	Trifluralin 10G		EPTC 10G	EPTC 10G	Untreated
	lb/A		lb/A		
	0.5	2	1	3	-
	Seedlings (per 3 ft of row)				
12 hrs.	0	0	12.7	1.3	51.7
3 days	0	0	23.3	13	48.7
5 days	0	0	38.3	28	44
7 days	0.6	0	48.7	15.3	48.0
10 days	5.3	0.3	39.3	15	50.7
14 days	5.3	0	20	19	44

MON-13200: A NEW BROAD SPECTRUM PREEMERGENCE HERBICIDE FOR COLUMBIA BASIN ALFALFA.

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Abstract. Mon-13200 provides excellent preemergence broadspectrum annual weed control in central Washington irrigated alfalfa. Following the last alfalfa cutting in September-October, fall applications of 0.25 to 1 kg/ha of Mon-13200 control narrowleaf and broadleaf weeds including chickweed, downy brome, shepherdspurse, foxtail and barnyardgrass. Unit activity of the product is greater on narrowleaf weed species. Established alfalfa is tolerant to granular and sprayable formulations of Mon-13200 even when applied to non-dormant, green regrowth in the fall. This fall application window for central Washington irrigated alfalfa is superior to a spring application, particularly for the granular formulation of Mon-13200.

ENHANCEMENT OF PARAQUAT WITH LOW RATES OF PHOTOSYNTHESIS INHIBITOR HERBICIDES FOR WEED CONTROL IN ALFALFA.

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INTRODUCTION

Winter annual weeds constitute the most common weed problem facing the alfalfa hay grower. Troublesome broadleaf weeds are mainly in the mustard family such as: flixweed, tumble mustard, and shepherdspurse. Other problem broadleaf weeds are prickly lettuce, and whitestem filaree. Troublesome grasses are downy brome, hare barley, and bulbous bluegrass.

The spring application period in the intermountain area of Northeastern California usually occurs between February 20 and March 15 at the 4,500 foot elevation. This is the period of time when weeds start to grow vigorously and alfalfa begins it's slow rebirth. The spring application period lasts from 2 to 4 wk depending on temperature, weather conditions and soil moisture. The spring application period ends when new spring growth of the alfalfa reaches 2 inches tall.

The timing for paraquat application is perfect during the spring application period. The winter annual weeds are growing vigorously and the alfalfa new spring growth is usually behind the weeds by at least two weeks. However, paraquat has given inconsistent weed control in the intermountain area. Poor control by paraquat has been attributed to the hardening of the weeds from high light intensities, winter draught, and low humidity conditions.

Plant reaction to paraquat mixed with photosynthesis inhibitors. Plants treated with paraquat and kept in darkness are not damaged quickly but they soon die if illuminated. The damage in those plants exceeds that of plants treated in light (2). This suggests movement of paraquat. Paraquat applied in full sunlight gave more rapid desiccation of plants than applications made in 70% shade. However, the shade applications gave more persistent control. Likewise, late evening applications reduced initial speed of damage and increased longevity of weed control two fold (4). Paraquat activity is dependent on light quality and intensity before treatment and on the length of the period of illumination after treatment (2).

Headford (4), evaluated the effects of paraquat applications in the shade verses full sunlight and late evening applications. He found that by mixing paraquat with a low rate of the photosynthesis inhibitor bromacil gave weed control similar to that of paraquat alone in the late evening or in the shade. This was basically a two fold response over the same rate of paraquat applied mid day in full sunlight. These results suggested a synergistic reaction.

There are problems associated with limiting applications of paraquat to late evenings. Often the window for correct application timing (spring application period) is very short, perhaps only one or two weeks. Enhancing the performance of paraquat by mixing it with a photosynthesis inhibitor can allow optimum performance of paraquat without limiting its use to time of day (4).

This enhanced activity can be attributed to both increased foliar absorption and the apoplastic movement of the photosynthesis inhibitor and paraquat. The increased activity of simazine when applied with paraquat results from the increased permeability of leaf cells because the paraquat action. There was likewise an increase in the absorption of paraquat and the movement of paraquat in the treated leaves (6). The increase in final kill when this mixture is made may result from the photosynthesis inhibitor reducing the rate of cell damage done by paraquat and allowing the paraquat to translocate locally within the leaf (7).

Reducing herbicide rates while maintaining weed control. By increasing the translocation of herbicides in plants, rates of herbicides may be decreased with no net difference in effectiveness. A reduction of the amount of herbicide introduced into the environment could possibly lower the hazard of harmful effects on the environment (13). This would only be true if the mechanism used to increase translocation did not increase the harmful effects of the herbicides on the environment.

The purpose of this study was to develop a practical program of weed control in alfalfa utilizing enhanced paraquat applications. Currently labeled tank mixtures of paraquat and photosynthetic inhibitors are limited to the high lethal doses of the photosynthesis inhibitors. As this review indicates, high rates are not the optimum rate for paraquat enhancement. The ICI Plant Protection Division is marketing a pre-mix formulation of paraquat and diuron in South America by the trade name 'Gramocil'. This pre-mix formulation will probably not be labeled in the United States. O'Donovan and O'Sullivan (5) experimented with one low rate of paraquat and one low rate of metribuzin with good success. More information was needed in order for alfalfa growers and pest control applicators to take the currently labeled photosynthesis inhibitor herbicides at the proper rate and tank mix them with the proper rate of paraquat in order to get satisfactory weed control in alfalfa. This study evaluated these several available herbicide mixtures under actual grower conditions and a wide spectrum of weeds.

METHODS AND MATERIALS

This study was conducted during the yr 1987 through 1990. Individual experiments were conducted at different sites within these yr. Each individual site was treated as an individual location when analyzing treatment effect combined by location. The site variation among location resulted from soil texture and moisture differences and weeds present, as well as environmental conditions such as rain and past cultural practices (Table 1). Each experiment was conducted on sites that were not treated with herbicides in previous yr.

A randomized complete block design was used in this study. Four replications were used. The plot size in the preliminary studies in 1985 and 1986, and also at the locations conducted in 1987, was 25 feet by 10 feet.

The treated area for each plot was 6.7 feet wide, leaving an untreated buffer of approximately 3 feet between the treated strips. These untreated strips were valuable in visually rating weed control in the adjacent treated areas. If there were no plants of a particular weed species present in the untreated strips, no rating was made for that weed in the treated plot. In 1989 and 1990, large plots measuring 20 feet by 100 feet were utilized. Once again an untreated buffer was used by treating a strip 18 feet wide down the length of the plot. The same technique was used for evaluating the presence or absence of weeds in reference to control.

Each experiment was established in grower managed alfalfa fields throughout Lassen County, California. Sites were selected because of known presence of weeds in the trial area. This allowed for a wide variety of weeds and environmental conditions to be used to evaluate the weed control efficacy of each herbicide tank mixture. It also provided a demonstration to the grower regarding the performance of how the various tank mixtures would perform in comparison to the standard treatment or to no treatment at all.

Table 1. Weeds evaluated at different locations.

	Location - year and site number					
Weeds evaluated	87-1	89-1	89-2	89-3	90-1	90-2
Grass weeds:						
Bromus tectorum, downy brome	X		X		X	X
Hordeum leporinum, hare barley	X			X		
Poa bulbosa, bulbous bluegrass		X				
Broadleaf weeds:						
Sisymbrium altissimum, tumble mustard	X	X	X	X		
Descurainia sophia, flixweed		X				
Erodium moschatum, whitestem filaree			X			

Timing of the herbicide applications was limited to the spring application period, when weeds were growing vigorously and before the alfalfa spring growth reached 2 inches. This is the same period of time that paraquat would normally be applied commercially by the growers. Because this limitation was imposed, the performance of the standard photosynthesis inhibitor herbicides when used alone was restricted severely. The results reported in this study should not be inferred as representative of normal weed control efficacy when photosynthesis inhibitor herbicides are applied at the correct time for the particular herbicide. Many of these photosynthesis inhibitor herbicides have only pre-emergence activity and should not be applied alone commercially during the spring application period. They were included in this study to provide a reference weed control level and a demonstration that these herbicides should not be used this late in the season. The treatments evaluated at each location are illustrated in Table 2. Five herbicide treatments that were tested in most of the individual experiments were selected to be analyzed by location.

Analysis of herbicide efficacy on weeds. The evaluated weeds listed in Table 1 were grouped into grass and broadleaf categories for the purpose of evaluating herbicide treatment effectiveness across location. When more than one grass or broadleaf species was evaluated at a particular location, the average of all grass weed species and the average of all broadleaf weed species were used for the plot values. All data were analyzed using the computer statistics program MSTAT-C. Single degree orthagonal comparisons were used to determine significant differences between specific treatment means.

Because this study is a compilation of experiments over many yr, not all of the herbicide treatments were used in each location. When analyzing these data over location, there are missing data that must be accounted for by reducing the error term in the analysis of variance. By reducing the error term, the test becomes less sensitive in detecting differences among treatments that may be real. In order to deal with this problem, I analyzed data of pairs of treatments from the maximum possible number of locations in which each member of the pair was present. A common question that growers ask is: "Are any of the paraquat tank mixtures any better than paraquat alone?" To attempt to answer this question, I compared the control following paraquat alone to that of each of the three paraquat/photosynthesis inhibitor mixtures. The comparison of paraquat to paraquat/hexazinone included data from one of the preliminary trials in 1986.

Table 2. Herbicide treatments evaluated at different locations.

Herbicide	Rate	Location - year and site number					
		87-1	89-1	89-2	89-3	90-1	90-2
	lb/A						
*Paraquat	0.5	X	X	X	X	X	X
Paraquat	0.375	X		X	X		
*Paraquat/hexazinone	0.375/0.25	X	X	X	X	X	X
Paraquat/hexazinone	0.375/0.125	X	X				
Paraquat/hexazinone	0.25/0.25	X					
*Paraquat/metribuzin	0.375/0.25	X		X	X	X	X
Paraquat/metribuzin	0.375/0.125	X		X	X		
*Paraquat/diuron	0.375/0.5	X	X	X	X	X	X
Paraquat/diuron	0.375/0.375	X					
Paraquat/diuron	0.375/0.25		X				
Paraquat/diuron	0.375/0.185			X	X		
Paraquat/simazine	0.375/0.5	X					
Hexazinone	0.5		X		X		
Metribuzin	0.5		X				
*Untreated	0	X	X	X	X	X	X

All treatments included surfactant at the rate 0.125% v/v; *= Herbicide treatments selected to be analyzed by location.

Analysis of herbicide phytotoxicity on alfalfa. Over the period of time that this study was conducted, the paraquat mixture with hexazinone had been used widely by growers throughout Lassen County and neighboring counties within Northeastern California. Because of the very narrow application window, or short time in which this paraquat/hexazinone mixture or paraquat alone can be legally applied, growers had gone beyond the application time that was permitted by the label. That label restriction is not to apply paraquat after alfalfa plants exceed 2 inches of new spring growth. On several occasions when later applications were made, growers experienced reductions in yield up to one ton per acre on the first cutting of hay. In order to substantiate that the time of application was the problem and not herbicide treatments, a study was done in 1990 to evaluate time of herbicide application.

An experiment utilizing the randomized complete block design was conducted using two application timings for each of the four treatments in this study along with an untreated check. The timing for the herbicide applications were: 1) the "correct" time when the alfalfa spring regrowth was less than 2 inches tall; 2) the "late" time when the alfalfa spring growth was more than 2 inches tall. These applications were made two weeks apart. The "correct" application was made when the alfalfa was 1 to 2 inches, and the "late" application was made when the alfalfa was 3 to 4 inches tall.

Alfalfa hay yield was used as the measurement of herbicide treatment phytotoxicity on the alfalfa. The yield was obtained by harvesting a 3 foot by 20 foot area with a Carter forage harvester. Fresh weights were recorded and sub-samples weighed and dried to determine percent dry matter of the fresh material. Fresh weights were then adjusted and reported on a 90% dry matter basis.

RESULTS AND DISCUSSION

Herbicide efficacy on weeds. Tables 3 and 4 contain the individual location herbicide weed control means of grass and broadleaf weeds respectively. Location effect on weed control is easily spotted on these tables. Differences among herbicide treatment means were significant at the 99% confidence level at all locations. Generally speaking, these results are quite typical of those observed following commercial grower applications.

Table 3. Grass weed control in alfalfa plots in different yr and sites.

Herbicide treatments	Rate	Year and site number					
		87-1	89-1	89-2	89-3	90-1	90-2
	- lb/A -	Grass control %					
Paraquat	0.5	79.8	95	85	89.5	90.8	83.8
Paraquat + hexazinone	0.375 + 0.25	90.3	97.5	100	90	99.5	92.8
Paraquat + metribuzin	0.375 + 0.25	83.5	95.2	100	97.5	99.5	95.8
Paraquat + diuron	0.375 + 0.5	90.3	92.5	92.5	95.0	83.8	79.5
Untreated	0	0	0	15	0	10	10
Probability		***	***	***	***	***	***
% C.V.		6.2	6.7	13.4	9.8	11	9.2
LSD (0.05)		6.6	7.3	16.5	11.3	13	10.2

*** = significant at the 99% confidence level.

Table 4. Broadleaf weed control in alfalfa plots in different yr and sites.

Herbicide	Rate	Year and site number			
		87-1	89-1	89-2	89-3
	- lb/A -	Broadleaf control %			
Paraquat	0.5	90	77.5	57.1	72.5
Paraquat + hexazinone	0.375 + 0.25	90	81.3	90.4	90
Paraquat + metribuzin	0.375 + 0.25	100	90.4	96.7	92.5
Paraquat + diuron	0.375 + 0.5	100	82.5	77.8	88.7
Untreated	0	10	0	0	0
Probability		***	***	***	***
% C.V.		20	12.8	24.2	10.6
LSD (0.05)		24.8	12.6	26.3	11.3

*** = significant at the 99% confidence level.

Table 5 displays the summary and analysis of the herbicide treatment data involving locations. The differences among herbicide treatment means were significant at the 99% confidence levels and the differences among location means were significant, but at the 90 and 95% confidence levels for grass and broadleaf control, respectively. There was no significant location by herbicide interaction.

Results of single degree of freedom orthagonal comparisons reveal that the paraquat/metribuzin mixture was significantly better than paraquat alone in grass and broadleaf weed control. The paraquat/hexazinone treatment was significantly better that the paraquat alone treatment in controlling grass weeds, but was not significantly different in controlling broadleaf weeds. Paraquat mixed with diuron did not give any improvement over the paraquat alone treatment in controlling either weed type.

Some data were missing for the analysis resulting in a reduction in the error terms. This reduced error term also reduced the sensitivity of the test. In order to increase this sensitivity, three more analyses were conducted using data from only those locations where the pairs of treatments were tested (Tables 6, 7, 8). Thus, paraquat alone was compared with the three mixtures in three separate single degree of freedom analyses of variance.

In Table 6 the effects of paraquat alone are compared against those of the mixture of paraquat and hexazinone. The analyses indicate that the paraquat/hexazinone mixture gave significantly better grass and broadleaf weed control than did paraquat alone. This contradicts the results of the orthagonal comparison of broadleaf control data presented in Table 5. The comparison in Table 6 is more likely to reflect the actual level of significance, because it involves a larger data base.

Table 5. Summary and analysis of weed control following five herbicide treatments combined from several locations, 1987-1990 data.

Herbicide	Rate	Grass control	Broadleaf control
	- lb/A -	- % -	- % -
Paraquat	0.5	87.1	73.3
Paraquat + hexazinone	0.375 + 0.25	95	87
Paraquat + metribuzin	0.375 + 0.25	95.2	94.9
Paraquat + diuron	0.375 + 0.5	87.9	85.3
Untreated	0.0	5.8	2.5
Probability:			
Location		*	**
Herbicide		***	***
L x H		NS	NS
% C.V.		10.7	17.4
LSD (0.05)			
Orthagonal Comparisons:		F	P
Grass Control			
Par vs. par/hex		3.0454	*
Par vs. par/met		3.1226	*
Par vs. par/diu		<1	NS
Broadleaf Control			
Par vs. par/hex		2.62	NS
Par vs. par/met		5.98	**
Par vs. par/diu		2.37	NS

* = significant at 90% confidence level
** = significant at 95% confidence level
*** = significant at 99% confidence level

The efficacy of the mixture of paraquat and metribuzin was compared to paraquat alone and summarized in Table 7. The paraquat/metribuzin mixture at these rates gave significantly better weed control than did paraquat alone. These data agree with the orthagonal comparisons in Table 5.

Paraquat mixed with diuron at the rates tested gave mixed, uncertain results when compared to paraquat alone. Table 8 indicates that the paraquat/diuron mixture was better in controlling weeds than paraquat alone only at the 90% confidence level while the orthagonal comparison in Table 5 states this difference is not significant. Both types of analyses agree that the level of grass control was not significantly different than that of the paraquat alone treatment.

Herbicide phytotoxicity on alfalfa. Table 9 contains alfalfa yield data which provides a measure of the phytotoxicity from the treatments in this study. The single degree orthagonal comparisons reveal that the "late" time of application reduced the yield of all herbicide treatments while the "correct" time of application did not.

Yield of plots treated with paraquat alone were not significantly different from those of the paraquat photosynthesis inhibitor mixtures when all treatments were applied at the correct time. The late paraquat application resulted in significantly (90% confidence level) reduced yields compared to those following the late applied paraquat mixtures.

Table 6. Summary and analysis of paraquat vs. the mixture paraquat and hexazinone from all possible locations (yr and sites).

Herbicide	Rate	Grass control	Broadleaf control
	lb/A	%	
Paraquat	0.5	86.8	76.2
Paraquat + hexazinone	0.375 + 0.25	95.7	89.6
Probability:			
Location		*	*
Herbicide		***	**
L x H		NS	NS
% C.V.		6.3	16.3
No. of locations		7	5

*** = Significant at the 99% confidence level.
** = Significant at the 95% confidence level.
* = Significant at the 90% confidence level.
NS = No significant difference.

Table 7. Summary and analysis of paraquat vs. the mixture of paraquat and metribuzin from all possible locations (yr and sites).

Herbicide	Rate	Grass control	Broadleaf control
	lb/A	%	
Paraquat	0.5	85.5	71.9
Paraquat + metribuzin	0.375 + 0.25	95.2	96.4
Probability:			
Location		***	**
Herbicide		***	***
L x H		***	*
% C.V.		5.3	15.7
No. of locations		5	3

*** = Significant at the 99% confidence level.
** = Significant at the 95% confidence level.
* = Significant at the 90% confidence level.

Table 8. Summary and analysis of paraquat vs. the mixture of paraquat and diuron from all posible locations (yr and sites).

Herbicide	Rate	Grass control	Broadleaf control
	- lb/A -	%	
Paraquat	0.5	87.1	73.3
Paraquat + diuron	0.375 + 0.5	87.9	85.3
Probabilty:			
Location		*	***
Herbicide		NS	**
LxH		NS	NS
% C.V.		7.4	15.6
No. of Locations		6	4

*** = Significant at the 99% confidence level.
* = Significant at the 90% confidence level.
NS = No significant difference.

The effects of "correct" vs. "late" applications of each treatment were compared. In most comparisons the "late" applications resulted in significantly reduced yields with a confidence level of 99%. The only departure from this pattern involved the paraquat/hexazinone treatment. Paraquat/hexazinone did not significantly reduce yield when applied "late". However, given the severe yield reductions shown by the other treatments, I believe that these data should be treated as an anomaly until further tests prove otherwise.

Table 9. Alfalfa yield following the recommended or correct vs. the late time of herbicide application.

Herbicide	Rate	Forage Yield - lb/A Correct	Forage Yield - lb/A Late
	- lb/A -		
Paraquat	0.5	3926	2450
Paraquat/hexazinone	0.375/0.25	3488	3553
Paraquat/metribuzin	0.375/0.25	4007	2868
Paraquat/diuron	0.375/0.5	3687	2837
Untreated	0.0	3429	
Probability		***	
% C.V.		14.9	
LSD (0.05)		731.9	
Orthagonal comparisons:		Yield - lb/A	P
Correct vs. untreated		3777 vs. 3429	NS
Correct vs. Late		3777 vs. 2927	***
Corr. par vs. Corr. mixes		3926 vs. 3727	NS
Late par vs. Late mixes		2450 vs. 3086	*
Par: Correct vs. Late		3926 vs. 2450	***
Par/hex: Correct vs. Late		3488 vs. 3553	NS
Par/met: Correct vs. Late		4007 vs. 2868	***
Par/diu: Correct vs. Late		3687 vs. 2837	***

Correct = correct application time when alfalfa spring growth is less than 2 inches.
Late = late application time when alfalfa spring growth is greater than 2 inches.
*** = significant at the 99% confidence level.
NS= no significant difference.

CONCLUSIONS

The mixture of paraquat and metribuzin, as well as the paraquat and hexazinone mixture gave better control of both winter annual grass and broadleaf weeds than did the standard paraquat alone treatment. Paraquat mixed with diuron at the rate of 0.5 lb/A did not control grass any better than did paraquat alone, but did control broadleaf weeds better. All four of the paraquat and paraquat mixture treatments gave satisfactory or near satisfactory weed control as compared to no herbicide treatment. The paraquat and paraquat photosynthesis inhibitor mixtures did not reduce alfalfa yield when the herbicide was applied before the alfalfa spring growth reached 2 inches. When applied after alfalfa spring growth exceeded 2 inches, the paraquat alone treatment reduced alfalfa yield more than did any of the paraquat mixtures.

The paraquat plus photosynthesis inhibitor mixtures may be an ideal treatment for alfalfa grown on soils with a high organic matter content. Soils with organic matter in excess of 5% tend to tie up and inactivate soil active herbicides such as hexazinone and metribuzin. Even when these herbicides are applied to organic soils, the rates must be increased. The cost of treating these soils are often double the cost of treating a mineral soil with an organic matter content of less than 3%. Paraquat plus a low rate of photosynthesis inhibitor herbicide can be cost effective and provide adequate weed control of winter annual weeds in alfalfa.

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YELLOW MIGNONETTE BIOLOGY AND CONTROL. Edward S. Davis, D. M. Wichman, and J. D. Harris, Assistant Professors and Research Associate, Central Agricultural Research Center, Moccasin, MT 59462.

Abstract. Yellow mignonette is a perennial species native to Eurasia that was introduced to North America as an ornamental. It was first reported in Montana in 1958 growing along a gravel road in Judith Basin county and since spread along roadways throughout the county. Infestations now occur in alfalfa-grass pastures, dryland cereal grain fields, rangeland and waste areas. Little information exists on the biology and control of yellow mignonette however it is known to be well adapted to the arid and semiarid rangelands of Iran where it occurs at elevations, temperature and precipitation zones similar to much of the western U.S. The rapid establishment and spread to crop and noncrop land documented in central Montana justifies concern for the potential proliferation of this perennial weed species.

The objectives of this research were to document the occurrence and spread of yellow mignonette in central Montana; measure the reproductive capability of yellow mignonette by seed and root sections; evaluate the forage quality and potential for livestock grazing of yellow mignonette; and evaluate herbicides for controlling mignonette in crop and noncrop situations.

Yellow mignonette was surveyed in 1989 and 1992. Roadside infestations increased from 14 miles in 1989 to 42 miles in 1992. Plants thrive in disturbed environments along gravel roads and produce seed pods ideally

suited for transportation by motor vehicles. Roadside herbicide trials were established October 2, 1991 and June 24, 1992. Treatments of dicamba plus 2,4-D, picloram plus 2,4-D and imazethapyr alone did not provide acceptable control 10 months after treatment (MAT). Imazapyr at 1 lb/A gave 77% control 10 MAT but also completely killed the perennial grasses. Metsulfuron at 0.12 to 0.18 oz/A plus 1 lb/A 2,4-D resulted in 99% and 86% control of yellow mignonette 9 and 10 MAT respectively.

Several grain fields and alfalfa-grass pastures in central Montana are heavily infested with yellow mignonette. The root system of yellow mignonette resembles alfalfa having a deep penetrating primary taproot and numerous secondary lateral roots. However, unlike alfalfa, yellow mignonette roots have vegetative buds along their entire length and under cultivation these severed root sections serve as reproductive structures. Root sections (10 cm long) taken from 1 and 2+ year-old yellow mignonette plants to a depth of 50 cm showed equal regenerative ability when planted in individual containers under greenhouse conditions.

Yellow mignonette also reproduces by seed which germinates best under conditions of darkness. Germination of seed collected in 1991 and 1992 showed 2 to 3 times greater germination in the dark than seed incubated under alternating light and dark, suggesting a need for burial to maximize germination. In depth of emergence experiments, maximum emergence occurred at depths of 0.5 to 1.5 cm and no emergence occurred from depths greater than 6 cm. Seed placed on the soil surface resulted in only 17% germination.

Yellow mignonette infests alfalfa-grass meadows that are utilized as spring pasture for cattle. Since selective removal of yellow mignonette from alfalfa with herbicides is difficult, grazing studies were conducted in 1992 to evaluate the potential of yellow mignonette as a forage for livestock. Plant samples analyzed for crude protein, neutral detergent fiber and acid detergent fiber showed yellow mignonette to be equal to alfalfa in terms of forage quality. However, yellow mignonette also tested high in nitrates indicating a potential hazard to livestock. Highest nitrate levels (2.5 to 3.1%) occurred in plants during the rosette to full flower growth stages when mignonette is most palatable and when cattle are using the pastures. Eighteen cow-calf pairs were confined to a 5 A pasture for 9 d and forage utilization was measured. The cattle grazed grass and alfalfa but did not graze the mignonette. Sheep were also confined in a similar study and after 5 d all of the available grass was removed and the yellow mignonette was trampled but not foraged. When left without supplemental feed for 2 additional d the sheep did consume the yellow mignonette and did not show signs of nitrate poisoning however, the site was severely overgrazed.

Herbicide trials were established in the fall and summer to evaluate yellow mignonette control post harvest to a barley crop. Several treatments provided temporary burndown but regrowth occurred within a month following application. Metsulfuron at 0.24 oz/A with 2,4-D at 1 lb/A gave 96 to 100% control of seedlings and perennial plants 10 MAT in the fall and 2 MAT in the spring. Yellow mignonette appears to be easily controlled with metsulfuron.

HARD RED WINTER WHEAT VARIETY TOLERANCE TO FALL APPLICATIONS OF QUINCLORAC. R. N. Klein and D. J. Thrailkill, Professor and Extension Research Technologist, University of Nebraska West Central Research an Extension Center, North Platte, NE 69101.

INTRODUCTION

For western Nebraska producers of hard red winter wheat in the wheat-fallow rotation, field bindweed is an important perennial weed. Field bindweed has proven hard to control and by using moisture during the fallow period it can have a detrimental effect on wheat yields. Quinclorac has been studied and may be a potential herbicide to control this weed in the winter wheat-fallow rotation. Initial work has demonstrated that hard red winter wheat varieties have some tolerance to this herbicide. The objective of this study was to determine the selectivity of 30 hard red winter wheat varieties to quinclorac when applied in the fall to the growing wheat crop.

MATERIALS AND METHODS

A field trial was used to evaluate the tolerance of 30 hard red winter wheat varieties. Three rates of quinclorac (0.15, 0.25, 0.5 lb/A) were applied at the winter wheats 1-leaf or 3- to 4-leaf growth stage. Including the untreated check this resulted in 7 herbicide treatments. Sunnit II (surfactant) was to be added to all treatments at 2 pt/A. The experimental design was a strip plot with variety strips running perpendicular to the herbicide strips. Four replications were used and initial plot size was 6 by 30 feet. Soil at the site has a sandy loam texture and an organic matter content of 2.3%. The winter wheat varieties were planted 2 inches deep on September 21, 1991 at 60 lb/A using a hoe drill with 12 inch spacings. The treatments applied at the 1-leaf stage were made on Sept. 30, 1991 and the 3- to 4-leaf treatments were applied on Oct. 15, 1991. A 15 ft hooded plot sprayer equipped with 11002XR nozzles (20 inch spacing) was used to apply the herbicide treatments with a carrier volume of 20 gpa.

A mixing error occurred during the second spraying and the Sunnit II was applied at 6.6 pts/A rather than the desired 2 pts/A. The mistake was corrected before spraying the final 2 replications of the 0.5 lb/A treatment. To allow the 0.15 and 0.25 lb/A treatments to be correctly represented the untreated check treatment was shortened from 30 to 15 feet with the 0.15 lb/A treatment (now containing the correct surfactant rate) applied to the remaining 15 feet of 2 replications and the 0.25 lb/A treatment (also containing the correct surfactant rate) applied to the remaining 15 foot of the other 2 replications. This resulted in only two replications of the treatments applied at the 3- to 4-leaf stage using the correct amount of surfactant. When average grain yields were compared between the treatments with the 2 pt rate of Sunnit II and those same treatments with 6.6 pts of Sunnit II, yields were similar (50.6 bu/A using 2 pt vs. 51.6 bu/A using 6.6 pt). To obtain four replications per treatment and facilitate a statistical analysis of the treatments applied at the 3- to 4-leaf stage, two replications using 2 pt/A Sunnit II were combined with two replications using 6.6 pt/A Sunnit II. Plots were evaluated for visual signs of injury through the fall of 1991 and the spring of 1992. Plots were harvested by machine with a small plot combine.

RESULTS AND DISCUSSION

No visual signs of injury occurred among any of the varieties either in the fall of 1991 or the following spring. The winter wheat suffered significant winter injury because of cold temperatures in late October, and plant stands were reduced. This caused a less competitive wheat crop and resulted in a modest downy brome problem in many of the plots. Plots were evaluated on May 8, 1992 for percent of plants headed. No differences in heading could be detected between herbicide treatments.

Yields were analyzed statistically. The variety by herbicide interaction was highly significant (p value of 0.0004) indicating that the effect of the herbicide treatments on yield was not the same across all varieties (i.e. some varieties were more susceptible to yield effects than others). Because the interaction proved significant, no general conclusions that would apply to all varieties can be drawn and it was necessary to analyze the yield data by individual variety (Table 1.).

Of the 30 varieties screened, five varieties showed statistically significant yield reductions with applications of Quinclorac. NE88595 was the most susceptible to yield reductions in this trial with significant reductions at all treatment levels analyzed except the 0.15 lb/A rate applied at the 3- to 4-leaf stage. 2163 (Pioneer), NE86L177, and NE88615 had significant yield reductions at the 0.5 lb/A rate at both application times when compared to the untreated check. Agripro Thunderbird showed a significant yield reduction at the 0.5 lb/A rate only when applied at the 3- to 4-leaf stage.

Although some relatively large yield differences exist among herbicide treatments in some other varieties, high variability between plots, due in part to the effects of winter injury and the ensuing downy brome infestation, will not allow us to determine that the differences are meaningful.

Table 1. Winter wheat grain yields[a].

		Application timing						
		1-leaf stage quinclorac rate (lb/A)			3- to 4-leaf stage quinclorac rate (lb/A)			
Wheat variety	Untreated check	0.15	0.25	0.5	0.15	0.25	0.5	LSD (0.05)
	(bu/A)							
2163 (Pioneer)	64.6 a	62.1 a	61.8 a	52.8 b	62.9 a	63.1 a	50.7 b	8.3
Agripro Abilene	42.9	46.8	51.3	46.4	56.2	51.2	45.9	NS
Agripro Expw87	56.4	48.0	53.7	51.5	54.4	56.2	51.3	NS
Agripro Longhorn	55.5	51.7	53.7	52.3	50.6	49.1	47.2	NS
Agripro Thunderbird	58.7 a	56.3 a	52.2 ab	53.8 ab	54.8 a	57.5 a	46.3 b	7.8
Agripro Tomahawk	56.6	49.8	52.7	50.9	55.4	55.9	48.0	NS
Arapahoe	54.2	48.0	51.0	47.2	51.3	49.4	48.1	NS
Centura	55.2	48.9	48.7	45.1	53.9	52.5	48.5	NS
Karl	45.2 cd	46.8 bc	47.1 bc	46.7 bc	54.4 a	53.0 bc	39.5 d	6.5
Lamar	51.6	47.3	44.0	45.4	50.4	46.6	46.3	NS
N86L177	52.8 a	54.9 a	53.4 a	43.6 b	55.0 a	54.9 a	44.0 b	8.7
N87V106	54.5	45.4	49.5	56.1	57.0	55.2	49.6	NS
NE83404	55.5	49.2	53.7	43.6	50.7	52.7	50.2	NS
NE86501	49.1	48.4	43.3	45.4	48.0	48.5	40.5	NS
NE87612	51.0 abc	50.2 bc	52.8 ab	47.9 bc	47.4 bc	58.8 a	44.5 c	7.7
NE87615	60.6 a	54.5 a	54.4 a	41.7 b	60.2 a	57.3 a	38.2 b	7.2
NE88427	54.5	51.5	51.5	52.7	54.5	50.8	49.4	NS
NE88595	72.7 a	62.4 bc	60.6 c	61.9 bc	67.9 ab	58.6 c	58.6 c	6.5
Quantum QT562	63.0	56.9	60.6	56.7	57.9	61.3	53.8	NS
Quantum QT577	53.5	46.3	49.9	48.3	51.3	51.5	46.4	NS
Rawhide	47.3	51.5	51.1	47.3	54.0	54.9	50.2	NS
Redland	63.2	49.2	55.2	53.1	55.6	54.5	54.3	NS
Sandy	57.1	55.6	54.6	56.4	55.1	61.2	50.2	NS
Scout 66	49.3	54.1	52.0	51.9	52.0	55.0	46.9	NS
Siouxland	49.3	51.7	47.6	47.6	52.3	50.2	44.6	NS
Siouxland 89	51.6 abc	53.1 a	49.6 abc	45.5 c	54.0 a	51.8 ab	45.6 bc	6.1
TAM 107	59.6	57.6	55.8	58.4	55.5	58.0	52.2	NS
TAM 200	54.8	55.2	54.5	49.2	54.9	58.0	50.9	NS
Turkey	54.2	46.6	48.1	50.0	49.9	47.7	46.1	NS
Yuma	53.9	44.4	46.7	51.2	52.0	51.2	44.1	NS
Average	55.0	51.5	52.0	50.0	54.3	54.3	50.0	

[a] Statistical comparisons were made between herbicide treatments within each particular variety. Yields followed by the same letter were not significantly different using Fisher's guarded LSD (alpha = 0.05). Those varieties which failed to show a significant herbicide treatment effect using an ANOVA procedure do not have letters following the yields.

SUMMARY

No visual signs of crop injury were detected among the 30 hard red winter wheat varieties tested, after the application of up to 0.5 lb/A of quinclorac. When yield data were analyzed, the variety by herbicide interaction was highly significant suggesting that some varieties are more tolerant of fall applications of quinclorac than others. Of these 30 varieties, 25 showed no significant yield reduction to application of quinclorac. One (NE88595) had significant yield reductions at all treatment levels analyzed with the exception of the 0.15 lb/A rate applied at the 3- to 4-leaf stage. Three varieties (2163, N86L177, and NE87615) had significant reduction in grain yield at the 0.5 lb/A rate applied when applied at either the 1-leaf stage or the 3- to 4-leaf stage. One variety (Agripro Thunderbird) showed a significant yield reduction only at the 0.5 lb/A rate when applied the 3- to 4-leaf stage.

QUINCLORAC CONTROLS FIELD BINDWEED IN FALLOW. Phillip W. Stahlman, Research Weed Scientist, Ft. Hays, Branch, Kansas Agricultural Experiment Station, Hays, KS 67601.

Abstract. Control of field bindweed in fallow with quinclorac alone and in combination with other herbicides was evaluated in west-central Kansas over a 2 yr period. Fourteen months after herbicides were applied in mid-May in a reduced-tillage fallow-winter wheat rotation, bindweed control with tank mixtures of quinclorac at 0.3 kg/ha plus surfactant or crop oil adjuvants and 2,4-D amine at 1.1 kg/ha, dicamba at 0.6 kg/ha, or a commercial package mixture of glyphosate and 2,4-D (Landmaster BW) at 1.5 kg/ha ranged from 75 to 84% compared with 57% control for quinclorac at 0.3 kg/ha plus adjuvant. The tank mixtures were equally as effective as the standard treatment of 2,4-D plus picloram at 1.1 + 0.3 kg/ha. Field bindweed control was not increased by increasing quinclorac rate to 0.6 kg/ha or by tank mixing quinclorac with picloram at 0.06 kg/ha.

FIELD BINDWEED CONTROL IN HARD RED WINTER WHEAT FALLOW WITH QUINCLORAC. R. N. Klein and D. J. Thrailkill, Professor and Extension Research Technologist, University of Nebraska West Central Research and Extension Center, North Platte, NE 69101.

Abstract. For producers in the hard red winter wheat-fallow rotation in western Nebraska, field bindweed is a most important weed. Research has evaluated several herbicide and/or tillage options in the past. Many treatments have given good initial control but regrowth of field bindweed and seedling establishment took place in most treatments. A potential herbicide, quinclorac, has been studied since 1990 in western Nebraska for control of field bindweed in the winter wheat-fallow rotation. The research has included rates, tank mix partners, time of application, and sequential applications.

Fall applications of 0.25 lb/A quinclorac plus 2,4-D or dicamba gave >95% control of field bindweed in the fall after application. Quinclorac treatments of 0.5 lb/A gave >95% control of field bindweed during the spring and early summer following a fall application but then control decreased with field bindweed regrowth and seedling establishment. The addition of dicamba to a fall treatment of quinclorac has increased the longevity of control the following calendar year. The greater the rate of quinclorac (0.15 to 0.5 lb/A) applied in a single fall treatment the longer control was sustained the following spring and summer. In an application timing study with three single application times (July 17, 1991, August 15, 1991, and September 14, 1991) treatments applied on August 15 or September 14 had the highest initial control while those on July 17 had the greatest field bindweed control when evaluated during the following spring and summer. Quinclorac treatments were less affected by application timing than a tank mix of glyphosate plus 2,4-D.

With fall (quinclorac plus atrazine at 0.25 + 1 lb/A) plus spring (quinclorac plus dicamba at 0.25 + 0.25 lb/A) applications of quinclorac, 85% field bindweed control was achieved into July but dropped off significantly beyond that date. A 3 yr study utilizing successive yearly applications of quinclorac is in progress. The October 1992 evaluation showed a single application of picloram plus atrazine at 0.25 + 1 lb/A applied July 14, 1991 sustaining greater control of field bindweed than fall plus spring applications of quinclorac. The final quinclorac application in this study will be applied in the spring of 1992.

CANADIAN STUDIES ON DOWNY BROME. Robert E. Blackshaw, Weed Scientist, Agriculture Canada, Lethbridge, AB T1J 4B1 Canada.

Abstract. Downy brome has rapidly increased in distribution and density in southern Alberta and Saskatchewan during the last decade and is now considered the most troublesome weed in winter wheat and winter rye. Studies were conducted to determine a) potential yield losses in these winter cereals caused by various densities of downy brome emerging at various times relative to the crop, b) the competitive ability of several winter wheat

cultivars varying in height and growth habit with downy brome, c) herbicides to selectively control downy brome in winter cereals, d) soil temperature and moisture effects on downy brome establishment, and e) crop rotation and tillage practices to reduce downy brome infestations.

Downy brome at densities up to 400 plants m^{-2} reduced the yield of winter wheat (up to 68%) more than that of winter rye (up to 33%). Crop yield losses were greatest when downy brome emerged within three weeks of the crop. Late fall or early spring flushes of downy brome had little impact on yield but plants were still able to set viable seed. Yield reductions increased as downy brome density increased but tended to plateau at densities of 200 to 400 plants m^{-2}. Downy brome reduced the grain yield of the semidwarf wheat cultivars 'Archer' and 'Norwin' more (14 to 30% more) than that of the tall cultivars 'Norstar' and 'Redwin'. The tall cultivars competed with downy brome for light more effectively than the semidwarf cultivars.

Metribuzin, BAY SMY 1500, diclofop, cinmethylin, and napropamide were efficacious on downy brome in the greenhouse but only metribuzin (0.42 to 0.56 kg ha^{-1}) and BAY SMY 1500 (1.5 to 2 kg ha^{-1}) consistently controlled downy brome in the field. Winter wheat tolerated metribuzin and BAY SMY 1500 well but winter rye was injured by BAY SMY 1500 applied preemergence and the 2 kg ha^{-1} rate applied postemergence.

Rate and final percentage emergence of downy brome was reduced in cool (5 C), dry (-1.53 MPa) soils more than that of winter wheat or winter rye but the magnitude of these differences was insufficient to develop cultural measures such as seeding and tillage practices to reduce establishment of competitive stands of downy brome. Including an oilseed crop such as mustard, canola, or safflower in the rotation was as effective or often more effective than fallow in reducing downy brome infestations in subsequently grown winter wheat and rye crops. Use of trifluralin, ethalfluralin, quizalofop, or fluazifop in these oilseed crops controlled downy brome well. Many farmers are growing winter wheat or rye only once in a 3- or 4-yr rotation because of their downy brome problem. A burndown treatment with glyphosate prior to seeding winter cereals controlled early flushes of downy brome in conservation tillage systems. This burndown treatment reduced downy brome densities in the crop and postemergence metribuzin was often more efficacious because targeted downy brome plants were smaller and easier to kill.

PURPLE NUTSEDGE CONTROL IN ARIZONA COTTON WITH NORFLURAZON. W. B. McCloskey and L. R. Russo, Assistant Specialist, Weed Science, Department of Plant Sciences, University of Arizona, Tucson, AZ 85718 and Product Development Field Scientist, Sandoz Agro, Inc., Clovis, CA 93612.

Abstract. Norflurazon is registered for use in cotton in the Southeastern U.S. but is not currently registered for use in Arizona. Arizona cotton producing areas are characterized by coarse textured soils containing less than 1% organic matter that have low adsorptive capacity. Pre-plant incorporated applications of norflurazon at the 2 lb/A rate required for adequate purple nutsedge control cause cotton injury and stand loss because norflurazon is readily available for uptake by cotton seedlings. During the 1992 cotton season, field experiments were initiated in Arizona to evaluate the efficacy and crop safety of split applications of norflurazon where pre-plant incorporated applications were followed by postemergence incorporated applications. Treatments included a control (no herbicide application) and 0, 0.5, 0.75, 1 lb/A of norflurazon applied pre-plant incorporated followed by a second postemergence application at 2, 1.5, 1.25, and 1 lb/A, respectively, to yield a total application rate of 2 lb/A. The postemergence application of norflurazon was made when the cotton was 3 to 4 inches tall. The spray solution was directed in the area between crop rows and was followed by incorporation with a rolling cultivator or knives and sweeps. Irrigations following the postemergence norflurazon applications resulted in further incorporation and movement of norflurazon into the crop row.

The pre-plant incorporated (PPI) applications of norflurazon did not cause cotton injury except in one experiment where there was inadequate soil mixing during incorporation. No norflurazon injury was apparent after the postemergence applications. The PPI applications provided early season suppression of purple nutsedge but the postemergence applications were necessary for adequate control. Visual weed control ratings were made

3 months after the postemergence applications (4 months after the PPI applications). The ratings for the 0+2, 0.5+1.5, 0.75+1.25 and 1+1 (PPI+POST) lb/A treatments were 31, 32, 46 and 49% control of purple nutsedge, respectively; earlier ratings were 10 to 20% points higher. The split application of 1 lb/A PPI followed by 1 lb/A postemergence consistently provided the best control in several experiments while the application of 2 lb/A postemergence provided the poorest control compared to the no herbicide treatment. Good soil mixing during incorporation enhanced crop safety and efficacy. Every row furrow irrigation within a week or two of postemergence norflurazon applications enhanced purple nutsedge control in the crop row. Nutsedge control was relatively poor in the experiments where irrigation was delayed for several weeks after the postemergence norflurazon applications and in which fewer irrigations were used to produce the cotton crop.lurazon applied pre-plant incorporated followed byrazon applied pre-plant incorporated followed by a second postemergence application at 2, 1.5, 1.25, and 1 lb/A, respectively, to yield a total application rate of 2 lb/A. The postemergence application of norflurazon was made when the cotton was 3 to 4 inches tall. The spray solution was directed in the area between crop rows and was followed by incorporation with a rolling cultivator or knives and sweeps. Irrigations following the postemergence norflurazon applications resulted in further incorporation and movement of norflurazon into the crop row.

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TRANSPORTABLE FIELD RESEARCH FACILITY - ANOTHER NEW TOOL FOR FIELD RESEARCHERS. P. J. S. Hutchinson, D. VanWinkle, T. J. Hartberg and D. Kammel, Senior Field Operations Coordinator, Senior Field Agriculturist and Field Agriculturist, American Cyanamid Company, Meridian, ID 83642, Princeton, NJ 08543 and Verona, WI 53593 and Professor, Agricultural Engineering Department, University of Wisconsin, Madison, WI 53706.

Abstract. In 1989, American Cyanamid's Agricultural Research Division chose a proactive posture to update and standardize facilities for the storage and handling of chemicals used by its field research staff. Safe storage was accomplished by designing and manufacturing specialized chemical storage units in 1990. The second project, ensuring the safe handling of chemicals, was completed in 1992 with the design, production and siting of unique Transportable Field Research Facilities. Design considerations included personal health and safety, environmental protection, and good laboratory practices (GLP). Assistance in design and construction was provided by the Agricultural Engineering Department, University of Wisconsin-Madison. Interior design included a fume hood, stainless steel work surfaces, spill containment, rinsate collection, and automatic fire suppression.

TIMING OF NICOSULFURON APPLICATIONS FOR CONTROL OF JOHNSONGRASS AT VARYING POPULATIONS IN SILAGE CORN. M. L. Campbell and R. C. Leavitt, Farm Advisor, University of California Cooperative Extension, Stanislaus County, 733 County Center 3, Modesto, CA 95355, and Senior Development Representative, Dupont.

INTRODUCTION

There are about 30,000 A of silage corn in the San Joaquin Valley in California that are infested with Johnsongrass. The problem is not as severe in areas of the state where the ground can be rotated to other crops, but in the northern part of the valley, land and rotation options are limited because dairymen need all of their available land to grow feed for dairy cows.

In this area, Johnsongrass seed is even more of a problem than rhizomes. Johnsongrass in the corn is chopped into silage and the seeds pass through the cows and ultimately end up in the dairy wastewater holding lagoon. The lagoon water is used to irrigate the corn, and the seeds in the water are distributed throughout the farm. The seeds spread from one operation to another mainly on commercial harvesting equipment because cleaning the equipment between ranches is usually not practical once harvest season is in full swing. Nicosulfuron is effective in controlling emerged Johnsongrass in corn, but is still 1 to 2 yr from registration in California.

MATERIALS AND METHODS

During 1992, two studies were conducted to determine timing of nicosulfuron application to corn silage as affected by weed population and cultivation. Data reported is taken from four 1000 A area hand harvested with corn cut first and weighed, then the Johnsongrass from the same area cut and weighed separately. Four whole corn plants from each plot were selected at random and chopped in an 8 HP chipper-shredder. A one quart minimum subsample was dried to determine moisture and subsequently ground for quality analysis. Several whole Johnsongrass plants from each plot were chopped and analyzed also. The total aerial biomass in these trials was calculated by first individually correcting both the corn and Johnsongrass yields from each plot to 70% moisture, then adding the two together. Whole ears plus husks were pulled at random from 25 of the harvested stalks and weighed. Four of these were run through the shredder and subsamples were dried to determine moisture content.

For the timing vs weed population study, we selected a field west of Modesto near a dairy lagoon which had a heavy stand of Johnsongrass seedling after the preirrigation. In order to obtain different populations of Johnsongrass, we treated some areas with preplant herbicide (EPTC + dichlormid) disked twice, others with the herbicide disked only once, and left the remainder untreated. On these strips were superimposed nicosulfuron at 0.0125 lb/A in 28 gpa water applied with a CO_2 backpack sprayer equipped with 8003 flat fan teejet nozzles at 30 psi. Plots were 20 feet long and eight rows wide (30 inch rows). Applications were made when the corn (and Johnsongrass) was 6, 12 to 18, 36, and 48 to 54 inches high. The corn was planted on June 3, and the applications made at 17, 26, 38, and 42 d after planting, respectively. Harvest was on October 24, 113 d after planting. All treatments were applied over the top of the corn except the last application, where drop nozzles were used to keep the material out of the whorl. Yield data was taken from 10 replications.

A second study compared cultivation with two different timings of nicosulfuron application. Different initial populations of Johnsongrass were achieved in this study by going into a field near Denair that had had portions of it planted to beans the previous season where the Johnsongrass had been controlled. The remaining portions of the field had been in corn silage and had much higher initial populations of Johnsongrass seeds and rhizomes. Irrigation checks within both portions of the field were randomly assigned to receive or not receive a preplant application of metolachlor. Each of the 16, 150 by 800 foot irrigation checks (now having differing populations of Johnsongrass) was subdivided into five treatments, each 800 ft long and 12 (30 in) rows wide. All treatments were with commercial equipment.

Treatments consisted of an untreated check, cultivation at 10 inches, nicosulfuron applied at 20 inches, nicosulfuron applied at 3 to 4 feet, and cultivation at 10 inches followed by nicosulfuron applied at 3 to 4 feet. The later applications of nicosulfuron were timed to determine if herbicide application can be delayed to coincide with the application of a miticide.

Both nicosulfuron treatments were applied commercially at 0.0125 lb/A using a Spray-Coupe set for 10 gpa at 40 psi and traveling at 8 mph. The first nicosulfuron treatment was on June 12, 1992, over the top of corn using flat fan teejet nozzles. The second application went on June 25 using drop nozzles, with two 8002 flat fan teejet nozzles per row. Propargite miticide was mixed with the herbicide. The same rate of miticide without the herbicide was applied to all plots not receiving a late nicosulfuron treatment.

Harvest was on August 25, 1992. Data from three replications each of moderately (18% to 21% Johnsongrass in the total biomass) and heavily (36% to 51%) infested main plots was obtained. Uniform areas from within each plot were selected for hand harvest. The data was analyzed as completely random for Johnsongrass population with a split block for the five treatments.

RESULTS AND DISCUSSION

Effect of Johnsongrass on yield. In the timing vs population study, populations of Johnsongrass ranged from 11 to 35% of the total aerial biomass of the check, however, differences were not necessarily related to the preplant herbicide treatment. Yield of pure corn (whole tops) was lowest in the check and highest in the two early treatments. There was visible and measurable injury from the three foot over-the-top treatment but no evidence of injury on the 4 foot treatment in which drop nozzles were used. The lower yields at this treatment timing was caused by competition from the weeds.

The yield of pure corn silage in the untreated check decreased as the Johnsongrass population increased. The linear equation is

yield (T/A corrected to 70% moisture) = 29.5 - (0.39 • % Johnsongrass in biomass)

(r = -0.73, Probability = 0.016).

Yield of pure corn silage can also be correlated with the number of days the Johnsongrass is allowed to compete with the corn before treatment. The equation

yield (T/A corrected to 70% moisture) = 30.1 - (0.08 • d before treatment)

has an r of -0.998 and P of 0.002 for applications 17, 26, 42 and 113 (untreated check at harvest) days after planting. The treatment at 38 d caused injury to the corn and was omitted from this calculation.

The interaction of days before treatment and percent Johnsongrass in biomass was also significant (r = 0.59, P = 0.001) and the equation is

yield (T/A at 70%) = 35.2 - (0.23 • % Johnsongrass in biomass) - (0.08 • d before treatment).

When silage is commercially harvested, both the corn and the weeds are chopped together. Because of the contribution of the Johnsongrass to the total biomass, yield losses in the corn were largely offset by the weeds and there were no significant differences between any of the treatments on a dry matter basis. (Table 1.)

Table 1. Johnsongrass control in corn silage with nicosulfuron, population vs timing, Modesto, California, 1992.

	70%				Protein		ADF	
Corn height at time of treatment	Corn only	Bio-mass	As har-vested	25 Ears	Corn only	Bio-mass	Corn only	Bio-mass
		T/A		-lb-		%		
6 inches	28.49	29.3	29.5	20.9	9.6	9.6	23.7	23.9
2 to 18 inches	28.21	29.0	29.4	19.7	10.2	10.3	24.8	25.0
36 inches	24.57	25.4	26.9	17.6	10.0	10.0	25.5	26.0
48 to 54 in	26.86	27.5	28.7	20.7	9.7	9.7	26.5	26.6
Untreated	20.98	26.7	28.8	16.0	10.1	10.3	25.9	29.6
% CV	12.32	11.95	6.76	8.93	10.95	11.02	11.02	10.72
Probability	0.000	0.07	0.04	0.00	0.625	0.393	0.064	0.008
LSD (0.05)	2.90	3.00	1.76	1.55			1.6	2.6
LSD (0.10)		2.49						

In the cultivation vs nicosulfuron study, control of Johnsongrass by nicosulfuron was excellent at both treatment times. The applications using drop nozzles went on easily where the weeds had been previously cultivated, however, in the untreated area, Johnsongrass between the rows would snag on the nozzles, necessitating frequent stops to clean it off. Despite this, control was excellent even in the most badly infested plots. Even though the Johnsongrass treated at four feet was stunted but not killed, there was no fall regrowth from the rhizomes after harvest, as there was in the untreated and cultivated plots. There was no obvious difference in mite control between plots where nicosulfuron was mixed with the miticide and where the miticide was applied by itself.

As expected, there were generally lower corn yields where weed pressure was greatest. At moderate Johnsongrass population, all weed control treatments were equally effective, as measured by the yield of pure corn silage. At high populations, the best treatment was an early cultivation followed by a later nicosulfuron treatment. Although the nicosulfuron treatment at 20 inches gave excellent weed control, apparently the delay from 10 to 20 inches was enough to affect the final tonnage at heavy weed pressures. The ear weight data also points to the possibility that there was some injury from the over-the-top treatment, especially where there was less Johnsongrass to shield the corn from the spray. Although in general, the earlier weed control gave better corn yield, at high Johnsongrass populations, early cultivation alone did little to improve yields because of intense in-row competition.

As in the previous study, when the contribution of Johnsongrass is added to the corn yield, differences in total biomass are not statistically significant. Cultivating at higher weed pressures tended to reduce total biomass yield, because even though there is more corn, the contribution of Johnsongrass from between the rows is eliminated and the corn and weeds within the rows are competing with each other. (Table 2.)

Effect of Johnsongrass on silage feed quality. Because corn silage is usually fed to dairy cows, feed quality is extremely important. In the timing vs population study, there was no difference in the protein content of any of the treatments, including the check, even though the protein content of the Johnsongrass was higher than that of the corn (11.2% vs 9.9%). In the cultivation vs nicosulfuron study, protein content of the corn itself was slightly higher where there was more Johnsongrass (8.7 vs 8.1), and the Johnsongrass protein was higher yet (9.6%). Differences in protein content of the total biomass were significant in this study.

Table 2. Johnsongrass control in corn silage with nicosulfuron, Denair, California, 1992.

Treatment/ corn height	Jgrass population	70% Corn only	70% Biomass	As harvested	25 Ears	Protein Corn only	Protein Biomass	ADF Corn only	ADF Biomass
		T/A			-lb-	%			
Check	med	27.04	33.55	23.15	15.13	7.53	7.77	36.41	40.16
	high	17.96	30.85	27.18	14.67	8.63	9.59	34.07	41.89
Cult 10 inches	med	32.28	33.94	24.84	17.70	8.53	8.49	32.44	33.40
	high	21.62	26.96	23.45	17.85	9.37	9.5	32.93	39.42
Nicosulfuron to	med	32.77	34.77	24.45	19.35	7.90	8.06	31.96	32.77
3 to 4 feet	high	24.88	30.51	25.99	19.72	8.47	9.27	33.59	35.64
Nicosulfuron	med	31.13	31.13	25.56	15.45	8.37	8.37	31.70	31.70
20 inches	high	27.31	27.76	22.19	19.39	8.67	8.37	30.93	30.90
Cult + nicosulfuron	med	30.21	30.44	24.50	18.77	8.30	8.30	32.96	32.97
3 to 4 feet	high	32.62	35.55	26.96	20.39	8.37	8.63	30.85	32.21
Probability		0.094	0.170	0.188	0.070		0.132	0.336	0.326
Check	both	22.50	32.20	25.16	14.90	8.08	8.68	35.24	41.03
Cult 10 inches	both	26.95	30.45	24.15	17.77	8.95	8.99	32.69	36.41
Nicosulfuron 3 to 4 feet	both	28.83	32.64	25.22	19.53	8.18	8.67	32.78	34.21
Nicosulfuron 20 inches	both	29.22	29.45	23.87	17.42	8.52	8.52	31.32	31.30
Cult + nicosulfuron	both	31.42	33.00	25.75	19.58	8.33	8.46	31.91	32.59
Probability		0.021			0.001	0.12		0.022	0.005
LSD (0.05)		5.92			2.27			2.28	3.79
LSD (0.10)		7.19							
All treatments	med	30.69	32.76	24.51	17.28	8.13	8.20	33.10	34.20
All treatments	high	24.88	30.33	25.16	18.40	8.70	9.13	32.47	36.01
Probability		0.054	0.035	0.188	0.318	0.06	0.02	0.31	0.021
% CV		14.94	12.95	11.13	7.34	6.77	6.29	5.69	8.82

Another measure of quality is Acid Detergent Fiber (ADF). Low fiber feeds have more carbohydrate and less undigestible fibrous matter. High ADF feeds have less feed value. Johnsongrass in both studies had much higher ADF than did the corn, and the higher the percentage of Johnsongrass in the total biomass, the higher the ADF. Johnsongrass ADF was 43.3% and 48.6% in the timing and cultivation studies, respectively.

In the timing vs population study, the total biomass of the check had significantly higher ADF than did the any of the treatments. However, the timing of the nicosulfuron treatment affected the ADF of the corn silage itself, and the later the Johnsongrass was removed, the poorer the quality of the pure corn. The equation

$$\text{ADF (whole corn tops)} = 22.0 + (0.10 \bullet \text{d before treatment})$$

has an r of 0.975 and a P of 0.025. This relationship did not apply to the untreated check.

In the cultivation vs nicosulfuron study, ADF was highest in the untreated and cultivation only plots because these contained the most Johnsongrass. ADF in the nicosulfuron treatment applied at 3 to 4 feet was also high because nicosulfuron applied at this stage does not kill Johnsongrass, but only stops it from growing. Consequently there was solid understory of 3 to 4 foot tall vegetative Johnsongrass that contributed considerably to the tonnage. Feed quality of this stunted material was better than that of the mature Johnsongrass, with ADF of 33.7% vs 39.7% and protein of 11.8% vs 9.6% for the stunted and the untreated mature Johnsongrass respectively.

In both studies, the Johnsongrass had a higher moisture content than the corn. This is important to growers because silage is sold by weight on an as-harvested basis. If the weeds have more water than the corn, then the weight contribution of the weeds is proportionately greater. In the timing vs population study, yield of the check plots was nearly the same as the best treated plots, and in the cultivation vs nicosulfuron study, yields were higher where there were more weeds.

CONCLUSIONS

Both Johnsongrass population and timing of weed control affect final corn silage yield. In this study, 0.4 tons of pure corn silage at 70% moisture was lost for every 1% increase in Johnsongrass in the total aerial biomass at harvest. Corn yield was also decreased by 1 T/A for every 12.5 d that the nicosulfuron treatment was delayed. Cultivation alone was an effective weed control method at moderate (20% of total biomass) Johnsongrass populations but was inadequate at higher weed pressures. An early cultivation followed by a nicosulfuron application mixed with a miticide to 3 to 4 foot corn provided satisfactory control of Johnsongrass even at high populations.

The contribution of Johnsongrass to the total biomass tended to compensate for the decrease in tonnage of pure corn silage, but feed quality was greatly diminished. Because the ADF of Johnsongrass is so much higher than that of corn, the more Johnsongrass was in the final biomass, the worse the quality of the mixture. Even if the Johnsongrass is removed, the ADF of the corn itself increased 1% for every 10 d delay in nicosulfuron application. Although Johnsongrass can have a higher protein content than corn, its higher fiber content far outweighs any added benefit from the protein.

EVALUATION OF VARIOUS SURFACTANTS FOR ENHANCED WILD-PROSO MILLET CONTROL WITH NICOSULFURON. T. D'Amato and P. Westra, Graduate Research Assistant and Associate Professor, Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

Abstract. Greenhouse and field research was conducted to evaluate the utility of Crop Oil Concentrate (COC), Sunit II, COC plus 28% nitrogen, and two experimental surfactants for enhancement of wild-proso millet control with nicosulfuron. When nicosulfuron was applied at 0.125 oz A^{-1} in the greenhouse, all surfactants improved control 15 d after treatment nearly 3-fold compared to nicosulfuron applied alone. When nicosulfuron was applied at 0.5 oz A^{-1} in the field, the addition of COC plus 28% nitrogen, or the addition of 2% v/v of an experimental surfactant significantly increased wild proso millet control compared to other treatments in the study. Adverse plant growth conditions or environmental concerns may increase interest in research to identify surfactants which can significantly enhance weed control with post emergence herbicides.

WEED CONTROL IN CORN WITH REDUCED RATES OF ALACHLOR, CULTIVATION, AND/OR POSTEMERGENCE HERBICIDES. M. J. VanGessel, E. E. Schweizer, and P. Westra, Graduate Research Assistant, Research Scientist, and Associate Professor, Colorado State University and USDA-ARS, Agricultural Engineering Research Center, Fort Collins, CO 80523.

Abstract. Ground and surface water contamination has become a major concern for corn producers throughout the U.S. As a result, research efforts have attempted to replace or supplement soil-applied herbicides with cultivation or remedial herbicide strategies. This experiment was designed to look at the interactions of reduced alachlor rates, rotary hoeing, standard and in-row (IR) cultivation, and post herbicides based on a bioeconomic computer model. Experimental design was split-split-split plot with four replications. Whole plots were weed seed bank (high or low). The first split was post control with an IR cultivator alone, IR with post herbicide, or standard cultivator alone. The second split was rotary hoeing (none, once, twice), and the final split was alachlor

rates (none, 33%, and 66% of recommended rate). Whole plots were 4 rows wide (76 cm apart) and 60 m long. Weeds were identified and counted at four quadrats, (1.5 m by 17 cm) placed directly over the corn row in each sub-plot prior to post weed control and at layby. Grain was harvested and gross margins calculated.

It was possible to reduce alachlor rates as low as 33% of the labelled rate for pigweed control if one pass of the rotary hoe was used. Two passes of the rotary hoe were needed if no alachlor was used. Use of IR cultivator will allow growers to reduce emphasis upon pre-cultivation pigweed control. Post herbicide in addition to IR cultivation had little impact on redroot pigweed control. Yields were reduced when no alachlor was used in high seedbank plots when IR or IR plus post herbicide was used, probably due to loss of corn stand. Gross margins were reduced when the post herbicide was followed by an IR cultivation.

WEED CONTROL IN FIELD CORN WITH DIMETHENAMID. E. J. Gregory, R. N. Arnold, and M. W. Murray, Professor of Agronomy, Pest Management Specialist, and Research Assistant, Agricultural Science Center, New Mexico State University, Farmington, NM 87499.

Abstract. Dimethenamid (SAN 582H) is a new member of the herbicide group chloroacetamide, discovered by Sandoz Agro LTD. Field research has demonstrated that dimethenamid provides consistent control of certain grass and broadleaf weeds in corn, soybeans, sorghum (safened), peanuts and dry beans when applied at rates recommended for commercial weed control. In 1991 and 1992 at the New Mexico State University Agricultural Science Center at Farmington, New Mexico, dimethenamid was applied at various use rates and timing methods for green foxtail and barnyardgrass control in field corn. Barnyardgrass and green foxtail control was excellent with all treatments. Stand counts ranged from 14 to 18 plants per treatment during both yr. Plant heights ranged in 1991 from 84 to 96 inches and in 1992 from 95 to 107 inches. All treatments produced more corn/A compared to the check.

PERFORMANCE OF DIMETHENAMID IN THE WESTERN CORNBELT: RESEARCH AND EUP RESULTS. J. M. Fenderson, Product Development, Sandoz Agro Inc., Kiowa, KS 67070.

Abstract. Dimethenamid (code number: SAN 582H) is a selective preemergence herbicide for control of many annual grasses, several broadleaf weeds and yellow nutsedge in corn. Dimethenamid has been widely tested throughout the western cornbelt in small plot research trials as well as commercial trials under an Experimental Use Permit (EUP). Dimethenamid has been tested at rates of 0.85 to 1.7 kg/ha alone and as a tankmix or sequential application with broadleaf herbicides. Recommended application rates are determined by soil type and application method. Application timings and methods include preplant surface, preplant incorporated, preemergence, and early postemergence stages of corn.

Results from dimethenamid trials indicate excellent control of annual grasses such as crabgrass, foxtail, barnyardgrass, and fair to excellent of annual broadleafs such as pigweed, nightshade, and common lambsquarter. Testing has indicated that dimethenamid has provided consistently higher levels of weed control across many soils, climatic conditions, and cultural practices. Corn tolerance has been excellent under all conditions, including 2X dimethenamid rates. Research and EUP results demonstrate that dimethenamid will offer producers a more consistent product for preemergence weed control in corn.

AN INTEGRATED CANADA THISTLE MANAGEMENT SYSTEM COMBINING MOWING WITH FALL-APPLIED HERBICIDES. K. George Beck and James R. Sebastian, Associate Professor and Research Associate, Colorado State University, Fort Collins, CO 80523.

INTRODUCTION

Canada thistle is an aggressive, perennial weed throughout most of the northern tier of the U.S. (1). In Colorado, it is a serious problem in irrigated and dryland crops, pastures, roadsides, and some rangeland areas. Research concerning its control has been conducted mostly in cropping situations and the majority of control research in pastures and non-crop areas has involved only herbicide use. Several mowing and/or grazing studies have been conducted; three or four mowings/yr nearly eliminated Canada thistle in 3 yr (3) and grazing for 4 d followed by mowing reduced Canada thistle stands nearly to 0 after 3 yr (2). However, other researchers indicated that mowing only kept Canada thistle stands in check and did not control the weed (4). Data to evaluate the combination of mowing plus herbicides are limited.

Data for Canada thistle integrated weed management systems (IWMS) in pastures and non-crop areas also are limited. Colorado's state weed law and Section 15 of the Federal Noxious Weed Act require the use of IWMS. Additionally, societal concerns suggest that weed scientists should develop IWMS that decrease herbicide use.

The objectives of this research was to determine if mowing Canada thistle one, two, or three times during the growing season followed by various fall-applied herbicides controlled the weed better than those herbicide applied alone in fall; an additional objective was to determine if mowing-imposed stress will enhance control such that comparable Canada thistle control is achieved at a lower rate of a given herbicide.

MATERIALS AND METHODS

The experiment was initiated in 1991 at a sub-irrigated pasture on the eastern plains near Kersey, CO. The site was dominated by Canada thistle (59% foliar cover); rushes (*Juncus* spp.; 8% foliar cover), foxtail barley (*Hordeum jubatum*) and saltgrass (*Distichlis spicata*) also were present (combined grasses averaged 1% foliar cover). The experimental design was a four (mowings) by 14 (herbicide treatments) factorial arranged as a split-block. Mowing frequencies comprised the main plots and herbicide treatments were sub-plots. Each treatment was replicated four times.

Mowing was initiated in spring (1991 and 1992) when Canada thistle was 25 to 38 cm tall and in the early-bud growth stage. Subsequent mowings occurred when the weed again was 25 to 38 cm tall and in the bud to early-flower growth stage. Typically however, Canada thistle did not reach 38 cm in height after the first mowing - this especially was the case in 1992. Herbicides (Table) were applied in all plots 4 to 5 wk after the third mowing through a CO_2 pressurized backpack sprayer at 225 L ha^{-1} and 110 kPa.

Canada thistle shoot control was visually evaluated in fall, 1992, immediately before spraying. A 0 to 100 scale was used where 0=no control and 100=100% shoot control. Data presented are a progress report representing the impact of 1 full yr of the IWMS and second season of mowing only. The IWMS was invoked for 2 consecutive yr. Control data were subjected to analysis of variance and means were separated by Tukey's (0.05). Changes in plant foliar cover by species as impacted by the IWMS also were collected but will not be presented.

RESULTS

A mowing by herbicide interaction was observed and results were compared for all possible combinations of treatments. However, data are presented to compare mowing impact within a group of herbicide treatments because the objective was to determine if mowing enhanced control by a given herbicide.

Canada thistle control from picloram at 210 g ha^{-1} was enhanced by two or three mowings compared to no mowing (Table). All mowing frequencies increased Canada thistle control from picloram plus 2,4-D at 210 + 1120 g ha^{-1} compared to no mowing. There were no differences among mowing treatments from picloram and picloram plus 2,4-D and no differences among other mow plus picloram and picloram plus 2,4-D treatments.

Canada thistle control from clopyralid plus 2,4-D at 140 + 750, 215 + 1120, and 425 + 2240 g ha^{-1} was increased from two or three mowings compared to no mowing (Table). All mowings enhanced Canada thistle control from clopyralid plus 2,4-D at 275 + 1460 g ha^{-1} compared to no mowing. Two or three mowings increased Canada thistle control from clopyralid plus 2,4-D at 140 + 750 g ha^{-1} and three mowings increased Canada thistle control from all clopyralid plus 2,4-D treatments compared to one mowing, except 275 + 1460 g ha^{-1}.

Canada thistle control from dicamba was increased with two or three mowings compared to no mowing or one mowing; no differences were observed between no mowing and one mowing. Canada thistle control from chlorsulfuron ranged from 90 to 100% and was not enhanced by mowing. All mowing alone treatments controlled Canada thistle and two or three mowings provided better control than one mowing.

SUMMARY

Two or three mowings consistently enhanced Canada thistle control from several herbicide treatments compared to those herbicides applied alone in fall. The lowest rates of picloram, picloram plus 2,4-D, all rates of clopyralid plus 2,4-D, and dicamba showed increased Canada thistle control when preceded by two or three mowings.

This progress report demonstrates that mowing during the growing season followed by selected herbicides fall-applied have potential as an IWMS for Canada thistle in pastures and roadsides. The experiment remains in progress and a second site will be initiated in 1993.

Table. Canada thistle control combining different mowing frequencies during the growing season followed by fall-applied herbicides.

		Canada thistle			
		Evaluation October 16, 1992			
Herbicide	Rate	No mow	1 Mow	2 Mow	3 Mow
	- g ha^{-1} -	% of check			
Chlorsulfuron	53	90	93	96	100
HSD (0.05)			22		
Clopyralid + 2,4-D	140 + 750	46	56	78	97
Clopyralid + 2,4-D	215 + 1120	44	64	84	88
Clopyralid + 2,4-D	275 + 1460	51	81	93	100
Clopyralid + 2,4-D	425 + 2240	70	73	92	95
HSD (0.05)			17		
Dicamba	2240	65	63	88	91
HSD (0.05)			22		
Picloram	210	73	89	95	97
Picloram	280	89	90	100	100
Picloram	560	97	98	100	100
Picloram	1120	100	100	100	100
HSD (0.05)			17		
Picloram + 2,4-D	210 + 1120	54	81	93	100
Picloram + 2,4-D	288 + 1120	92	93	96	96
Picloram + 2,4-D	560 + 1120	98	100	100	100
HS (0.05)			16		
Mow only		0	58	74	85
HSD (0.05)			22		

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MANIPULATING PERENNIAL WEED GROWTH STAGE THROUGH CULTIVATION TIMING TO MAXIMIZE HERBICIDE EFFICACY. Jerry D. Harris, E. S. Davis and P. K. Fay, Research Associate and Assistant Professor, Central Agricultural Research Center, Moccasin, MT 59462, and Professor, Plant and Soil Science Dept., Montana State University, Bozeman, MT 59717.

Abstract. Canada thistle and field bindweed are perennial noxious weeds of cropland and are particularly difficult to control due to an extensive, persistent root system. Effective long-term control can be achieved only if the root system is severely depleted of carbohydrate reserves through intensive cultivation or if regenerative growth from root buds is impaired by herbicides. Herbicide translocation is influenced by the growth stage of perennial plants at the time of application. Plants exhibiting a vegetative growth stage in late summer have a greater degree of basipetal movement of substances within the symplast to replenish the carbohydrate reserve within the root system, whereas perennial plants exhibiting a reproductive growth stage late in the summer exhibit more acropetal movement of substances in the symplast to supply the energy needs of reproductive organ development and maturation of the shoot. Since daylength controls the physiological growth stage of these plants, cultivation timing during a fallow period can be used to manipulate the emergence date of new shoots at a time of the season when a short photo period will insure vegetative growth instead of reproductive thereby maximizing downward movement of the herbicide along with the sugars.

Field trials were established in fallow for controlling Canada thistle in 1989 and field bindweed in 1991. Two tillage programs were compared. In one program the last tillage operation occurred the first wk of July and herbicides were applied 30 d to Canada thistle and 50 d later to field bindweed. In this program the plants expressed a reproductive growth stage. The second program involved one additional cultivation the last wk of July and herbicides were applied in the same manner as the first program except the plants were in a vegetative growth stage due to the shorter daylength experienced by newly emerging shoots.

Canada thistle control evaluated the following season was considerably better for dicamba (1.1 kg/ha) and clopyralid (0.2 kg/ha) when applied to vegetative plants 30 d after a late July tillage. Canada thistle control with glyphosate (1.1 and 2.2 kg/ha) was excellent following both tillage programs.

Field bindweed control was evaluated 1 yr after applying combinations of dicamba (0.55 kg/ha), 2,4-D (0.88, 1.1, and 2.2 kg/ha), picloram (0.138 and 0.275 kg/ha), glyphosate (0.55, 0.83, and 1.65 kg/ha) and quinclorac (0.275 and 0.55 kg/ha). All individual and combined applications exhibited significantly better control when applied to vegetative plants 50 d after a late July tillage except treatments containing the highest rates of picloram, glyphosate and quinclorac (0.275, 1.65, and 0.55 kg/ha respectively), which gave good control when applied at either growth stage.

EXTENSION, EDUCATION, AND REGULATORY

USING A FLUORESCENT DYE TO DEMONSTRATE HERBICIDE INCORPORATION. D. W. Morishita, R. W. Downard, and B. Beckman, Assistant Professor, Research Associate, and Electronic Media Specialist, University of Idaho, Department of Plant, Soil, and Entomological Sciences and Agricultural Communications Center, Twin Falls, ID 83303.

Abstract. Fluorescent dyes have been used in the past to demonstrate herbicide incorporation with various tillage implements. A project was initiated near Twin Falls, Idaho to evaluate the incorporation effectiveness of some implements that have not been used previously and under Idaho soil conditions. A fluorescent dye was applied to 1.5 by 1.5 m plots. After incorporating the dye with each implement, a visual score for incorporation efficiency was recorded. Slide photos and video tape were taken of each incorporation method and dye distribution. The slides will be used for educational presentations to help improve the incorporation efficiency of various secondary tillage implements. The video tape will be available for use by individuals or groups. Among the tillage implements evaluated, a roller harrow and seedbed conditioner were the most effective for providing an even distribution of the dye in the top 5 to 7 cm of soil. Two passes, made at right angles to each other were more effective for distributing the dye than one pass. A single pass with a disk or field cultivator provided the poorest incorporation and distribution of the dye.

GUIDE TO HERBICIDE INJURY SYMPTOMS IN SMALL GRAINS. Richard K. Zollinger and James S. Ladlie, Assistant Professor, Crop and Weed Sciences Department, North Dakota State University, Fargo, ND 58105, and Agri-Growth Research Inc., Hollandale, MN 56045.

Abstract. Many interacting factors govern the effectiveness of herbicides and the potential for crop injury. If crop injury does occur, diagnosticians must be able to accurately identify the causes and consider interacting and look-alike symptoms. A guide to herbicide and look-alike symptoms in small grains was produced to provide a systematic approach for identifying symptoms resulting from herbicides and to distinguish those symptoms from other causes of small grain injury.

The first segment of the guide consists of sections addressing small grain growth and development, tables of herbicide names and premixes, and cross reference tables showing primary symptoms, cause of injury, look-alike symptoms between other herbicides and non-herbicide factors. The main section of the guide gives information arranged by herbicide family and includes color photographs showing primary symptoms of crop injury caused by the most commonly used herbicides of that family. Each herbicide family page is divided into the following six sections: Key Symptoms, Symptoms Often Confused With, Mode Of Action, Cause Of Injury, Areas In A Field Most Likely To Show Injury, and Recoverability From Early Crop Injury.

Several non-herbicide factors comprise the final section of the guide and include several cultural, environmental, and nutrient factors, and pathological and insect pests. Each guide is presented in a 8.5 inch by 5.5 inch 3-ring binder. The contents are printed on enamel gloss paper and covered with plastic lamination to allow for durable in-field use.

LEARNING STYLE PREFERENCES: CAN WE ACHIEVE COLLABORATIVE ACTION BETWEEN REGULATORS, PUBLIC, AND AGRICULTURE? Ray D. William, Professor, Department of Horticulture, Oregon State University, Corvallis, OR 97331.

INTRODUCTION

People associated with agriculture often believe that consumers, regulators, and neighbors can be "educated", if given the facts. This belief is based on the assumption that other people will interpret the same set of data or information similarly. Experience often suggests that personal friends share common beliefs and interests. Why do some consumers, regulators, and farmers remain skeptical? Do they share similar learning and action styles? What can we learn, if we listen?

This paper presents the concept of **preferred learning and action styles** and suggests possible applications in agriculture. Learning styles can be a "tool" toward learning and discovery; they represent another way of seeing and acting on reality. Sometimes learning style preferences are used to label and therefore restrict communication, but they also can be used as a means to enhance understanding and common action among people. Learning styles do not provide a simple answer to complex questions.

PREFERRED LEARNING AND ACTION STYLES

Learning preferences are a lot more diverse than we recognize or were taught (4, 5). Four learning style preferences are shown in the figure: learning in groups, learning by analyzing or listening, learning by individual participation in problem-solving, and learning by actually doing the learning task. Although learning theory says everyone practices each of these learning approaches, each individual exhibits different preferences. Actions, in turn, depend on how each person learns.

Job choice is one important action that often is linked to learning preferences (3, 4, 6). Even within a given profession, we can see the influence of these preferences. While strategic planners share preferences related to basic research in other fields, planners who design implementation plans share action preferences similar to engineers, family doctors, and applied researchers. The latter group prefer to apply theory or data to solve practical problems, while strategic designers create the future.

People involved in production agriculture in the 1990's often prefer a similar action-oriented problem-solving approach. Thus, farmers (both genders) were overwhelmingly action oriented compared to society (2). Similarly, many County Extension Directors share this same action preference (7). Both groups prefer structure and stability rather than rapid, futuristic change. It makes sense when agriculturists say "if the wheel ain't broken, don't fix it."

Organizations also tend to exhibit preferential learning and action styles, often depending on the function of the group (1). Large manufacturing companies are recognized by everyone as being very different than new enterprises pioneering new products. Even departments within organizations function differently. Strategic planning departments design jobs and hire people to achieve futuristic planning while engineers plan the next generation of products. This phenomena of common learning and action styles also occurs among organizational trustees, environmental advocacy leaders, performing arts companies, and many or most groups (1). In reality, we know that groups or organizations may practice "group think" by approaching similar functions with similar values.

What does this mean for the agricultural community? As mentioned above, agriculturists are concentrated in one particular approach. As agriculture becomes more integrated into society as a whole, agriculturists are being forced into closer contact with groups including consumers, environmental advocates, and government agency personnel. These groups are likely to have different learning preferences and action styles from agriculturists. Thus, it becomes more important to recognize these preferences and turn them into advantages rather than liabilities.

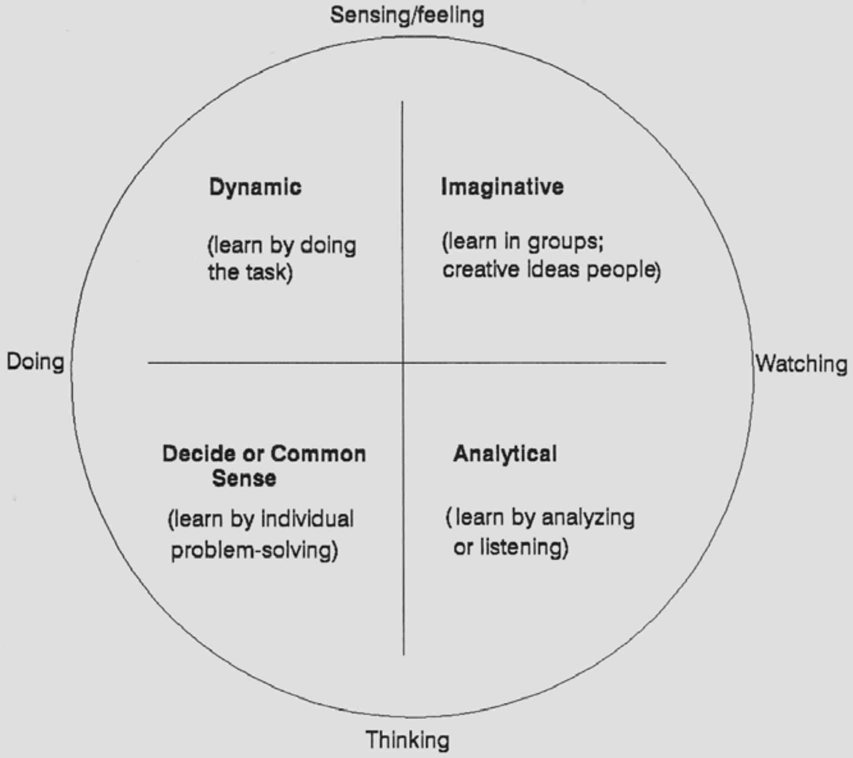

Figure. Learning and action style preferences (modified from Kolb, 1984 and McCarthy, 1987).

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INTEGRATING INFORMATION FROM INTEGRATED PEST MANAGEMENT RESEARCH.

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Abstract. The Palouse hills of eastern Washington are renown for two features: soils capable of producing high yielding dryland winter wheat and soil erosion that can exceed 50 tons/A. To sustain long-term profitability, conservation cropping systems that conserve the soil while providing grower profits need to be developed, evaluated, and adopted. However, growers often perceive that conservation tillage results in lower profits due to weed and disease management problems and lower yields. To evaluate if profitable wheat cropping systems are feasible, a 6 yr integrated pest management research project was conducted from 1986 through 1991 near Pullman, Washington. The study evaluated two crop rotations grown under conservation and conventional tillage systems. Each rotation/tillage combination received minimum, moderate, and maximum levels of weed management. To conduct the study, 15 scientists from six disciplines, including weed science, soil science, plant pathology, agricultural economics, entomology and statistics, contributed from USDA-ARS, Washington State University, and the University of Idaho. At the conclusion of the study, the winter wheat-barley-dry pea rotation grown under conservation tillage and moderate or maximum levels of weed management provided the highest profit with the least risk.

To transfer this information, a field day in the study's final year was conducted to summarize the research results and explain the factors contributing to the success of 3 yr rotation/conservation tillage system. The field day design was unique in two respects. First, field day attendees toured each crop of the best performing system where operations, inputs, yields, profits, etc. were summarized. Because of the experimental design, each crop in each rotation was grown every year. This allowed us to walk the growers sequentially through the 3 yr of the rotation in 1 h. Secondly, scientists had to integrate their presentations to describe all of the factors from the various disciplines that contributed to the cropping system's success. As a result, the 250 attendants received an in depth description of the best performing cropping system rather than an assortment of discipline-specific presentations on crop production.

To capture this information for clientele unable to attend the field day, a 30 minute video entitled "Conservation cropping systems: Insights from the USDA IPM project" was produced. The tape summarizes the research objectives, experimental variables, primary results, and factors accounting for the success of the wheat-barley-pea rotation/conservation tillage system in a format similar to the field day. The video's primary goal was to inform growers on the IPM study results as well as the potential benefits of conservation tillage. Secondly, the video provides non-agricultural viewers an appreciation of the complex interactions involved in cropping systems. Over 125 videos have been purchased by agencies, growers, cooperative extension, and others.

REVITALIZING OUR WESTERN RANGELAND: A NEW LOOK AT SAGEBRUSH MANAGEMENT (VIDEOTAPE SCRIPT).

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Abstract. There is a considerable amount of excitement today among ranchers, governmental agencies, rangeland researchers and wildlife biologists about improving wildlife habitat while enhancing forage for livestock production by thinning big sagebrush. Early sagebrush treatments were non-selective and did not provide flexibility for partial control required for multiple use management. Observations of long-term university studies conducted 12 and 13 yr ago have shown that the pelleted herbicide tebuthiuron can be used to thin big sagebrush while leaving important wildlife forage species. In looking at some of these long-term studies you can't help but wonder what the effects of thinning might be on wildlife. Studies are

currently being conducted at the University of Wyoming to determine what effects various levels of thinning will have on wildlife habitat. It is known that creating species diversity, edge effects and horizontal diversity has positive effects on wildlife. These effects are being observed by ranchers who have seen long-term effects of tebuthiuron on wildlife.

We know that big sagebrush has not always been as dense in most areas as it is today. In order to fully understand why big sagebrush densities have increased lets' review the history of rangeland use and techniques that have been used in the past for big sagebrush management. Before the passage of the Taylor Grazing Act intensive unrestricted grazing from 1880 to 1934 brought about major changes of several species of plants that dominated western grazing lands. One woody species, big sagebrush, was present during the time of the buffalo but was not the dominant landscape plant that it has become in many areas today. This dominance has come about principally by selective grazing and the control of wildfires that were also common in earlier years.

Studies about big sagebrush allow us to understand how it has become so dominant on the western range. One characteristic that allows it to survive during years of low precipitation is its extensive root system which grows to depths greater than 40 inches, depending on the soil type. This root system extends far below that of perennial grasses and forbs that it competes with for available moisture. During dry years when moisture levels are too low or grazing levels are too great for perennial forbs and grasses to survive, big sagebrush has a ready supply of seed available to take over the new site. The seed shed by big sagebrush lives only 1 yr in the soil after being shed in the fall. It must germinate that year or will die. A young sagebrush seedling does not develop a deep root system the first year, therefore it cannot compete with vigorous stands of perennial grasses and forbs. Without unoccupied space to fill a young sagebrush seedling usually dies. Once big sagebrush becomes firmly established, it lives over 50 yr and can dominant the site it occupies. Sagebrush utilizes great amounts of water that would otherwise be available for springs and streams or other perennial rangeland plants. Springs and streams often develop when sagebrush areas are managed. (Mike McCarrell talks about water development on his ranch in Utah). The ability of big sagebrush to use moisture from subsoil levels has allowed it to become the dominant species on over 100 million acres of western rangeland.

Of the 100 million acres of land occupied primarily by big sagebrush, approximately 50% of that area is owned by the federal and state government, while the other 50 million acres is on privately owned land. Several good questions are asked about the effects of sagebrush and changes that might occur with a management program. Soil conservationists are concerned about the topsoil and how dense sagebrush stands affect erosion. Wildlife groups and agencies are interested in populations shifts that might occur within various wildlife species. Food production and consumer groups are very interested in the beef and lamb produced in the west. Simply ignoring the issue and leaving things the way they currently exist might be the solution to some, while others feel that we are loosing a valuable renewable resource that is currently being wasted. It is not as if there are no control techniques available and the situation of a domination of sagebrush is here to stay. We know that perennial grasses and forbs produce 2 to 4 times as much available forage for wildlife and livestock when sagebrush thinning and management occurs. We also know that when sites have become dominated by big sagebrush, they can be thinned and managed to increase diversity in the plant community.

Early techniques used for management have included: fire, hand grubbing, removal with machinery and flooding areas with water. These methods remain effective today and are still used. The use of the herbicides 2,4-D and 2,4,5-T have provided effective management on about 2% of acreage dominated by big sagebrush since they were introduced in the 1950's. The use of 2,4-D (low volatile ester) is limited to early spring applications when moisture levels are good and big sagebrush is actively growing. The herbicide tebuthiuron was introduced as a sagebrush control under the trade name Graslan in 1982. Tebuthiuron is applied as a granular herbicide and does not require proper timing of application as is necessary with 2,4-D. It is soil active and is taken up by the root system of big sagebrush. Following the application of tebuthiuron, big sagebrush is defoliated because energy from the sunlight trapped in the chloroplasts can not be used for the manufacture of plant sugars. The plant eventually dies from this continuous defoliation process. The leaves of forbs and grasses may show a yellowing appearance from tebuthiuron the first yr after application. By the second yr, the chemical will move through their shallow root systems and green up will occur as the new moisture available from the thinned stand of big sagebrush is utilized. Extensive trials have been conducted by researchers from the University of Wyoming on land covered with big sagebrush since 1979 to help determine proper application rates, product formulations and species sensitivity to the herbicide tebuthiuron.

Important facts discovered as a result of testing include: 1) cool season grasses such as western wheatgrass, green needlegrass and prairie junegrass can tolerate tebuthiuron at levels up to 0.75 lb/A, and 2) big sagebrush can be thinned according to the management objectives with rates ranging from 0.25 to 0.75 lb/A tebuthiuron. The Soil Conservation Service and the Agricultural Stabilization and Conservation Service in some counties are currently encouraging the control of sagebrush to allow for better soil conservation and to encourage more effective use of our rangelands.

The effects of sagebrush management on wildlife is currently being studied by researchers at the University of Wyoming. These studies include intensive, detailed studies on the effects of management on small mammals and birds. Many ranchers have observed increased populations of elk, deer and sagegrouse during various seasons of the yr after sagebrush management. Ranchers have taken a particular interest in sagebrush thinning because of the dramatic increases of forage that can be attained for their livestock as a result of this management practice.

Two questions often asked about big sagebrush thinning are: what sites should be selected for thinning and what levels of thinning should be used to maximize livestock and wildlife habitat? It is known that the most productive sites are those on deep soils in valley areas. Management practices would not be recommended for rangeland with steep slopes or rocky soils.

SUMMARY

1. Big sagebrush increased in density from 1880 to 1934 on our western rangelands as cattle and sheep (both selective grazers) replaced the buffalo (a non-selective grazer).

2. Proper grazing alone will not reduce dense populations of sagebrush. Reductions in sagebrush density must be done with mechanical methods, fire, flooding or with the use of selective herbicides.

3. 2,4-D has been used since the 1950s to control big sagebrush. It is limited in plant species selectivity, controlling big sagebrush and other woody species, as well as forbs while leaving grasses. To be effective it must be applied in early spring when moisture is available and big sagebrush initiates early growth.

4. A second selective herbicide (tebuthiuron) was introduced in the early 1980's for control of big sagebrush. It is much more selective, produces consistent results and can either be used to thin or totally control big sagebrush while leaving most other woody species as well as forbs and grasses. The level of thinning depends on the amount of tebuthiuron/A. It is slower in it's activity, requiring up to 2 yr to thin the sagebrush. Tebuthiuron applications often cause a yellowing of desirable grasses the first yr but leach out of their shallow root zones after 1 yr allowing them to fully recover. It is important that tebuthiuron be applied at rates recommended on the label.

5. In developing habitat for wildlife and livestock by sagebrush thinning, managers of the land should consider that when this newly reclaimed resource is over utilized, that their old friend big sagebrush or some other equally competitive species will come back to ride the range once again.

ENHANCING RESOURCES THROUGH INTEGRATED MANAGEMENT SYSTEMS, A VIDEO.

George F. Hittle, Weed & Pest Coordinator, Wyoming Department of Agriculture, Cheyenne, WY 82001.

SUMMARY

Audience. Landowners, land managers and public interest groups are the anticipated audience for this 17-minute video. It is expected that this video will be distributed nationwide.

Goal. The goal of this video is to effectively and accurately communicate that resources threatened by noxious weeds can be protected, and even enhanced, as noxious weeds are managed using existing and potential integrated weed management. The following combined strategies have proven to be effective in managing noxious weeds.

Objective. The objective is to introduce landowners, land managers, and public interest groups to the concept of the "Integrated Management System."

Integrated Management System (IMS). IMS is the planning and implementation of a coordinated, ecologically based program using all proven methods to prevent, contain and control undesirable plants (noxious weeds). This includes, but is not limited to: education; preventive measures, physical methods; biological agents; herbicide methods; cultural methods; and management.

Integrated Weed Management (IWM). IWM is a system that utilizes all proven methods based on the best available scientific facts, current technology, and economic considerations to reduce weed populations to levels below those causing acceptable economic or ecological consequences.

Education. This is the method of teaching society (clientele) about weed management, awareness, environmental considerations, economic impact, aesthetic value, and the natural (native) ecosystem. It also includes selecting method(s) to manage undesirable plant species (noxious weeds) through use of an IMS.

Management. Management includes methods which can be controlled by decisions through an IMS to achieve the optimum management desired with the least possible environmental damage.

Preventive measures. The process of preventing the contamination of an area by noxious weeds, and destroying the weed's reproductive potential. This reduces the possibility of introducing undesirable plants into an area.

Physical methods. Cutting, mowing, rogueing, tillage, clean cultivation, or burning prior to cutting or harvesting, no later than bud or boot stage, for grasses classified as weeds, are physical methods employed to control the spread of noxious weeds.

Biological agents. Organisms such as insects, pathogens, parasites, diseases, natural enemies or domestic animals have been proven effective in diminishing weed seed production, increasing plant stress, and in limiting the expansion of underground parts of the plant's reproductive system.

Cultural methods. Revegetation projects, which include reseeding with competitive desirable plant species, crop rotation, mulching, and livestock manipulation, are examples of cultural methods used to control noxious weeds.

Herbicide methods. Using the best available scientific facts and current technology, applying EPA-registered herbicides on the target species can be effective in controlling noxious weeds.

BASIC SCIENCES

THE IMPACT OF INTRA-SPECIFIC COMPETITION ON BARLEY AND WILD OATS GROWTH AND CARBON ALLOCATION. C. M. Dunan and P. Westra, Graduate Research Assistant and Associate Professor. Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

Abstract. Carbon allocation plays an important role in wild oats and barley competitive ability and it may be responsible for the increase in wild oats competitive ability under nitrogen fertilization. The objective of this study was to determine the impact of plant density and nitrogen on growth and carbon allocation of barley and wild oats. A factorial experiment with two nitrogen levels (0, and 100 units) and three plant densities 1, 4, and 10 plants per plot (88, 353, and 885 plants m^{-2}) was performed under greenhouse conditions during the spring of 1991. A RCB with three replications was used. Barley and wild oats plants were harvested at three different times: full tillering, flowering, and final harvest. Leaf, stem, root, and inflorescence dry weight, and leaf area per plant were recorded at the first two harvests. There was a significant interaction between plant density and nitrogen level. Nitrogen increased leaf area, shoot, and root biomass per plant. Relative growth rate, relative leaf expansion rate, and net assimilation rate were higher at the high nitrogen level for both species. These rates show no response to plant density. Wild oats lower root-shoot ratio and larger specific leaf area may be responsible for its higher competitive ability with nitrogen fertilization.

PHYSIOLOGICAL EFFECTS OF MODIFIED ACETOLACTATE SYNTHASE IN CULTIVATED LETTUCE, BACKGROUND. Mary J. Guttieri, Charlotte V. Eberlein, Marilyn K. Manley, Carol A. Mallory-Smith, and Donald C. Thill, Research Associate, Associate Professor, and Scientific Aide, Department of Plant, Soil, and Entomological Sciences, University of Idaho Aberdeen Research and Extension Center, Aberdeen, ID 83210, Postdoctoral Associate and Professor, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83843.

Abstract. Although weed biotypes resistant to inhibitors of acetolactate synthase (ALS) have become widespread, understanding of the physiological effects of resistance is limited. Therefore near isogenic lines (isolines) of resistant (R) and susceptible (S) 'Bibb' lettuce, derived from backcrossing prickly lettuce resistance into a cultivated background, were used to characterize the ALS activity in a uniform genetic background. R/S ratios of I_{50} values for inhibition by chlorsulfuron, triasulfuron, metsulfuron methyl, imazapyr, imazethapyr, and imazaquin follow those from R and S biotypes of prickly lettuce. However, genetic background affected expression of the R phenotype: R/S ratios in the Bibb isolines were less than R/S ratios in the prickly lettuce biotypes. Extractable ALS activity from the R Bibb isoline, as measured by nmol acetoin formed·mg protein^{-1}·hr^{-1}, was only 27% of the extractable activity from the S parent. ALS isolated from the R isoline was less sensitive to feedback inhibition by 1 mM valine, leucine, or isoleucine than ALS isolated from the S isoline. Branched chain amino acid levels were measured in seed of R and S Bibb from plants grown in a replicated greenhouse trial. Standardized to internal phenylalanine concentration, the levels of valine, leucine, and isoleucine in R seed were 183, 195, and 205%, respectively, of the levels in S seed. Therefore, despite reduced ALS activity, R plants deposited a larger quantity of branched chain amino acids in seed.

EFFECT OF SURFACTANTS ON GLYPHOSATE TRANSPORT INTO PLASMA MEMBRANE VESICLES ISOLATED FROM COMMON LAMBSQUARTERS LEAVES. Dean E. Riechers, Rex A. Liebl, Loyd M. Wax, and Daniel R. Bush, Graduate Research Assistant and Associate Professor, Department of Agronomy, University of Illinois, Professor, Department of Agronomy and USDA-ARS, University of Illinois, and Assistant Professor, Department of Plant Biology and USDA-ARS, University of Illinois, Urbana, IL 61801.

Abstract. Various surfactants have been screened in prior field and greenhouse studies to determine effective surfactants to be used with glyphosate. Previous studies suggest that beneficial surfactants may have an effect on the plasma membrane, as well as the cuticle, in enhancing glyphosate phytotoxicity. The objectives of this study were to determine if the plasma membrane is a barrier to cellular uptake of glyphosate, and whether surfactants

play a role at the level of the plasma membrane in increasing cellular uptake of glyphosate and promoting whole plant phytotoxicity. Plasma membrane vesicles were isolated from mature common lambsquarters leaves grown in the greenhouse. An aqueous two-phase partitioning method (PEG:Dextran) was used to purify plasma membrane vesicles (PMV) from the microsomal fraction. PMV were isolated and resuspended in an osmotically-balanced buffer at pH=8.0. Transport experiments were initiated by diluting PMV into a pH=6.0 acidic uptake solution, which included radiolabelled substrates in the presence or absence of the proton ionophore, CCCP. This experimental treatment imposed a transmembrane pH gradient (ΔPh) that was capable of driving several proton-amino acid symports, indicating that these membrane vesicles were transport competent and functional. Glyphosate, atrazine and bentazon transport were tested using this experimental system. Atrazine accumulated inside the PMV but uptake was not influenced by the transmembrane Ph gradient. Bentazon also accumulated inside the PMV and accumulation was driven by the imposed ΔpH. Glyphosate transport was very low and unresponsive to the imposed pH gradient, indicating that the plasma membrane is a significant barrier to cellular uptake of glyphosate.

Surfactant concentration (0.1 to 0.0001% v/v) in the uptake solution was evaluated for effects on ΔpH (via acetate and alanine accumulation) and glyphosate transport. At concentrations above 0.01%, acetate and alanine accumulation in response to the pH gradient were greatly diminished, indicating loss of membrane integrity and dissipation of the transmembrane ΔpH. At 0.01%, the imposed pH gradient was still present and glyphosate transport was stimulated 3 to 4 fold. Our initial hypothesis suggested that effective surfactants with glyphosate (*e.g.* cationic *vs.* nonionic) might form a molecular complex with glyphosate that contributes to increasing membrane permeability. However, all surfactants tested at 0.01% demonstrated an ability to increase glyphosate transport into the PMV. Thus, no correlation was observed between surfactant whole plant efficacy and glyphosate transport into PMV. Current data suggests that cationic surfactant efficacy with glyphosate may involve a differential ability to diffuse away from the cuticle and into the subtending apoplastic space, where the surfactant can reach the plasma membrane in conjunction with glyphosate to increase cellular uptake of the herbicide.

MECHANISMS OF SPREAD OF KIKUYUGRASS POPULATIONS IN CALIFORNIA.

Cheryl Wilen and Jodie S. Holt, Graduate Student and Associate Professor, Department of Botany and Plant Sciences, University of California, Riverside, CA 92521.

Abstract. Many weedy and domesticated plant species can spread by both sexual (seeds) and asexual (vegetative structures) means. A crucial aspect of weed control is understanding the mechanism of weed spread. Evaluating the amount of genetic diversity in a species over a wide area is one way of determining whether spread is mainly by seeds or by vegetative means.

We examined the genetic variability of kikuyugrass collected from three golf course sites within its geographical range in California including the San Francisco Bay area, the central coast, and southern California. Samples from roughs and fairways of each of these locations were compared. The primary thrust of this research was to determine the method of spread of kikuyugrass and to examine the importance of seeds versus vegetative propagules in the establishment of kikuyugrass where it is considered an invasive species. Starch gel electrophoresis techniques were used to help clarify the relationships of individuals among and within populations. Using genetic information obtained in this manner we made inferences about the mode of reproduction and spread of kikuyugrass.

Of the 354 plants examined for genetic diversity, fourteen genotypes were found and only 3 of the 9 loci varied among the genotypes. These were IDH-1, PGI-1, and PGM-2. The genes for MDH-1, MDH-2, PGD-2, and SKD were all homozygous and the genes for MDH-3 and GOT-1 were heterozygous over all plants examined. Two genotypes represented 73% of the plants examined and these were found at all three geographic locations.

Our results imply that under common golf course practices, kikuyugrass is maintained clonally. However, where open areas exist there is the possibility for spread of this grass initially via seed. This appears to be one of the mechanisms that makes kikuyugrass an effective invasive species. Since kikuyugrass produces seeds regardless of whether it is densely or sparsely growing, it is not a facultative sexual species; however, it does appear to be a facultative sexually *spreading* species. That is, kikuyugrass appears to be an opportunistic plant that colonizes relatively open areas by seeds, but where plants are already established as turf, seedlings may not be able to survive and kikuyugrass spreads vegetatively. We conclude that lack of genetic variation does not preclude a plant species from being an aggressive invader. Although genetic variability is associated with method of reproduction, it is not a good predictor of the invasive behavior of a plant.

HOST CAPACITY FOR SOUTHERN ROOT-KNOT NEMATODE (RKN) OF SEVEN COMMON WEEDS IN NEW MEXICO. Barbara Vezzani, Jill Schroeder, and Stephen Thomas, Graduate Student, Assistant Professor, and Associate Professor, Department of Entomology, Plant Pathology, and Weed Science, New Mexico State University, Las Cruces, NM 88003.

Abstract. Yellow nutsedge (YNS) and purple nutsedge (PNS) are established alternate hosts of southern root-knot nematode (*Meloidogyne incognita* (Kofoid and White) Chitwood, host race 3, RKN) in chile pepper crops in New Mexico. A wide range of other annual and perennial weeds are also known to compete for resources in the same crops. However, their capacity to host RKN remains unknown. A preliminary field survey was conducted in the fall of 1992. The results of this survey indicated that common lambsquarters, common purslane, London rocket, lovegrass, Palmer amaranth, Russian thistle, and Wright's groundcherry might also host RKN. Therefore, a greenhouse study was conducted to determine the RKN host capacity of each of the above seven weeds. Six 10 cm pots of each weed were established in the greenhouse and allowed to grow for 56 d. On the 16th d, each pot was inoculated with 5,000 RKN eggs. On the 56th d, the plants were harvested. RKN eggs were extracted from the roots with a 10% bleach solution and counted. Roots were dried and RKN eggs/g dry root calculated.

Reproduction of RKN occurred on all seven weeds. From greatest to least reproduction, RKN produced 142,000 eggs/g common purslane, 126,000 eggs/g Wright's groundcherry, 1,665 eggs/g Palmer's amaranth, 1,177 eggs/g common lambsquarters, 914 eggs/g Russian thistle, 112 eggs/g lovegrass, and 108 eggs/g London rocket. Greenhouse conditions may not accurately simulate growing conditions in the field. Temperature fluctuations, for example, might have an effect on the RKN host capacity of various weeds. Other factors, such as intensive management of chile crops and a wide range of potential RKN hosts among summer and winter annual and perennial weeds may also be involved in RKN weed host interaction. Therefore, a field study is planned to evaluate RKN presence on weeds growing in association with chile pepper.

DIFFERENCES IN ETHYLENE BIOSYNTHESIS BETWEEN PICLORAM-SUSCEPTIBLE AND -RESISTANT YELLOW STARTHISTLE AND THE ROLE OF ETHYLENE IN RESISTANCE. M. K. Pedersen, T. M. Sterling, and N. K. Lownds, Graduate Assistant, Assistant Professor, Department of Entomology, Plant Pathology, and Weed Science, and Assistant Professor, Department of Agronomy and Horticulture, New Mexico State University, Las Cruces, NM 88003.

Abstract. Picloram-resistant yellow starthistle has been detected in a pasture in Washington treated with picloram for 10 yr. Susceptible (S) and resistant (R) accessions of yellow starthistle do not differ in absorption, translocation, or metabolism of foliar-applied picloram suggesting that resistance may be due to an altered site of action. Picloram is an auxin-like herbicide, and because auxins are known to induce ethylene production, it is hypothesized that resistance may be due to differences in picloram-induced ethylene production. Picloram-induced ethylene production increased in S with increasing picloram rates, whereas ethylene production in R

plants was not altered. To determine the role of ethylene on efficacy, picloram-induced ethylene production was blocked using the ethylene biosynthesis inhibitor aminoethoxyvinylglycine (AVG) or ethylene was supplied by treating with ethephon (an ethylene-releasing compound).

Ethylene production was blocked in both S and R when treated with AVG plus picloram compared to picloram treatment alone. Ethephon decreased the total fresh weights of both S and R. These results suggest that both accessions respond similarly to ethylene and that ethylene may play a role in picloram-induced injury symptoms. To determine differences in the ethylene biosynthetic pathway between S and R, ethylene was measured after application of exogenous 1-aminocylopropane-1-carboxylic acid (ACC), the immediate precursor to ethylene.

ACC increased ethylene production in S and R suggesting that ACC oxidase is present and functional in both accessions. Wounding, which induces ethylene synthesis through increased ACC synthase activity, increased ethylene production in S and R suggesting that this step in the ethylene biosynthesis pathway is present and functional in both accessions. No difference in auxin-induced ethylene production between S and R was observed when treated with 2,4-D or NAA suggesting that differences in ethylene production in S and R is a picloram-specific response. Differences in N-malonyl-ACC (MACC), a storage form of ACC, were not detected between S and R suggesting that resistance is not due to conversion of ACC to MACC.

Overall differences in ethylene production appear to play a role in resistance and might be due to an alteration in the ethylene biosynthetic pathway. Alternatively, resistance may be due to a regulatory aspect such as altered picloram-binding to auxin binding proteins resulting in a limited transduction signal for induction of ethylene production.

EFFECTS OF FLUOROBENZOATE TRACERS ON CROP GERMINATION. R. J. Heightman, J. Schroeder, and R. S. Bowman, Graduate Assistant, Assistant Professor, Department of Entomology, Plant Pathology, and Weed Science, New Mexico State University, Las Cruces, NM 88003; and Associate Professor Department of GeoScience, New Mexico Tech, Socorro, NM 87801.

Abstract. Water quality research investigating movement of herbicides through soil must compare herbicide movement to water movement. Anions such as bromide and chloride have been used to trace water movement in this area of research. However, these anions are not always appropriate due to background interference and analytical difficulties. Fluorinated benzoic acid derivatives, also known as fluorobenzoates, have many of the properties required of nonreactive soil and groundwater tracers, and have been used successfully under bare ground conditions. However, the effect of fluorobenzoates on plants is unknown. This lack of information has prevented the general use of these compounds in water quality investigations involving growing plants. Therefore, growth chamber studies were conducted to determine the responses of several crops to increasing concentrations of fluorobenzoate tracers.

The two tracers evaluated were pentafluorobenzoic acid (PFBA) and bromide as the control. Corn and cotton were the crops used in this experiment. Stock solutions of 0, 1, 10, 50, 100, 250, and 500 ppm of each tracer were prepared. The solutions were made in a 25% potassium phosphate buffer at pH 7.0. Electrical conductivity of the solutions ranged from 1.83 mS/cm to 2.71 mS/cm and pH values were 6.8 to 7.1. Each experiment was established as a completely randomized design with 10 replications of each treatment. In individual 100 ml petri dishes 25 seeds of each crop were placed between two sheets of germination paper, and the appropriate amount of tracer solution was added. The dishes were placed in a covered plastic box in a growth chamber at 29 C. After four days, seeds having a minimum of 5 mm shoot or root length were counted. Germination was expressed in terms of percent. Data were expressed in terms of mean ± standard deviation for each concentration, tracer, and crop combination. Results showed that neither bromide nor PFBA affected germination of corn or cotton at any concentration. This implies that fluorobenzoates may make good tracers to use with corn and cotton.

ALTERNATIVE METHODS OF WEED CONTROL

TIMING OF INFECTION OF DYER'S WOAD BY A *PUCCINIA* RUST UNDER FIELD CONDITIONS.

Karen M. Flint, Sherman V. Thomson, Steve Dewey, and John O. Evans, Research Associate, Plant Pathologist, Extension Weed Scientist, and Weed Scientist, Dept. of Biology, Utah State University, Logan, UT 84322.

Abstract. Natural stands of dyer's woad infected with a rust (*Puccinia* sp.), provided inoculum for a study to determine the timing of infection of woad seedlings and young rosettes in a field situation. At 2 wk intervals beginning on April 23, 1992 and continuing through September 23, 1992, cohorts of 10 pots each of 2-, 8-, and 14-wk-old uninfected woad plants were placed in close proximity to infected plants. Following this 2 wk exposure period, the pots were removed to a site isolated from other stands of woad to allow for incubation of infections; they were replaced in the field by successive cohorts. Plants exposed beginning on May 7 began to show symptoms by July 24. By mid-October, plants in 0, 77, 50, 50 and 3% of pots exposed for 2 wk beginning on April 23, May 7, May 21, June 5, and June 18, respectively, showed symptoms of rust infection. The age of plants at the time of exposure had no apparent influence on likelihood of infection. No plants exposed from July through early October have yet expressed symptoms. Preliminary studies conducted in 1991 showed similar results, and suggest that most natural infections occur in spring; but symptoms are not apparent for at least 2 and up to 9 months after infection. The lack of infection on plants exposed in late June through September may be related to the lack of rainfall and reduced populations of teliosori of the rust.

JOINTED GOATGRASS PROCESSING TO REDUCE GERMINATION OF CATTLE-FED SEED.

Drew J. Lyon and Ivan G. Rush, Assistant Professor Agronomy and Professor Animal Science, University of Nebraska-Lincoln, Scottsbluff, NE 69361.

Abstract. Winter wheat containing jointed goatgrass seed is often docked or rejected by grain purchasers. This grain may be fed to cattle. Winter wheat and cattle producers in western Nebraska were interested to know if feeding wheat contaminated with jointed goatgrass seed poses a risk of spreading this troublesome weed or if it is a feasible way to utilize this commodity. The objectives of this research were to determine if nonprocessed jointed goatgrass seed would remain viable after passage through the digestive system of cattle, and if so, to determine if processing of this seed would reduce seed germination to an acceptably low level. Nonprocessed jointed goatgrass seed viability was 75 and 76% for seed collected in either the rumen or the feces, respectively (Lyon, D.J., D.D. Baltensperger, and I.G. Rush. 1992. Viability, germination, and emergence of cattle-fed jointed goatgrass seed. J. Prod. Agric. 5:282-285). This high seed viability suggests that livestock fed nonprocessed jointed goatgrass contaminated wheat may act as a mechanism to disperse seed. A roller mill and hammer mill were used to coarse- and fine-grind jointed goatgrass seed. Germination was reduced by processing alone, but not to acceptable levels. Jointed goatgrass seed placed in the rumen of a fistulated steer for 24 h, after fine-grinding in a hammer mill, did not germinate. The hammer mill may be used to reduce the risk of disseminating jointed goatgrass when the milled jointed goatgrass contaminated wheat is fed to cattle.

Table Processing jointed goatgrass joints reduces germination of seed with and without 24 h of cattle rumen digestion at Scottsbluff, NE in 1992.

	Germination without rumen digestion		Germination after 24 h of rumen digestion	
Treatment	Undamaged seed	Damaged[a] seed	Undamaged seed	Damaged seed
	%	%	%	%
Nonprocessed	92	-	20	-
Course-grind roller mill	43	5	4	0
Fine-grind roller mill	22	1	2	0
Course-grind hammer mill	38	8	2	0
Fine-grind hammer mill	16	7	0	0

[a] Seed were classified as damaged if injury to the seedcoat was noticeable with the naked eye.

SHEEP GRAZING FOR WEED CONTROL IN SEEDLING ALFALFA. Carl E. Bell and Juan N. Guerrero, Weed Science Farm Advisor and Area Livestock Farm Advisor, Cooperative Extension, University of California, Holtville, CA 92250.

Abstract. Sheep grazing for weed control in seedling alfalfa is a traditional practice in the desert valleys of southeastern California. Alfalfa is sown in the fall and fields are grazed in the late winter in lieu of cutting for hay. Grazed fields are not treated with herbicides. This grazing is very close, sheep are left on the field until all alfalfa and weed leaves and stems above 3 cm high are gone. After the grazing, fields are irrigated and the second harvest is for hay.

A research trial has been completed comparing sheep grazing to standard herbicide practices, and to untreated, mown plots. The trial was repeated 3 yr and was conducted at the University of California Desert Research and Extension Center in Holtville, CA. Herbicide treatments were either; 1) EPTC preplant incorporated followed by 2,4-DB and sethoxydim postemergence, or 2) 2,4-DB plus sethoxydim postemergence. Herbicide treatment 1 controlled the weeds present in the experimental area well all 3 yr; weed biomass was less then 1% of total forage biomass the first yr of the trial, 24% of total biomass the second yr, and 4% of total biomass the third yr prior to the first cutting. Weed biomass as a percentage of total forage biomass for herbicide treatment 2 was 21% the first yr, 30% the second yr, and 9% the third yr at the same time. In the untreated, mown plots and the grazed plots, weeds represented 30% of total forage biomass the first yr, 35% the second yr, and 31% the third yr prior to the first cutting or the grazing. Compared to the untreated plots, the herbicide treatments did not reduce alfalfa biomass the first yr, however, during the second and third yr these treatments lowered alfalfa biomass by approximately 50% and 29%, respectively, at the first harvest.

Results from the first and second yr of this study show that at the second harvest there were no differences ($P > 0.05$) between herbicide treatment 1 and the sheep grazing for weed biomass. During the third yr, the grazed plots had higher ($P < 0.05$) weed biomass than herbicide treatment 1. In the first yr, alfalfa biomass at the second harvest was not different ($P > 0.05$) for the herbicide treatment and the grazing. Alfalfa biomass at the second harvest was decreased after the grazing during the second and third yr. At the third harvest of the alfalfa, biomass was slightly reduced in the grazed plots for the first yr, but not for the second or third yr. At all subsequent harvests, including 1 yr after the first harvest, there were no differences ($P > 0.05$) for alfalfa or weed biomass for any treatment. Alfalfa population (stand counts) did not vary ($P > 0.05$) between treatments at the first harvest, the second harvest, or one yr later.

During the second and third yr of this trial, quantitative data were collected on sheep feeding preferences using esophageal canula. Visual observations of sheep feeding behavior were made all 3 yr. Both measures indicate that sheep will eat many weeds (e.g. London rocket and volunteer wheat) before they eat alfalfa. Analysis of the nutritional value of the weeds present is being conducted. Analysis conducted to date suggest that, for some measures of nutritional value (e.g. % crude protein, % acid detergent fiber) many weeds have feed value equal or better than alfalfa.

EFFECT OF TILLAGE TREATMENTS ON ANNUAL GRASSES IN WINTER WHEAT. R. L. Cartee, J. H. Slade, C. B. Thompson, J. O. Evans, and R. W. Mace, Research Assistant Professor, Research Assistant/Farm foreman, Farm foreman, Professor, Research technician, Plants, Soils, and Biometeorology Department, Utah State University, Logan, UT 84322-4820.

INTRODUCTION

The original intent of this study was to investigate the effect of different tillage practices on water harvest, water conservation, crop residue management and yields of dryland winter wheat. During the early yr of the study, considerable differences in annual grass control between treatments were observed. At this time, other treatments were introduced to enhance control of these grasses.

Both the Nephi and Bluecreek experimental farms were infested with jointed goatgrass. Wild rye appeared at Nephi after surrounding land was enrolled in the Conservation Reserve Program (CRP). It is not known how these CRP lands became infested. Some jointed goatgrass seed can germinate on the surface of undisturbed soil (2) which may account for the increased population over time on these lands.

As the physiological characteristics of these annual grasses and winter wheat were similar (1) there are no selective herbicides for grass control during the wheat production period. Therefore it becomes imperative to control them during the fallow period. Post harvest field burning appears to be an effective deterrent to jointed goatgrass populations (4), unfortunately this method does not conform to USDA residue requirements. All of these factors indicate there is a dire need to determine a tillage chemical combination that will control these annual grasses while maintaining the proper residue levels, harvest and conserve water.

MATERIALS AND METHODS

The objective of this study was to determine an optimum combination of tillage and chemical fallow for weed control, yield, water and residue management. The treatments at the Nephi station were as follows:

1. No-till chemical fallow (no tillage operations, 64 oz/A of glyphosate + 2,4-D (Landmaster BW) during fallow period as needed for weed control).
2. Fall ripped-conventional fallow (ripped stubble after harvest tilled as needed during fallow period).
3. Fall chisel-conventional fallow (chisel plowed stubble after harvest tilled as needed during fallow period).
4. Fall ripped-spring seedbed-chemical fallow (ripped after harvest semi-smooth seedbed prepared early spring and 64 oz/A of glyphosate + 2,4-D as needed).
5. Fall chisel-spring seedbed-chemical fallow (chiseled after harvest, semi-smooth seedbed prepared early spring and 64 oz/A of glyphosate + 2,4-D as needed).
6. Fall ripped-chemical fallow (ripped after harvest, 64 oz/A of glyphosate + 2,4-D as needed).

The Bluecreek site had two additional treatments:

7. Fall chisel-chemical fallow (chiseled after harvest, 64 oz/A of glyphosate + 2,4-D as needed).
8. Fall chisel-spring seedbed-conventional fallow (chiseled after harvest, semi-smooth seedbed prepared early spring and tilled as needed).

The ripping was accomplished with a subsoiler with parabolic shanks, spaced at 24 inches at a depth of 22 inches. A chisel plow with 2 inch shovels spaced at 12 inches, 10 inches deep was used for the chiseled treatments. Conventional fallow was accomplished with a 16 inch duckfoot rodweeder combination. A skew-treader was used for the spring seedbed preparation unless there was excessive vegetation then the sweeps were used first.

RESULTS AND DISCUSSION

There were significant differences in control of the annual grasses due to treatments at both sites as shown in Table 1. The no-till chemical fallow treatment is considered as the control treatment for annual grass control since many studies have verified that these grass populations increase with reduced tillage (1, 2, 3). In this study, the no-till treatments had significantly more grass plants at both sites than any of the other treatments. The peak emergence periods for these grasses are in the fall and to a lesser extent early spring (3). Although some of the grass seed will germinate at the surface of undisturbed soil, it appears that the majority of seeds in the no-till treatment did not germinate until they were disturbed or covered with soil at planting time. It appears to have success in controlling these grasses in the following crop. Some tillage after harvest must be performed as shown by the data. This operation produced about 50% better control. The chisel operation appears to be better than ripping in grass control as some of the seeds are covered by too much soil by ripping, to germinate at this time. The early spring seedbed preparation also is beneficial in grass control as these treatments had the best control of all the treatments. Grass population had no effect on wheat yield as the grass plants were removed after counts were taken.

Table 1. Effect of tillage treatments on wild rye control and wheat yield at Nephi and jointed goatgrass control and wheat yield at Bluecreek in 1992.

Tillage	Plants/ 18 ft^2	Control	Yield
Nephi		%	bu/A
No-till chem fallow	29	0	30.5
Ripped conventional	8	72	31
Chisel conventional	7	76	33.9
Ripped spr till chem fallow	5	83	32.6
Chisel spr till chem fallow	4	86	32.7
Ripped chem fallow	14	52	28.3
(LSD = 0.05)	3		2.5
Bluecreek			
No-till chem fallow	35	0	37.6
Ripped conventional	10	71	33.2
Chisel conventional	6	83	33.4
Ripped spr till chem fallow	6	83	37.5
Chisel spr till chem fallow	4	89	38.9
Ripped chem fallow	20	43	35.8
Chisel chem fallow	16	54	36.5
Chisel spr till conventional	2	94	36.7
(LSD = 0.05)	2		NS

The different tillage treatments did have an effect on the increase of soil water as shown in Table 2. Fall tillage treatments revealed a significant increase in water harvest in the fall and winter months over the no-till treatment. In these areas, the majority of the water for October through March comes as snow. There is usually significant rain in October to wet the soil and to freeze the no-till plots, however ripped or chiseled plots are rough and fractured enough not to freeze. When snowmelt occurs in the spring the water will not infiltrate into the frozen soil as well as the unfrozen soil. Therefore, considerable runoff occurs from the no-till plots.

Table 2. Effect of tillage treatments on soil water increase measured for various periods for 1991.

Treatment	Oct-Mar		Fallow Period		Total		Increase	
	Nephi	Bluecreek	Nephi	Bluecreek	Nephi	Bluecreek	Nephi	Bluecreek
	inches						%	
No-till chem fallow	1.49	1.55	3.85	4.31	5.34	5.86	46	49
Ripped-conventional fallow	3.79	3.82	3.19	3.60	6.98	7.42	60	62
Chisel-conventional fallow	3.26	3.49	3.28	3.52	6.54	7.01	57	59
Ripped-spring seedbed-chem fallow	3.90	3.85	3.93	4.17	7.83	8.02	68	67
Chisel-spring seedbed-chem fallow	3.31	3.58	3.68	4.10	6.99	7.68	61	65
Ripped-chem fallow	3.94	3.72	3.98	4.38	7.92	8.10	69	68
Chisel-chem fallow	--	3.38	--	4.45	--	7.83	--	66
Chisel-spring seedbed-conventional fallow	--	3.45	--	3.45	--	6.90	--	58
Precipitation	4.80	4.71	6.75	7.19	11.55	11.90		

The chemical fallow treatments retain more precipitation that occurs during the fallow period than those that are tilled. The ripped chemical fallow treatments retained the most water at both sites. However, because the surface was so rough at planting time, stands of wheat were not adequate, thus decreasing yields as shown in Table 1. The fall ripped spring seedbed chemical fallow treatment was second in water retention at both sites, second or third in yield and second or third in grass control. All of the treatments maintained more than 50% of the previous crop residue after planting. Post harvest burning does not maintain residues at acceptable levels and spring wheat yields are about 50% of winter wheat at these sites. Annual grasses must be controlled in the non-crop yr. This study shows that grass control can be done by increasing germination after harvest using fall tillage with a non-inversion implement. Fallowing with a non-inversion implement in early spring destroys the fall germinated grasses and increases spring germination. These plants can be destroyed during the fallow period. Delaying planting until mid October can also improve grass control by allowing seeds to germinate after late summer/early fall rains then destroying them preplant.

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SOIL COMPACTION EFFECTS ON WEED SEEDLING EMERGENCE AND CONTROL. Milton E. McGiffen, Jr., Janet F. Johnson, Ward B. Voorhees, and Dennis D. Warnes, Assistant Plant Physiologist, Technician, Research Leader, and Professor, Department of Botany and Plant Sciences, University of California, Riverside, CA 92521-0124, USDA-ARS, North Central Soil Conservation Research Laboratory, Morris, MN 56267, and University of Minnesota, West Central Experiment Station, Morris, MN 56267.

Abstract. Herbicide application, seed bed preparation, and other early season activities often compact the soil. Soil compaction increases seed-to-soil contact and soil moisture, and decreases soil pore space. Soil compaction may increase seed germination under hot and dry conditions, or decrease seedling emergence in cool, wet weather. For three field seasons, we measured how wheel traffic affects bulk density, soil temperature, and seedling emergence of foxtails (*Setaria* spp.), wild mustard, common lambsquarter, redroot pigweed, and wild oats. Wheel traffic has its greatest effect on bulk density in the upper 15 cm of soil, where germinating weed seeds typically occur. Soil temperature was less variable in compacted soil. Soil compaction caused the greatest decrease in weed seed emergence and largest increase in control when experiments were initiated early in the season and the soil was not saturated by rain until several days after treatment. Herbicides that provided marginal weed control in uncompacted soils were most affected by wheel traffic. Additionally, runoff was greatly increased by compaction. Thus, decreasing the rate of herbicide application over wheel traffic areas may be desirable both from the standpoint of herbicide efficacy and groundwater quality concerns.

WSWS HERBICIDE RESISTANCE SYMPOSIUM

SPECIES DIVERSITY AND GEOGRAPHIC RANGE OF HERBICIDE RESISTANT WEEDS IN THE WESTERN REGION OF NORTH AMERICA. P. Westra, Associate Professor, Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, CO 80523.

Abstract. Weed scientists once believed that weeds would be immune to the severe resistance problems which have long complicated disease and insect management strategies. However, developments since the 1970s indicate that herbicide resistance in weeds not only complicates broad spectrum weed control in western North America, but may even threaten the utility of key new herbicides only recently developed for highly effective weed control in diverse agronomic crops. Triazine resistance in kochia, redroot pigweed, Powell amaranth, and common chickweed has altered the widespread use of this relatively inexpensive class of chemistry. Altered photosynthetic output and biomass accumulation in some triazine resistant species led weed scientists to speculate that herbicide resistant weeds were less "fit" or less "competitive" than susceptible accessions. However, research with sulfonlyurea resistant kochia and prickly lettuce has shown that in these weeds, there likely is no detectable penalty associated with the resistance trait. Reports of herbicide resistant weeds are increasing. Annual ryegrass and Russian thistle sulfonylurea herbicide resistant accessions have been documented in 1992. Wild mustard resistant to 2,4-D has been identified in Canada, as well as picloram resistant yellow starthistle in the state of Washington. Green foxtail resistant to trifluralin and diclofop-methyl has been identified in Canada. Wild oats which developed triallate resistance in Montana has been shown to be cross resistant to difenzoquat, and has probably been increasing in severity over the past 5 to 10 yr. While herbicide resistant weeds clearly have complicated chemical strategies for weed control, they have also opened up new opportunities for basic plant science research which may ultimately improve our understanding of the basic biology and ecology of key weeds in western North America.

Table 1. Western North American weed species which have developed herbicide resistance.

Avena fatua
Setaria viridis
Digitaria spp.
Lolium multiflorum
Lolium perenne
Bromus tectorum
Poa annua
Kochia scoparia
Amaranthus retroflexus
Amaranthus arenicola
Amaranthus powelli
Amaranthus hybridus
Salsola iberica
Lactuca serriola
Senecio vulgaris
Stellaria media
Centauria solstitialis

Chenopodium album
Commelina diffusa
Brassica kaber

Classes of chemistry to which herbicide resistance has developed

- Phenoxy acids
- Propanoic acids
- Triazines
- Picolinic acids
- Dinitroanalines
- Thiocarbamates
- ALS inhibitors
- ACCase inhibitors
- Bipyridyliums

Table 2. Chronology of herbicide resistance in western North America.

Year	Herbicide	Weed	Location
1954	2,4-D	*Commelina diffusa*	Hawaii
1962	Dalapon, TCA	*Digitaria spp.*	Hawaii
1968	Atrazine	*Senecio vulgaris*	Washington
1987	ALS Inhibitors	*Kochia scoparia*	Kansas
		Lactuca serriola	Idaho
1988		*Salsola iberica*	Kansas
		Stellaria media	Alberta
1987	Diclofop	*Lolium multiflorum*	Oregon
1988	Picloram	*Centauria solstitialis*	Washington
1988	Trifluralin	*Setaria viridis*	Manitoba
1990	ACCase inhibitor	*Avena fatua*	Manitoba
1990	2,4-D	*Brassica kaber*	Manitoba
1991	ALS inhibitors	*Salsola iberica*	Washington
1992		*Lolium perenne*	Texas

Aspects of herbicide resistance in western North America

- 178,300,000 A of total U.S. cropland
- 28,000,000 A of irrigated U.S. cropland
- Resistance is found in 16 of the 18 states
- Resistance is found in 4 western Canadian provinces
- 20 weed species have developed resistance

Table 3. Time from introduction of key herbicides and development of weed resistance.

Herbicide	Year introduced	Year of resistance
2,4-D	1945	1954
Dalapon	1953	1962
Atrazine	1958	1968
Picloram	1963	1988
Trifluralin	1963	1988
Diclofop	1980	1987
Triallate	1964	1987
ALS Inhibitors	1982	1987

THE INFLUENCE OF THE BIOLOGY AND ECOLOGY OF ITALIAN RYEGRASS ON THE EVOLUTION OF HERBICIDE RESISTANCE.

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

INTRODUCTION

Italian ryegrass occurs in grain fields, pastures and roadsides of the Willamette Valley, Oregon. Intensive usage of diclofop-methyl in the wheat cropping systems of this region has led to the selection of diclofop-methyl resistant I. ryegrass populations (1, 7). Kunjo (5) characterized nine populations of diclofop-methyl resistant ryegrass populations, determining that each of the nine populations survived the postemergence application of 1,100 g ha^{-1} diclofop-methyl. Two of these nine populations were resistant to diuron, a herbicide that had also been repeatedly used on these fields.

As a short term solution farmers are utilizing herbicides with alternate modes of action, such as triallate, pronamide, metribuzin, barban and trifluralin, to control diclofop-methyl resistant I. ryegrass. The long term solution to delay resistance in I. ryegrass will involve an integrated weed control strategy that includes a combination of rotation of herbicide modes of action, spring planting, delayed tillage, and planting of competitive crops.

In this paper I primarily discuss factors influencing the evolution of herbicide resistance in I. ryegrass and relate these detailed studies to herbicide resistance in general. I thank Arnold Appleby, Bill Brewster, Mary Lynn Roush, Claudio Ghersha, Ebrima Kunjo, Myron Shenk and Steve Radosevich, for providing information from their studies on diclofop-methyl resistant I. ryegrass. All reside at Oregon State University, Corvallis.

MODELS OF HERBICIDE RESISTANCE

Models of herbicide resistance have been developed to predict, with greater accuracy, the onset of herbicide resistance. Two models, the first developed by Gressel and Segel (4) and the second developed by Maxwell et al. (6), mathematically relate the factors that influence the rate of evolution of herbicide resistance. At present these models do not reliably predict the onset of resistance for new herbicide/weed combinations, but they do allow us to identify the gaps in our knowledge about the evolution of herbicide resistance.
Below are factors that have been included in the modelling of herbicide resistance.

- Initial resistance gene frequency
- Selection pressure
- Inheritance of resistance
- Gene flow
- Breeding system
- Seed dormancy
- Fitness of resistant vs. susceptible populations

Initial resistance gene frequency. Herbicide resistance genes, originating from mutations, are likely to exist within weed populations prior to herbicide usage. The initial resistance gene frequency has a major influence on the number of years of herbicide usage before resistance becomes apparent. If the initial resistance gene frequency is high then fewer years are required before resistance becomes a field problem. Research has not been conducted to establish the frequency of resistant individuals, or resistance genes, in I. ryegrass populations prior to the application of diclofop-methyl.

Management of Resistance. The initial resistance gene frequency is not a factor that can be easily modified.

Selection pressure. Selection pressure has two components - the effective kill of the herbicide and the number of applications of the herbicide. Selection pressure increases over time with each additional application of a herbicide or herbicides that have the same mode of action. The effective kill is a function of herbicide efficacy and persistence. Effective kill is measured in terms of the relative seed return of resistant and susceptible plants after treatment with the herbicide. Selection pressure has the largest impact on the rapidity of evolution of herbicide resistance.

Management of Resistance. Selection pressure can be altered by growers and is the key to reducing the rate of evolution of herbicide resistance. Rotation of herbicides that have different modes of action is a practical resistance management strategy that decreases selection pressure.

Inheritance of resistance. In a cross-pollinated species, resistance is likely to develop faster if the gene(s) for resistance are effectively dominant. Diclofop-methyl resistance in I. ryegrass is inherited as a single partially dominant nuclear gene (2). At field rates the heterozygote (RS) is effectively resistant.

Management of Resistance. The inheritance of resistance can not be easily manipulated. High herbicide rates/selection pressures are likely to select for single dominant resistance genes that code for an altered site of action and confer very high levels of resistance. In a cross-pollinating species such as I. ryegrass, low herbicide rates/selection pressures are likely to select for a polygenically inherited trait with many resistance genes conferring a low level quantitative resistance. The low rates of diclofop-methyl used in Australia (375 g ai ha^{-1}) has contributed to the evolution of quantitatively inherited resistance to diclofop-methyl in rigid ryegrass (*Lolium rigidum*).

GENE FLOW

The movement of resistance genes is primarily mediated via seed, vegetative propagules and pollen. Gene flow between populations occurs prior to herbicide usage but is of little practical consequence as it is unlikely that there will be a net change in resistance gene frequencies. The concern about gene flow arises once there is a differential in resistance gene frequencies between populations. This differential has usually resulted from differential herbicide usage on the populations.

Pollen. Resistance in I. ryegrass is inherited as a nuclear trait and can be transmitted via pollen (2). I. ryegrass is a predominately cross-pollinated species and pollen movement is wind mediated. Copeland and Hardin (3) studied gene flow via pollen movement in both I. ryegrass and perennial ryegrass under field conditions in the Willamette Valley. Gene flow via pollen movement from a genetically marked source was found to be very low at 6 m and undetectable at 12 m for both species. Similar results obtained by Maxwell (pers. comm.) indicate that the frequency of crosses between I. ryegrass populations separated by greater than 30 meters is likely to be extremely low. This low frequency of crossing may still be sufficient to increase the frequency of resistance genes in a neighboring population. Populations of I. ryegrass releasing resistant pollen will also be producing resistant seed. It is likely that the movement of seed will be the primary method of resistance gene movement, particularly over large distances. Pollen is, however, extremely important in the development of polygenic resistance.

Management of Resistance. Gene flow via pollen is not a factor that can be easily modified. Physical barriers that reduce wind speeds may reduce movement of pollen but are only likely to be practical for small plot work.

Seed. For most species seed is likely to account for the greatest proportion of resistance gene movement. Unlike pollen, seed does not require a recipient population or have a short (24 h) life span. Weed seeds are spread naturally by wind (tumble weed - kochia, russian thistle), water and animals, or assisted by man through combines, swathers, untarped trucks, hay and grain. In particular the practice of custom combining can rapidly spread resistance throughout an area.

Progression of resistance. Step 1. Initial independent selections of resistant populations (usually 6 to 12 yr usage of herbicides with the same mode of action). Step 2. Less predictable appearance of resistance as a result of spread of resistant seed via combines, grain etc. (2 to 12 yr usage of herbicides with the same mode of action).

Management of Resistance. The use of certified seed, along with the rigorous cleansing of all equipment is a practical method of reducing the spread of resistance.

GENE FLOW MANIPULATION IN I. RYEGRASS

There are few instances of herbicide resistance where the resistant weed freely crosses with an economically viable crop. In the Willamette valley, Italian ryegrass is both a weed and a crop. In theory the resistant wild type I. ryegrass could be "swamped" with susceptible genes (via pollen) from commercial I. ryegrass without loss of crop production. Leaving unsprayed strips of I. ryegrass within fields has also been suggested as a method to delay the onset of resistance.

Planting of commercial ryegrass. Commercial I. ryegrass and resistant wild type I. ryegrass differed in timing and abundance of both ovule production and pollen release such that pollen from the commercial I. ryegrass had a much greater chance of fertilizing the resistant plant population than vice versa (Ghersha and Roush, pers. comm.). There is, however, substantial pollen flow from the resistant wild type to the commercial I. ryegrass. The resultant seed will contaminate the commercial crop and facilitate the rapid spread of resistance. Contamination will also result directly from the resistant wild type I. ryegrass seed as this seed cannot be separated from the commercial I. ryegrass. A high level of contamination with the inferior resistant wild type I. ryegrass would downgrade commercial varieties and spread herbicide resistance.

Unsprayed strips. After four years of gene flow between unsprayed strips of susceptible commercial and resistant wild type I. ryegrass there was only an 18% reduction resistance in seed collected from the resistant wild type strips (Ghersha and Roush, pers. comm.).

Management of Resistance. The manipulation of gene flow in I. ryegrass is a novel, but unfortunately ineffective, approach to resistance management.

FITNESS

Weed populations are variable and any two populations, chosen at random, are likely to exhibit differences in fitness. Observed differences in fitness between a resistant and a susceptible population may be independent of resistance. To overcome this problem, near isogeneic lines can be used to accurately evaluate the fitness of resistance genes. The environment under which fitness is evaluated will also dramatically affect the outcome.

Resistant vs. susceptible or resistant vs. crop. Most fitness studies have focussed on the difference in competitive abilities between R and S populations. But, under normal cropping practices, it is rare for R individuals to be competing with S individuals. After successful weed control strategies have been implemented there are normally far fewer susceptible weeds than crop plants. Resistant individuals primarily compete with the crop and other uncontrolled weed species, not susceptibles of the same species. Susceptibles of the same species still exist within the crop (herbicide misses, late staging etc), but generally at low densities. Once resistance is in its final stages and large patches are infested with resistant plants then R individuals are likely to be competing primarily with themselves and secondarily with the crop.

If a herbicide with a different mode of action is employed it will control R and S individuals equally and the few escapes, both R and S individuals, will be competing primarily with the crop. R and S plants will only compete with each other when heavy infestations of susceptibles are left after failure of the weed control strategy. A comparison of resistant individuals with the crop(s) is more relevant than with susceptible individuals.

Given a fixed initial starting density of resistant weeds on an area of land, the appearance of resistance as a field problem will depend on the multiplication and expansion rate of these individuals. The multiplication rate will be dependent on the competitiveness of the crop - species, seeding rate, rapidity of establishment, seedling vigor, etc. Competitive crops such as barley and rye will delay the onset of resistance, whilst crops such as flax and lentils will allow rapid multiplication of resistant individuals.

Management of Resistance. Use competitive crop species and establish competitive crops by using certified seed, increasing seeding rates, and using agronomic practices that favor the crop over weeds.

DENSITY OF RESISTANT INDIVIDUALS VS. RESISTANCE GENE FREQUENCY

The number of resistant individuals per unit area (density of resistant individuals) is a factor of the resistance gene frequency, the inheritance of resistance and the population density. Below is a scenario of two fields, both 100 ha in size. Resistance is inherited as a single dominant gene:

Field A	Resistance gene frequency	1:10,000,000
	Population density	100 plants m^{-2}
	No. resistant individuals/100 ha	10 plants
Field B	Resistance gene frequency	1:1,000,000
	Population density	10 plants m^{-2}
	No. resistant individuals/100 ha	10 plants

In a predominately self-pollinated species, and under identical management strategies, resistance will appear as patches at the same time in the two fields. The number of resistant individuals per unit area is a better predictor of resistance than either the resistance gene frequency or the population density alone.

Management of Resistance: Do not apply selective herbicides on very dense infestations of weeds. First reduce weed densities by cultural means, or use a herbicide that will not be used in the crop rotation on a regular basis (eg: paraquat, glyphosate). Then use selective herbicides judiciously.

SUMMARY

I reiterate the initial factors considered by herbicide resistance modelers, and suggest some changes (**in bold**) that should be considered.

- Initial resistance gene frequency
- **Density of resistant individuals (gene freq., inheritance and population density combined)**
- Selection pressure
- Inheritance of resistance
- Gene flow **with a greater emphasis on seed movement by man**
- Breeding system
- Seed dormancy
- Fitness of resistant vs. susceptible populations
- **Competitiveness of the resistant weed vs. crop**

Herbicide resistance models are often used in hindsight, after the development of resistance, to predict the initial resistance gene frequency. In order to make forward predictions about new weed/herbicide combinations we must obtain accurate measurements of initial resistance gene frequencies/densities of resistant individuals.

Immediate action is required to delay herbicide resistance. To delay herbicide resistance:

- Rotate herbicide modes of action
- Reduce seed dispersal
- Use competitive crops and certified seed
- Use cultural practices for weed control
- Alternate all weed control measures, not just herbicides.

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HERBICIDE RESISTANT WILD OATS (*Avena fatua* L.) IN NORTH AMERICA. S. S. Seefeldt[*], D. R. Gealy[*], E. P. Fuerst[*], B. D. Brewster[#], A. P. Appleby[#], and P. K. Fay, Graduate Research Assistant, Plant Physiologist, USDA-ARS, Pullman, WA 99164; Assistant Professor, Research Associate, and Professors, Crop and Soil Science Department, Washington State University[*], Pullman, WA 99164; Crop Science Department, Oregon State University[#], Corvallis, OR 97331; Department of Plant and Soil Science, Montana State University, Bozeman, MT 59717.

Abstract. The frequency of wild oat resistance to herbicides is increasing in North America.

Montana. Resistance to triallate was documented during the winter of 1991 to 1992 in an irrigated malt barley district in Fairfield, Montana. More than 40 seed samples out of 67 contained seeds that were resistant to triallate, and cross resistant to difenzoquat. There were 67 samples collected by Monsanto personnel in response to performance to complaints. Randomly selected wild oat seed samples were collected throughout Montana in 1992 and screened to determine the extent of resistance. There has been no wild oat resistance to other herbicides documented to date.

Oregon. There are approximately 12 fields in western Oregon with wild oat resistant to diclofop, fluazifop, and sethoxydim. The diclofop resistant biotypes are always cross resistant to fluazifop but not always to sethoxydim. One line, resistant to diclofop, is not resistant to fenoxyprop.

Physiological aspects. Three of several diclofop-resistant biotypes show greater than 10-fold resistance to diclofop. They differ significantly in their cross resistance patterns, indicating that they have evolved independently. In general, however, they are resistant to the 'fops' (fluazifop, etc.) but not the 'dims' (sethoxydim, etc.), and they show little resistance to wild oat herbicides with other modes of action. The diclofop-resistant wild oats from Canada show a great diversity of cross resistance patterns, again indicating independent evolution. As yet, research has failed to identify the mechanism of resistance. The inheritance of resistance is being evaluated by research groups at Oregon State and Washington State Universities.

DNA SEQUENCE VARIATION IN THE ACETOLACTATE SYNTHASE GENE OF ALS INHIBITOR RESISTANT KOCHIA BIOTYPES. C. V. Eberlein and M. J. Guttieri, Associate Professor and Research Associate, University of Idaho Aberdeen Research and Extension Center, Aberdeen, ID 83210.

Abstract. Kochia biotypes resistant to acetolactate synthase (ALS) inhibitors are widespread, with well over 400 confirmed sites of kochia resistance in North America. To determine whether one or several resistance mutations are present in kochia, a region of the ALS gene known to be pivotal in conferring resistance was sequenced from chlorsulfuron-resistant (R) kochia biotypes collected in the western United States and Canada. Most R biotypes had mutation in the codon for the proline residue in Domain A, as previously reported. However, the nature of the amino acid substitution was highly variable. Six different amino acid substitutions, alanine, arginine, glutamine, leucine, serine, and threonine were observed in R biotypes. Some R biotypes did not have an amino acid substitution in Domain A, although *in vitro* assays of ALS inhibition indicated resistance was due to an altered form of ALS. Therefore, other regions of the ALS gene may be involved in resistance to ALS inhibitors. Our results indicate that multiple alleles confer resistance to ALS inhibitors in kochia. Thus, widespread kochia resistance to ALS inhibitors is due in part to multiple founding events.

THE BIOLOGY OF SULFONYLUREA HERBICIDE RESISTANT KOCHIA BIOTYPES. Donn C. Thill, Carol A. Mallory-Smith, Curtis R. Thompson, and George P. Stallings, Professor, Research Scientist, Research Associate, and Graduate Assistant, Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID 83843.

Abstract. Kochia biotypes exist that are resistant to sulfonylurea (9), triazine (5), and both triazine and sulfonylurea herbicides (9). Kochia is an introduced herbaceous annual ornamental that escaped from cultivation to cropland, roadsides, and waste areas (4). The species is a colonizer of saline and dry areas that germinates in the spring over a wide temperature range. The plant has a highly variable form, flowers about 8 to 12 wk after emergence, and typically produces over 14,000 seeds/plant. Seed longevity in soil ranges from less than 2 yr (1) to over 3 yr (14). Kochia is diploid with a 2n chromosome number of 18 (13). Cross pollination in kochia appears to be obligatory (6, 10). Observations indicate that male and female floral parts mature sequentially. Stigmas appeared receptive to pollen several days before pollen grains were shed from anthers in the same flower. Usually these stigmas desiccated before pollen was shed by the anthers. Thus, pollen grains deposited on stigmas likely come from other flowers on the same plant (kochia flowers indeterminately) or from pollen on neighboring plants.

Inheritance of sulfonylurea herbicide resistance in kochia is reported to be a dominant, nuclear trait (7, 10). About 75% of F_2 plants (for F_1 plants, resistant kochia was the pollen donor and these plants were allowed to self pollinate to produce F_2 seed) showed little or no effect from chlorsulfuron applied postemergence at 53.5 g/ha, while 25% of the plants died (10).

Resistant biotypes of kochia germinated faster than susceptible biotypes at cooler temperatures (7, 10). At 8 C, resistant and susceptible kochia seeds attained maximum germination at 192 and 336 h, respectively (10). At 18 C, maximum germination was attained at 110 h for the resistant biotype and at 144 h for the susceptible biotype. Both biotypes germinated the same at 28 C.

Resistant and susceptible kochia biotypes have nearly equal relative competitive ability. For example, the competitiveness of resistant and susceptible kochia biotypes from Kansas were compared in two greenhouse experiments using third generation greenhouse produced seed for both biotypes (10). The average relative competitive ability was 0.75 and 0.85 for the resistant and susceptible biotypes, respectively. Relative growth rate studies showed that both biotypes grew similarly (10). Greenhouse and field studies in Colorado also showed little or no difference in biomass and leaf area between resistant and susceptible kochia biotypes (2).

Cross pollination, pollen dispersal, and pollen viability have been investigated with resistant and susceptible biotypes of kochia. Cross pollination between resistant and susceptible kochia in the field ranged from 0.5 to 13% (8, 12). Hybridization has been recorded at about 30 m from the closest resistant plant (12). Pollen grains have been collected up to 62 m from the closest pollen source (12). Pollen remained viable longer at 4 C and high relative humidity compared to 28 C and 33% relative humidity (8).

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SIMULATION OF CHLORSULFURON RESISTANCE EVOLUTION IN KOCHIA POPULATIONS.

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INTRODUCTION

Frequent use and persistence of chlorsulfuron provided rapid selection for chlorsulfuron resistant *Kochia scoparia* in wheat and barley fields in Montana. Several studies have been conducted in Colorado, Idaho and Montana to determine the gene flow potential, inheritance and relative fitness of the chlorsulfuron resistant (R) and susceptible (S) biotypes of kochia. Information from these studies was used to parameterize the RSIM model (1) and then simulate chlorsulfuron resistance evolution in kochia under different relative fitness assumptions and herbicide management scenarios.

MATERIALS AND METHODS

Kochia is a summer annual broadleaf weed that can germinate and grow under moisture stress. There is little dormancy in the seed and an estimated viability of 2 to 3 yr in the soil. Therefore, seed mortality was estimated to be 80% in soil for both R and S kochia. Average germination rates have been estimated at 35 to 38% for kochia in the field. However, under cool conditions germination was recorded as high as 97% for the R biotype and 86% for the S biotype of kochia. In addition, the S biotype was observed to have a delayed emergence behind the R biotype under cool conditions. Since the model does not account for differences in emergence time, the effect of different R and S emergence times was simulated by increasing natural S seedling mortality to 70% and leaving R at 50%. Both biotypes were assumed to have 50% seedling mortality under warm weather conditions and when there was no herbicide in the system. Maximum potential seed production per plant was set at 12,940 for the R and 11,130 for the S biotypes. The R biotype was assumed to be the same or slightly more competitive than the S biotype based on biomass accumulation under a range of densities and proportions of the two biotypes. Chlorsulfuron resistance inheritance in kochia was assumed to be associated with a single dominant allele. Kochia was assumed to be self-fertilized with approximately 13% outcrossing.

RESULTS AND DISCUSSION

Chlorsulfuron resistance evolution in kochia populations was first simulated under the assumption that the R biotype was equal in fitness to the S biotype. When resistance was assumed to exist in the population at a mutation rate of 10^{-7} at the onset of chlorsulfuron use, resistance was predicted to reach nearly 90% after 6 yr of continuous exposure to the herbicide. Upon discontinuing the use of chlorsulfuron, resistance remained at the proportion reached in the final year of chlorsulfuron use.

Simulations were conducted under the assumption that there was a fitness advantage for the R biotype as described above for cool weather conditions and relative competitive ability. The first simulation under the constant cool conditions examined resistance evolution under no herbicide selection and indicated that the resistant biotype would take approximately 110 yr to replace the S biotype as the dominant phenotype in the kochia population starting with a 10^{-7} proportion of R in the initial population. When the simulation was conducted with a R fitness advantage only due to relative competitive ability then the shift in dominance from S to the R biotype took approximately 240 yr. These results raise the question of why the original population would have been susceptible to chlorsulfuron when selection began. There is little indication that chlorsulfuron was not effective on kochia in the testing phase of the herbicide, therefore resistance probably existed at very low proportions in most populations. Thus it is unlikely that under field conditions there is a R biotype fitness advantage.

Further simulations under the assumption of a R biotype fitness advantage indicated that resistance increased to 85 and 95% in the kochia population after 6 yr of constant selection with chlorsulfuron under warm and cool conditions, respectively. In subsequent simulations, management strategies that have been suggested to reduce the rate of resistance selection were assessed. Rotating an alternative herbicide (90% efficacy) with chlorsulfuron (95% efficacy) every other year delayed resistance selection by 4 yr and mixing the two herbicides delayed resistance selection 11 yr. While it is not possible to simulate the evolution of cross- or multiple resistance with the RSIM model, the selection intensity imposed by each strategy for cross- or multiple resistance to chlorsulfuron and the alternative can be suggested by determining which management strategy maintains the total kochia population the lowest. In theory, the lower the population the higher the probability that less fit rare mutants (cross resistant individuals) can be successful (grow and produce seed). Total (R + S) kochia seed bank populations were monitored under the rotate and mix management strategy simulations. The mix strategy maintained the kochia population at the lowest level for the longest period suggesting that it may provide the highest risk of selecting for cross resistance. Therefore, these simulations suggest that to reduce selection for chlorsulfuron resistance and cross or multiple resistance the rotation of chlorsulfuron with an alternative herbicide may be preferred over mixing the two chemicals.

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ACCase HERBICIDES: AN INDUSTRY PERSPECTIVE ON HERBICIDE RESISTANCE.

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Abstract. ACCase resistance has occurred after many years of highly successful use in cereal and dicot crops. Grower acceptance has led to over-reliance in certain areas where this chemistry fits especially well. ACCase resistance can occur in both monoculture crops and rotated crops with the numerous products based on this family of herbicides.

What should be done once a grower has herbicide resistance? What should industry do to prevent a resistance problem from getting worse? These are simple questions but there are no easy answers. Testing for resistance and monitoring the results of testing is crucial for industry to be able to address resistance. Before resistance occurs, growers need to be aware of which chemistries are similar and which are not, so that many different types are employed. After resistance occurs to a particular type of herbicide, industry should acknowledge the resistance and use those experiences to educate growers. In the case of ACCase herbicides, some grassy weeds can be selectively controlled in a particular crop by many herbicide families, while other grassy weeds have limited options. Crop rotations and the availability of similar and dissimilar chemistries will impact resistance strategies. These considerations will affect how industry responds to ACCase resistance.

PREVENTION AND MANAGEMENT OF HERBICIDE-RESISTANT WEEDS IN A GLOBAL CORPORATE ENVIRONMENT.

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INTRODUCTION

This report is an overview of how one global agricultural products company views the issue of herbicide resistance and responds accordingly. As an example, I will use the global company, Cyanamid, and then the national company, American Cyanamid Company. I will focus on the herbicides difenzoquat and the imidazolinone family (imazapyr, imazethapyr, imazaquin, imazamethabenz-methyl, and AC 263,222) and on wild oats, an important weed to most members of this society. The various documents described were distributed at the meeting, and can be obtained from your local Cyanamid representative.

Cyanamid is an international corporation, composed of subsidiary companies representing individual countries or groups of countries. These subsidiary companies are grouped into four divisions: American Cyanamid Company's Agricultural Products Division (Wayne, NJ) and Agricultural Research Division (Princeton, NJ), Latin America Group representing Central and South American countries, and the International Division representing Canada and the rest of the world.

American Cyanamid Company recognizes the potential for herbicide-resistant weeds to occur from the repeated use of any class of chemicals and is committed to maintaining the long-term use and efficacy of herbicides. This can only occur by effectively managing herbicide-resistant weeds and by being good stewards of all our herbicide products and the environment.

We believe that weed resistance is an issue that can be managed to prevent its onset and mitigate its effects. It is in the best interest of Cyanamid worldwide, American Cyanamid, the agricultural chemical industry, and the farmer to preserve the efficacy of herbicides which are both effective and environmentally attractive.

Three keys to success. Three key elements for successful prevention and management of herbicide resistance are 1) leadership in industry, academia, and government, 2) grower attitudes, knowledge and practices, and 3) continued research, communication and cooperation by all groups. This report will focus on Cyanamid's activities in these three key areas. The preceding talks in this symposium, as well as reports in other sections of this meeting, highlight the key importance and advances in basic and applied research conducted by other companies, and by university and government weed scientists.

Industry leadership is one key to preventing and managing herbicide resistance. As used here, the term "industry" refers to the community of primary manufacturers, distributors and commercial applicators. Cyanamid's agricultural divisions are well coordinated with multi-dimensional research, educational, and marketing programs on a global scale.

Cyanamid research. Cyanamid's Research, Development, Marketing, and Sales divisions have conducted many yr of investigation. Examples of the multi-dimensional scope of our efforts are highlighted in Table 1.

Table 1. Cyanamid's multi-dimensional global research and development programs.

I. SCOPE OF ACTIVITIES

1. Cyanamid global research
2. University research
3. Multi-industry task forces
4. Multi-country task forces
5. Professional society committees

II. BASIC RESEARCH PRIORITIES

1. New Products: Mode(s) and Mechanism(s) of Action
2. Rapid Bioassays for Herbicide Resistance Assessment: biochemical to whole plant (growth chamber/greenhouse)
3. Computer Modeling: weed biology, crop rotation, market share, Treatment Acreage Dynamics Model (A. N. Sinha)
4. Weed Biology, Biochemistry

III. FIELD RESEARCH PRIORITIES

1. Management Methods - prevention
2. Management Methods - mitigation (rescue, containment)
3. Management practices by geography and crop
4. Do not support research to find resistance

CORPORATE POSITION STATEMENTS

Position statements are one means for a corporation to report key information. In a large organization, each position statement takes a significant amount of time to research and develop. Input from and the impact on each of the following functional groups must be obtained and balanced: Research and Development, Marketing, Sales and Technical Service, distributors (e.g. AgriCenters) and commercial applicators, university and government weed scientists and farm advisors, and growers.

American Cyanamid Company issued its first "Position Statement On Herbicide Resistance" in June 1990. This statement defined the issue, listed major dependent factors, affirmed our commitment to maintaining the efficacy of herbicides, indicated that we were assessing the potential impact and developing strategies to minimize any significant risks, and reported on our participation in the Herbicide Resistance Action Committee (HRAC) of the International Group of National Associations of Agrichemical Manufacturers (GIFAP).

In October 1991, American Cyanamid issued a "Position Statement On Weed Resistance/Imidazolinone Herbicides" which was distributed to attendees at the WSWS meeting last year. The statement recommended 1) six techniques to prevent the occurrence of weed resistance and 2) a list of herbicide tank mixes or sequential combinations for both soybean and corn to further lessen the likelihood of weed resistance developing when using imidazolinone-tolerant corn in areas where imazethapyr and imazaquin are also options for soybean weed control. A position statement on herbicide resistance in wild oats will be issued soon.

When one compares the printed position statements of Cyanamid to those of other groups, I see general unity in the principles for management of herbicide resistance. There are differences in specific recommendations, which I suggest are good. It is a fundamental principle of democratic free enterprise systems that competition creates multiple solutions to a problem. Each entity recommends the solution that fits their region or product line. Well-informed consumers make the final choice for their specific situation.

We have developed strategies to minimize identified significant risks and continue to actively assess the potential impact of weed resistance on the performance of our products. Cyanamid recommends the following techniques to help prevent or delay the occurrence of weed resistance (Table 2).

Table 2. Techniques to help prevent or delay the occurrence of weed resistance.

Use as many techniques as possible in an integrated weed management program.

1. Use scouting and follow university recommendations on commercial weed thresholds to determine the need for herbicide treatment.
2. Utilize tank mixes or sequential applications of herbicides with different modes of action that control the same weed species.
3. Avoid extended use of herbicides from the same chemical family alone on the same acre of land.
4. Use a minimum number of herbicide applications per season.
5. Combine tillage practices with herbicide treatments.
6. Practice crop rotation.
7. Read and follow herbicide label recommendations.

Cyanamid recommends using an integrated weed-management program because data clearly show that reliance on only one management technique may not prevent herbicide resistance. Note that Cyanamid recommends tank mixing or sequential applications of different mode of action herbicides as being an effective prevention method (Table 2).

If resistance is suspected, Cyanamid recommends immediate containment. Our Technical Service and Sales Representatives are trained in procedures to determine whether a grower's weed problem is due to resistant weeds or other causes.

When resistance has occurred, monocultural practices were usually used. For example, in 1992, imidazolinone-resistant cocklebur was discovered in a few isolated Mississippi Delta soybean fields where growers used the product in a manner not recommended on the label: low rates of imazaquin applied in two to three sequential applications per year over four consecutive years. Technical Service and Sales Representatives worked closely with growers to immediately control the resistant cocklebur with postemergence applications of bentazon or lactofen or imazaquin plus acifluorfen.

Numerous cases of resistant wild oats have been reported both in this and other meetings as a result of consecutive use over several years of a single product alone (e.g. triallate or diclofop), but also even after chemical rotation of herbicides with different modes of action. In Canada, triallate-resistant wild oats were found to have multiple-resistance to difenzoquat. Cyanamid has confirmed multiple-resistance to difenzoquat in several U.S. biotypes examined to date. The extent of multiple-resistance in the U.S. is under investigation.

No wild oat resistance to imazamethabenz-methyl has been reported to date. In cases of triallate-resistant wild oats, imazamethabenz-methyl is an effective alternate herbicide for use in wheat, barley, and sunflowers. In cases of only diclofop- or fenoxaprop-resistant wild oats, imazamethabenz-methyl, difenzoquat, or the tank mix of reduced rates of imazamethabenz-methyl plus difenzoquat are effective alternate herbicide treatments in wheat and barley.

Containment of resistant wild oats is a serious matter. In addition to the above techniques (Table 2), use seed certified free of herbicide-resistant biotypes. Do not use crop seed from fields with known or suspected wild oat resistance.

EDUCATION AND TRAINING

Maintenance of the efficacy of herbicides can only occur when products are used correctly over time by well-informed growers, custom applicators, independent field advisors, university weed scientists, and company sales and service representatives. Cyanamid is taking a leading role in the industry in ensuring that herbicide-resistance education occurs and that the recommendations for prevention and management of resistance are disseminated and followed. The following tables outline American Cyanamid's vast network of educators/resource people (Table 3), customer educational opportunities (Table 4), and examples of training materials and programs for employees (Table 5) and growers (Table 6).

Table 3. American Cyanamid's network of educators/resource people.

100+	Scientists	
	Basic Research Scientists	
	Product Development Managers	LARGE NUMBER OF PEOPLE
	Field Agriculturalists	+
	Technical Service Reps	RAPID INTERCOMMUNICATION
7,900+	Sales Reps & Managers	
	Cyanamid + AgriCenter*	
8,000+	Educators/Resource People in U.S.A.	

*AgriCenter is a trademark of American Cyanamid Company.

Table 4. Customer educational opportunities.

- One-on-One Meetings, Field Calls
- Grower Meetings
- Dealer Meetings
- University Seminars
- Field Days
- Special Marketing Programs
- News Media Interviews/Stories
- Conferences

Table 5. Examples of internal company training programs.

- TRAINING MANUAL
  - Herbicide Resistance in Weeds - Sales Training Guide PE-0473
- EFFECTIVE COMMUNICATION SKILLS

Second key. The grower (attitude, knowledge, practices) is also a key to maintaining effective herbicides for a sustainable agriculture. Herbicides are essential national resources that are limited in number and need to be protected. It is important that growers learn and use an integrated approach to weed control in order to prevent the development of, or control the spread of, resistant weeds. While resistance management practices are under the control of growers, everyone--including growers, industries, and consumers--loses if herbicide-resistant weeds develop. When resistance develops, growers will usually incur higher input costs and, consequently, decreased profits. Cyanamid is committed to working with growers in these matters through the educational programs and opportunities described above.

Third key. Continued research, communication, and cooperation between growers, industry, university, and government will be necessary to effectively manage herbicide-resistant weeds in the future. Table 7 lists examples of the herbicide resistance committees which Cyanamid participates in on a world wide basis.

Cyanamid Company recognizes the potential for herbicide-resistant weeds to occur from the repeated use of any class of chemicals and is committed to maintaining the efficacy of herbicides. Three key elements for successful prevention and management of herbicide resistance are 1) leadership in industry, academia, and government, 2) grower attitudes, knowledge and practices, and 3) continued research, communication and cooperation by all groups. Cyanamid's divisions are well coordinated with multi-dimensional research, educational, and marketing programs on a global scale. Cyanamid has published recommendations to help prevent or delay the occurrence of weed resistance and to control it if it occurs. The grower (attitude, education,and practices) is also a key to maintaining effective herbicides for a sustainable agriculture. Cyanamid is taking a leading role in the industry in ensuring that herbicide-resistance education occurs and that the recommendations for prevention and management of resistance are disseminated and followed. Continued research, communication, and cooperation between growers, industries, universities, and governments will be necessary to effectively manage herbicide-resistant weeds in the future.

Table 6. Examples of public training programs and published information.

EFFECTIVE COMMUNICATION SKILLS
  Ambassador/NAWG Program - national level
  Statesman Program - state level

BOOKLET, PE-12208 "Herbicide Resistance in Weeds, An Overview"

RISK ASSESSMENT WHEEL, PE-0570
  "Lowering Your Herbicide Resistance Risk"

INFORMATION BULLETIN, PE-0427
  "Position Statement, Weed Resistance/Imidazolinone Herbicides"

TASK FORCE BROCHURES AND PUBLICATIONS
  Herbicide Resistance Action Committee, descriptive brochure. ALS/AHAS Inhibitor Resistance Working Group: "Guidelines for Managing Resistance to ALS/AHAS-Inhibiting Herbicides"

Scientific Papers in Professional Journals

Table 7. Cyanamid participation on herbicide resistance committees.

Intercompany committees

  Herbicide Resistance Action Committee
  ALS/AHAS Inhibitor Resistance Working Group
  Grass Herbicide Resistance Working Group
  ACCase Inhibitor Resistance Working Group

  International Organization of Pest Resistance Management
  Australian Herbicide Resistance Action Committee

Academia/Company/Government committees

  WSSA Herbicide Resistance Committee
  NCWSS Herbicide Resistance Committee
  WSWS Herbicide Resistance Committee

PROJECT 1: WEEDS OF RANGE AND FOREST

Chairperson: Paul F. Figueroa

Subject: The Net Effects of Herbicide Restrictions on Forest and Range Lands

1. The Rapid Spread of Noxious Weeds: A Major Threat to Millions of Acres of BLM Lands. Jerry Asher, BLM, Portland, Oregon.

Maintaining and restoring native vegetation diversity is a major BLM management goal. The single greatest negative impact on native vegetation diversity is the continual spread of exotic noxious weeds. This "explosion in slow motion" is occurring on private, state and federal lands throughout the west. Weed infestations reduce wildlife habitat, wildlife and livestock forage and recreational values. Weed infestations also increase erosion and fire hazards. The BLM is currently averaging about 65,000 A/yr of noxious weed management. Although good efforts are underway the BLM is unable to halt the spread of noxious weeds. The BLM has about 6 million A infested with noxious weeds which spread at about 14%/yr. It is estimated that 15 to 20 million additional acres will be lost to noxious weeds by the yr 2000.

Weed management efforts can be effective and economical if they include strong efforts of prevention, coordination, control of small infestations and containment of large infestations. But are we winning if only containing the spread? The people hit the hardest economically listen, but what about others? One problem is the educational system does not fully educate students. Many graduate with attitudes against pesticides, even in IPM management strategies. Alternative species grazing needs more investigation. But, large scale switching of species could affect commodity markets. As well as shifting vegetation. A proper mix of grazing livestock species could help with vegetation management and sustainable producer income.

2. Consequences of Restrictions on Herbicide Use on U. S. Forest Service Timberlands in California. Duane A. Nelson, U. S. F. S., Placerville, California.

The USFS manages about 20 million A of public woodland in California. Using intensive management techniques, including pesticides, these lands have the potential to produce a sustainable annual yield of about 1.9 billion board feet. Direct value of the standing trees is about $850 million. The industry generates 29,000 jobs per year, representing $1.3 billion of employment generated income. Timber yields can be reduced by losses to insects, disease, vertebrate pests and competition with other vegetation. Management of competing plants is the cornerstone for integrated pest management in conifer plantations. Funding sources are becoming increasing constrained. Therefore, managers must find more cost effective ways to meet vegetation management objectives. Mechanical treatments are expensive and largely ineffective. Herbicides (though safe, effective and inexpensive) are controversial. Some land managers seek to avoid controversy by using less effective and more costly methods. Unless this trend changes, conifer survival and growth will be sacrificed. In addition, overall forest health, resistance to wildfire and ability to sustain wildlife will also decline.

An industry-wide commitment to excellence in vegetation management may help resolve the controversy of herbicide use between land managers and the urban population. A determined effort must be made to reach the "public" with science and facts. Land managers must gain the public trust and establish their role as stewards of the environment, as well as the producers of valuable commodities for society's consumption. But we all must work together. We (WSWS) have a good resource. We must share information better between regions and projects. Networking of resources and information would help. So would a National Program Loader for Weed Management. A coalition could be build with representatives from all agencies or maybe departments. This group might start with exotic plants but work also with undesirable native plants. This could be a funding source in the future. A coalition could also help resolve inter- and intra-agency conflicts.

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PROJECT 2: WEEDS OF HORTICULTURAL CROPS

Chairperson: Jill Schroeder

Subject: Integrated Weed Management Systems for Horticultural Crops

1. Integrated weed management. Steve Guldan, New Mexico State University Agricultural Science Center at Alcalde.

Steve defined integrated weed management as "looking at all the decisions we make and the operations we do in crop production for their effects on weeds, and as much as possible, try to increase the number (variety) of things that we do to keep weeds at acceptable levels. An integrated approach does not limit itself to just herbicides or tillage, for example." He indicated that some of the interest in integrated weed management is a result of herbicide resistance in weeds and regulatory action. However, a key for successful weed management is knowledge of crop loss thresholds which is not available for all horticultural crops. Methods of weed management were reviewed to stimulate discussion. A list of integrated management methods, mostly cultural, included rotating crops, varying planting or harvest time, rotating crops with livestock, clean ditches, irrigation management, rotating herbicides, banding herbicides, sensor controlled sprayers, cultivation by varying methods, fertilizer placement, utilizing critical weed free periods, cover crops, mulches, allelopathic effects of plants, thermal and flame weeding, biological controls, planting and growing methods, clean seed, and recognizing any benefits of a weed. Steve then asked for discussion on inclusion of methods that he might have missed. Offered for inclusion in the list was rotation of crop varieties, flood and drying of crop ground, management of resistant weeds.

Examples of integrated weed management were discussed. A crop rotational scheme in North Dakota included the planting of oats underseeded with sweet clover, sweet clover growing in the second year and disced in early summer before too much moisture use, fallow, rye in fall, and sunflowers in the third year. Examples of integrating livestock in weed management included an apple grove, grazing sheep in flax, using goats to manage leafy spurge in rangeland, and using weed seed for livestock feed. Carl Bell pointed out the California Ag Commissioner stopped the practice of using weed seed for livestock seed in the Imperial Valley because no pesticide tolerances for weed seed existed.

2. Solarization as a tool in weed management. Carl Bell, University of California Cooperative Extension, Holtville, CA.

Solarization has not been generally adopted as a weed management tool due to the difficulty of making it work in each growers situation. Solarization can be successful in the Imperial Valley due to high summer temperatures, but it requires a complete change in growing practice. Carl presented a case study of one large organic vegetable grower in the Imperial Valley who uses soil solarization. He is the only grower that has adopted the practice in the valley. The grower has obtained good weed control, a positive growth response, disease and nematode control with the use of soil solarization at a cost of about $300/A. The optimum type and color of plastic was discussed. The plastic functions to increase and maintain high soil moisture and temperature conditions which controls the weeds. Holes in the plastic can be a problem and wind can move the plastic around. The disposal of the plastic after use is another problem because the rules of organic production allow no plastic residue in the field. Weed control between rows and the use of mulches under the plastic during solarization were also discussed. An interesting point was the grower's philosophy that weeds mine micronutrients from the soil that can be made available to the crop after mulching them into the soil.

3. Mulches as a tool in weed management. Clyde Elmore, University of California, Davis, CA and Ray William, Oregon State University.

The discussion centered on use of living mulch in perennial and annual crops. The purpose of mulches was discussed. Mulches are used for erosion control, organic matter or nitrogen increases in soil, reducing or increasing the moisture in soil, temperature modification of the soil or in the crop canopy, modification in the amount of light available to crop, pest complex effects, including weed control. The use of mulches requires an increase in management by the producer. Examples of the use of mulches were presented, primarily in perennial tree and vine crops between rows. Clyde stated that he thought it was better to plant a cover crop in trees and vines between rows rather than to manage resident vegetation. In another example, the cover crop is grown in between the rows of perennial crops, the mulch is chopped and then thrown into the row. Potential problems were raised with this practice such as rodent damage to the trees or vines under the mulch. A major issue discussed was that recommendations for mulch use are site specific rather than subject to generalization. Ray stated that, in addition, weed control may be a minor reason for managing a cover crop in tree and vine crops. More important reasons include speeding traffic movement in the field after rains or irrigation, and beneficial insect interactions.

Successful mulch use in annual crops during the growth of the horticultural crop could not be demonstrated. The discussion of the use of mulches in annual crops pertained to rotational cover crops and intercropping as a trap crop for pests.

1994 Officers of Project 2:

Chairperson:
Mark Sybouts
Product Development
BASF Corporation
6605 E. Olive Ave.
Fresno, CA 93727
(209)255-5301

Chairperson-elect:
Rick Arnold
NMSU Ag Science Ctr
P.O. Box 1018
Farmington, NM 87499
(505)327-7757

PROJECT 3: WEEDS OF AGRONOMIC CROPS

Chairperson: Chris Boerboom

Subject: Recommending Reduced Herbicide Rates

Three brief presentations by Ford Baldwin, University of Arkansas Extension Weed Scientist, Dale Aaberg, Monsanto Product Development Manager, and Scott Partridge, Attorney, introduced extension, industry, and legal perspectives, respectively, on the topic of recommending reduced herbicide rates. A panel discussion followed and issues and responses are included in the summary below.

Ford Baldwin outlined the Arkansas extension program where reduced rates have been recommended since 1985 in soybeans. The program recommends the reduced rate based on the soil type for soil active herbicides and the time of weed emergence for postemergence herbicides. For instance, 0.25 to 0.33X rates may be recommended for postemergence applications at 1 to 6 days after emergence (DAE), 0.5X rates for applications from 7 to 12 DAE, and full rates for applications after 13 DAE. Major advantages to this popular program have been to reduce the grower's cost and to encourage timely applications. Basically, the growers are replacing some of their herbicide input with more intensive management. Weed control from reduced rate applications and the resulting yields are comparable to full labeled rate applications. The University of Arkansas willingly supported the program and the recommendations are based on an extensive data base. To date, no claims have been made against the university for herbicide performance failures as a result of the reduced rate recommendation. There were several comments that extension needs to provide the best recommendation based on our scientific knowledge. If we only provide growers with the available options, we are not providing the intended service and will lose public support.

Dale Aaberg reviewed many of the decisions that influence the rate selected for a label. The final rate is based on scientific data and then coordinated with certain business decisions. In the risk/benefit analysis, the labeled rate needs to provide consistent performance and minimize the potential for failures and complaints. Obviously, herbicide labels are not static documents. They evolve over time and companies will adopt some of the rates being endorsed at the local level. As evidence, labeled rates may change on the federal label or they may be adjusted in supplemental labels to address local needs. When questioned whether labels are written for the worst farmer to minimize complaints, the response was that labels are actually written for the majority of farmers using the product.

Scott Partridge illustrated some little known consequences of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) in regards to inconsistent use, criminal liability, and civil liability as related to reduced rate recommendations. Specifically, a label stating that up to 1 pint/A of product may be used would allow a reduced rate to be used without being in violation. However, if a label states that 1 pint/A must be used, a recommendation and application of 0.5 pint/A would be considered inconsistent use and illegal. Most weed scientists are aware that violations of FIFRA can result in civil liability, but criminal liability also exists under FIFRA. State regulations also differ in allowing applications at below labeled rates. Several examples were cited where states either allow or prohibit such reduced rate uses in their regulations. It was suggested that FIFRA needs to be changed in this regard as well as state pesticide regulations.

The claims resulting from failures of reduced rates will likely list the manufacturer, applicator, and the recommender in the lawsuit. Subsequently, the manufacturer will be able to prove that its product was not defective. The applicator will claim that he made a proper application of herbicide as recommended. This will leave the recommender as the liable party. To protect against such claims, private consultants and extension personnel need to either have insurance or university support.

Related liability items discussed were that conversations with growers on the performance of a herbicide in research trials are considered legal recommendations. Also, an organization can develop legally binding "releases" that would remove the liability for the recommendation from the recommender.

1994 Officers of Project 3:

Chairperson:	Neal Hageman Monsanto Company 9348 Crosspointe Drive Highlands Ranch, CO 80126 (303)791-9371	Chairperson-elect:	Edward Davis Montana State University HC 90, Box 20 Moccasin, MT 59462 (406)423-5421

PROJECT 4: EXTENSION, EDUCATION, AND REGULATORY

Chairperson: Stott Howard

Subject: The Development and Publication of Weed Control Recommendations

Discussion of the Project 4 topic was facilitated by posing questions to three panel members: Richard Zollinger (NDSU), Rick Boydston (USDA-ARS), and Don Koehler (DPR-CAL/EPA). Each of these gentlemen shared excellent information and, therefore, provoked thoughtful discussions. Some of the questions asked of the panel included:

What are the roles and responsibilities of personnel involved in the registration and recommendation process?

What is involved in the recommendation process?

What resources/technology are necessary to adequately develop weed control recommendations? How should these be driven (commodity groups/private industry)? How do you deal with information developed for, and funded by, commodity groups that involves and unregistered use pattern for a herbicide?

Are weed control publications mere listings of possible weed control methods or are they preferred or recommended techniques? Are non-chemical weed control methods routinely included in weed control circular? Has anyone been involved in a nonperformance complaint for a cultural weed control method?

Is there any liability associated with the recommendation of nonchemical weed control techniques? Do these recommendations receive the same intensity of research and investigation in order to become recommendations? Should nonchemical weed control methods require approval or review by regulatory personnel? Should these be regulated or registered?

Highlights. Comments regarding the use of computer based weed control handbooks that could be updated periodically. When consumers requested information at the county level, a printout of updated information could be made available. This would prevent the printing of material that may soon become dated and, therefore, useless.

California requires that all herbicide recommendations are hand written. Weed scientists representing other states believed that this would be soon be the norm in their states as well. A considerable amount of time was spent discussing herbicide resistance management. In particular with regard to herbicide label statements promoting use programs that would decrease or reduce the onset of herbicide resistant weed populations. The group discussed introducing a resolution to the WSWS membership encouraging private industry to deal swiftly and openly with the problem.

1993 Officers of Project 4:

Chairperson: Phil Peterson
Cenex/Land O' Lakes
11275 Avalon Road N.E.
Moses Lake
Washington 98837
(509) 766-7539

Chairperson-elect: Richard Zollinger
Crop and Weed Sci. Dept
470H Loftsgard Hall
North Dakota State Univ.
Fargo, North Dakota 58105
(701) 237-8157

Project 5: WEEDS OF AQUATIC, INDUSTRIAL, AND NON-CROP AREAS

Chairperson: Ron Crockett

New Business. Under new business, a motion from the floor was offered.

Motion: The Western Aquatic Plant Management Society should participate and coordinate with Project 5: Weeds of Aquatic, Industrial, and Non-Crop Areas in a combined meeting of the two groups (Project 5: Weeds of Aquatic, Industrial, and Non-Crop Areas and Western Aquatic Plant Management Society).

The motion passed unanimously by the group. Chair Ron Crockett indicated that he would bring the approved motion before the Executive Board of the Western Society of Weed Science.

Subject: Controlling Exotic Weeds in Habitat Restoration Projects

1. Restoration of giant reed (*Arundo donax*) habitat with glyphosate. Nelroy Jackson, Monsanto, Corona, CA.

The perennial weed is present in the Santa Ana River Basin in southern California. It creates the following problems: fire hazard, phreatophyte, reduces ground-water recharge, interrupts surface water flow, displaces native plants, and provides habitat for exotic and feral wildlife. The plant may contribute to mosquito habitat and mosquito control challenges.

Project planning to use glyphosate herbicide to manage the plant began in early 1992. Numerous city, county, state, and federal agencies expressed interest and jurisdiction in the project; this massive interest prompted a series of informational meetings to analyze and process city, county, state, and federal permits for the project. Although the coordination process was overwhelming and time consuming, the process was completed so that glyphosate application occurred in the fall of 1992. It is important to coordinate often and early on all projects dealing with multiple agencies and interest groups.

2. *Spartina* Working Group. Jim Sayce.

Smooth cordgrass (*Spartina alterniflora*) was introduced to Willapa Bay in 1880 through contaminated ship ballast. A search of historical records noted that the Refuge Manager of Willapa National Wildlife Refuge observed that *Spartina* was becoming evident on the refuge in 1945.

Beginning in 1988, the Willapa Bay oyster industry and the U.S. Fish and Wildlife Service held their first meeting to consider management action for *Spartina*. The group's concern was that the structural modification of the bay was occurring as a result of the plant's expanding growth.

The *Spartina* Working Group held monthly meetings during the initial years and held meetings from 4 to 6 times per year during the last 2 yr (1991 and 1992). Coordination between local agencies, state agencies (Washington Department of Agriculture, Washington Department of Fisheries, Washington Department of Wildlife), and federal agencies occurred frequently. The group found that the coordination of interest groups, political representatives, and multi-jurisdictional, government agencies was essential to project implementation.

3. Blackbird and Cattail Management in the Prairie Potholes. George Linz, USDA-APHIS, Fargo, ND.

The U.S. Department of Agriculture, Animal Plant Health Inspection Service helped to coordinate blackbird habitat modification by reducing cattail habitat on the prairie potholes. This coordinated effort began with an action plan.

The action plan identified the end users and players, critical issues, comfort levels, and communication needed for the project in the agriculture community (including sunflower growers), fish and wildlife agencies, and the public that might be interested in the blackbird and cattail issues. Through this intensive effort of communication, the cattail management project was started and completed without breakdown through special interest group coordination.

4. Saltcedar Management Along the Pecos River, Tom Davis.

Approximately 70,000 A of saltcedar exist along the Pecos River in New Mexico. Although mechanical clearing of saltcedar is possible, this method encourages resprouting of saltcedar and is largely ineffective in controlling the plant. Arsenal and Rodeo herbicides were used in an effective effort to manage the species.

A series of discussion groups, publicity, and information meetings were established to solicit interest and feedback on the project soon after treatment was first discussed. Through this early coordination effort, the nonprofit group was established to focus on the saltcedar control project. The group's non-profit status enabled them to cut operational expenses and to focus on the project coordination.

Comments and Questions from the Audience

Don Hope, Yuma County, Arizona Water Users: Was saltcedar also a problem along irrigation canals? We are having a problem with saltcedar adjacent to our canals which are constructed of earth/rock.

No, the canals along the Pecos River are concrete-lined.

Unidentified person: What native vegetation was used to replant sites where saltcedar was removed?

Saltcedar stands will be killed by the herbicide. The dead saltcedar stands will prevent water and wind erosion and allow natural and artificial re-introduction of cottonwood and black willow.

Unidentified person: The Maricopa County, Arizona, Gila River floodplain restoration project by the Arizona Department of Transportation will use native vegetation to restore sites formerly occupied by saltcedar.

Unidentified university student: Some universities are beginning to offer courses in weed science and habitat restoration.

The group suggested that it would be helpful for students and agency representatives that see the lack of weed science in the natural resource curriculum as a problem to make their suggestions to add weed science to natural resource education to the appropriate university administrations.

1994 Officers of Project 5:

Chairperson:	Scott M. Stenquist U.S. Fish and Wildlife, (ARW-DBS) 911 N.E. 11th Ave. Portland, OR 97232-4181 (503)231-6235	Chairperson-elect:	Diane Dolstead Washington Dept. of Agriculture P.O. Box 42560 Olympia, WA 98540 (206)902-2067

PROJECT 6: BASIC SCIENCES

Chairperson: Bill Dyer

Subject: Mechanisms of Gene Flow in Plants

The Project 6 discussion section was held from 9:30 to 11:30 am on Thursday, March 11 with about 35 people in attendance. Dr. Stephen Buchmann, research entomologist with the USDA/ARS Carl Hayden Bee Research Center in Tucson gave an interesting presentation outlining his work on bee behavior and movement, coupled with an overview of Mathematica® software for computational research. Dr. Bruce Maxwell, Montana State University, continued by leading a discussion concerning specific research approaches and problems in plant gene flow experimentation.

Bees represent highly effective and nearly ubiquitous vectors for plant pollination and therefore gene dissemination. There may be as many as 40,000 bee species worldwide, adapted to widely varying environments. With foraging areas of 80 to 100 km^2 per hive, bees can dominate pollen transfer on a large geographic scale. Bee movement among flowers may be monitored by indirect means such as pollen traps and pollen identification, or the use of marked flowers. Since individual bee flights are consistent within a plant species, pollen packets may be collected and identified by color or grain morphology. In his studies of bee population dynamics, Steve Buchmann designed micro-sized bar codes to monitor movement of individuals during various behaviors. X-band radar has also been used to track individual bees at distances up to 2 km. A related technology that may be applicable to studies of individual plants within populations involves attaching small passive transponders which will respond with a unique alphanumeric code when activated with a radio signal.

Studies of insect- and wind-mediated gene flow in plants usually generate massive amounts of data. Recent developments in mathematical software now allow the analysis of such data on personal computers previously possible only on large main frames. One example discussed in this section is Mathematica® software, a structured hierarchical computational program by Wolfram Research, Inc. (100 Trade Center Dr., Champaign, IL 61820). The software is specifically designed to allow researchers to compute and visualize data using advanced mathematical functions, without requiring in-depth mathematical knowledge. The program is widely used in engineering and mathematical sciences, and is only recently being exploited in biological research. The system is highly interactive and flexible: since it contains almost 900 built-in formulae, it can be used in a variety of research and teaching situations. Mathematica® has been successfully used to map and display the foraging patterns from multiple bee hives on a large field scale.

A currently relevant question in weed research involves the relative contribution of seed vs. pollen movement in overall gene flow. Naturally the emphasis varies depending on the species being studied, but the fundamental question is critical as it applies to the spread of herbicide resistance among weeds and the potential for transgene escape from engineered crops. Gene flow by seed dispersal may be especially important for long-distance spread, as illustrated by research documenting rapid and far-ranging Russian thistle tumbleweed movement via wind. Pollen dispersal in some species (eg. kochia) may significantly contribute to the spread of traits within neighborhoods. Since most pollen is relatively short-lived due to environmental exposure, dissemination of traits via pollen may be most important at the field and neighborhood scales. Even so, pollen-mediated transfer of traits has been observed over long distances albeit at low frequencies, pointing out the necessity of considering this mechanism in designing field research of gene flow.

Practical considerations for field gene flow studies via pollen include plot isolation distances, uncontrolled pollen sources in waste areas or adjacent fields, and the availability of proper insect vectors. Adequate plot isolation distances have been worked out for most crop species by plant breeders, but the same information is not available for weed species. A general conclusion from this section is that plots should be separated by more than 1 km if possible. Until more data are available, farmers wishing to prevent movement of herbicide resistant weed pollen into crop fields should be encouraged to physically separate resistant weeds from crop fields as much as possible. For seed dispersal studies, seed surrogates (colored plastic or metalloplastic beads) which are easily tracked and recovered have been used. Although it has been fairly straightforward to monitor invasion of new weed species using herbarium records, movement of weeds within and among fields has received relatively little emphasis. Perhaps more research should be directed towards understanding weed seed production and dispersal, since farmers generally have more tools available to impact this phase of weed movement. Investigations in this area will undoubtedly enhance our understanding of the entire biology of weedy species, and may provide insight into life cycle traits to be exploited in weed management schemes.

1994 Officers of Project 6:

Chairperson:	Bill McCloskey Dept. of Plant Sci. Univ. of Arizona Tucson, AZ 85721 (602) 621-7613	Chairperson-elect:	Carol Mallory-Smith PSES Department Univ. of Idaho Moscow, ID 83843 (208) 885-7730

PROJECT 7: ALTERNATIVE METHODS OF WEED CONTROL

Chairperson: Edward E. Schweizer

Subject: Controlling Weeds Without Herbicides

Approximately 30 people attended Project 7 and participated in the discussion of three topics. The topics were:

1. Postemergence Harrowing for Control of Winter Annual Grass Weeds in Dryland Winter Wheat Dan Ball, Oregon State University.

Ball discussed his experience of controlling downy brome in winter wheat using two postemergence harrowing implements (flex-tine harrow or skew treader) versus the application of metribuzin or diclofop. Postemergence harrowing worked well when done at an early stage of downy brome development if used after an application of metribuzin. The combination of harrowing and metribuzin provided better downy brome control than either operation used alone. This technique seemed to work well in a dry year, but mechanical harrowing cannot be done in a timely fashion in a wet year. His results were promising enough to continue this study.

2. In-row Cultivation for Weed Control in Dry Beans. Mark VanGessel, Colorado State University.

VanGessel shared his experience using a flex harrow or rotary hoe in conjunction with an in-row cultivator or standard cultivator in dry beans. The stand of dry beans was not reduced significantly by growth stage of the crop or the number of cultivations. The in-row cultivator seems to control weeds on all soil types, but probably cannot be used in solid-seeded beans. The interaction between type of cultivator and diseases needs to be investigated. In California, agricultural engineers are using a video camera to differentiate between a crop and weeds for close cultivation.

3. Solarization Using Clear Plastic for Solarizing Soil. Clyde Elmore, University of California.

Elmore discussed several factors that must be considered in soil solarization, including soil moisture, wind, cloud cover, weed species, and type of plastic materials. Weed control results are best when there is adequate soil moisture under the plastic; the plastic is sealed well with soil; and there is high radiation without clouds or wind. Costs to solarize can run as high as $300/A.

Potential topics for next year's meeting are:
- Additional information on the in-row cultivator
- More information on cover crops
- Timing of tillage versus soil temperature
- Nighttime tillage

1993 Chairpersons of Project 7:

Chairperson:
Dan Ball
Oregon State University
Columbia Basin Agricultural
P.O. Box 370
Pendleton, OR 97801
(503)276-5721

Chairperson-elect:
Bruce Maxwell
Montana State University
Plant & Soil Sci. Dept.
Bozeman, MT 59717-0312
(406)994-5717

MINUTES OF THE BUSINESS MEETING
WESTERN SOCIETY OF WEED SCIENCE
46TH ANNUAL BUSINESS MEETING
DOUBLETREE HOTEL, TUCSON, ARIZONA
MARCH 11, 1993

The meeting was called to order by President Steve Miller at 7:19 a.m. Minutes of the 1992 business meeting were approved. M/S/C

Local Arrangements Committee. Kai Umeda
a. Activities were well-attended, particularly the Old Tucson BBQ.
b. Thanks to the Doubletree Hotel for their cooperation.

Program Committee. Doug Ryerson
a. Breakdown of papers:
   68 Regular oral presentations
   19 Posters
   8 Invited papers
b. The facilities were excellent

Research Section and Research Progress Report. Charlotte Eberlein
a. Contributions to each project:

	Papers
Project 1: Weeds of Range and Forest	56
Project 2: Weed of Horticultural Crops	15
Project 3: Weeds of Agronomic Crops	100
Project 4: Extension, Education and Regulatory	4
Project 5: Weeds of Aquatic, Industrial and Noncrop areas	2
Project 6: Basic Sciences: Ecology, Biology, Physiology, Genetics, and Chemistry	4
Project 7: Alternative Methods of Weed Control	3

b. The 1993 Research Progress Report has 404 printed pages and includes 185 separate reports.
c. A permanent editor for the Research Progress Report was approved at the Executive Committee Meeting on March 8, 1993.

Education and Regulatory Section Report. Don Morishita
a. Six papers were presented in this section.

Business Manager/Treasurer Report. Wanda Graves
a. Total of 302 registered for the Tucson WSWS Meeting which included 13 spouses and 31 graduate students.
b. Poor response to preregistration. Approximately 50 people preregistered. We must do better at meeting the preregistration deadline.
c. The WSWS funds need to be spent wisely. "Pocket-change" attitude will not serve the society well.
d. Purchases of the WSWS History have been weak.

Finance Committee Report. Jeff Tichota
a. We found the records of the Business Manager in good order.
b. The salary of our Business Manager/Treasurer was increased from $275/month to $325/month at the Executive Committee Meeting on March 8, 1993.
c. The WSWS is in strong financial shape.

Member-at-Large Report. Phil Westra
a. After surveying WSWS academic faculty, a student poster contest was initiated this year.
b. Results of the same survey suggested that we should not initiate a summer Collegiate Weed Science Contest patterned after other regional societies at the present time.

Past President's Report. Paul Ogg
a. A Student Educational Enhancement Program was initiated at the Summer Business Meeting. Five students will participate this year.

WSSA Representative Report. Rod Lym
a. The WSSA met on February 8 to 11, 1993 in Denver, Colorado.

b. Several members of the WSWS were honored at the WSSA meeting:
Jodie Holt - Coauthor Outstanding Paper in Weed Science
Larry Burrill - Outstanding Extension Award
Clyde Elmore - Fellow Award
Jack Evans - Fellow Award
c. The WSWS is also well-represented on the WSSA board of directors:
Alex Ogg - President-elect
Don Thill - WSSA Secretary
Pete Fay - Member-at-Large
d. A special Weed Science Symposium will be held in Washington, D.C. on April 15, 1993 to communicate the value of weed science programs to Washington staffers.
e. WSSA has developed a program for professional certification of weed scientists with ARCPACS.
f. A ballot will be sent to WSSA members to determine if units for reporting in WSSA journals should be changed from -1 to /.
g. Poor sales of WSSA publications are causing a financial drain.
h. WSSA will meet in St. Louis in 1994.

CAST Representative Report. Jack Evans
a. CAST will be sponsoring two symposia this summer.
b. Dr. Deon Stuthman is president of CAST and Dr. Justin Morris is president-elect.
c. Dr. Richard Stuckey was named executive vice president of CAST.
d. WSWS members are encouraged to become individual members of CAST.

Nominations Committee Report. Frank Young
a. Election results:
President-Elect - Tom Whitson
Secretary - Charlotte Eberlein
Research Section Chair-Elect - Rick Boydston
Education Section Chair-Elect - Stott Howard

Awards Committee Report. Harvey Tripple
a. 1993 WSWS Outstanding Weed Scientists:
Sheldon Blank - Private Sector
Ed Schweizer - Public Sector

Fellows and Honorary Members Committee Report. Larry Mitich
a. Please send nominations in early.
b. Nomination forms will be in the Summer WSWS Newsletter.

Poster Committee Report. Jesse Richardson
a. Nineteen abstracts were submitted for presentation as posters at the 1993 WSWS Tucson meeting.
b. The poster presentations included six submissions for the new Student Poster Contest.

Student Paper Judging Committee Report. Joan Lish
a. Thirteen students participated in the oral paper contest, and six participated in the poster contest.
b. Monetary awards will be $100 for 1st place $75 for 2nd, and $50 for 3rd. First place winners will also receive a $25 WSSA book certificate.
c. 1993 WSWS Student Paper Contest Winners:
1st Place - Marianne K. Pedersen, New Mexico State University
2nd Place - Kris H. Johnson, University of Wyoming
3rd Place - John M. Squire, Utah State University
d. 1993 WSWS Student Poster Contest Winners:
1st Place - Abdul Mesbah, University of Wyoming
2nd Place - Yanglin Hou, New Mexico State University

Necrology Committee Report. Steve Kimball
a. Deaths during the past year: Dr. Wendell R. Mullison, Bruce J. Thornton, and Paul G. Lauterbach

Public Relations Committee. Jack Schlesselman
a. Various agricultural publications and organizations were notified of the 46th Meeting of the WSWS held in Tucson, Arizona.

b. Photographs will be taken of the 1993-1994 WSWS Officers and Executive Committee members, contest winners and award recipients after the breakfast meeting.

Placement Committee Report. Mark Ferrell

a. Positions available and positions desired forms were slightly modified to make them easier to fill out.
b. Placement information from the WSSA was brought to the WSWS and was available in the Redwood Room.

Site Selection Committee Report. Steve Miller (for Kurt Volker)

a. A contract has been signed with the Red Lion Columbia River Inn in Portland, Oregon for the March 11 to 13, 1997 WSWS meeting.

Sustaining Membership Committee Report. Jesse Richardson

a. There are 18 Sustaining Memberships for 1993.
b. These sustaining members contributed $5800.

Resolutions Committee Report. John Orr

a. One resolution: "...Be it resolved that the Western Society of Weed Science expresses its appreciation to the members of the 1993 WSWS Program Committee, to Kai Umeda, chairman of the Local Arrangements Committee, and to the management and staff of the Doubletree Hotel." Motion was made to accept resolution. M/S/C

Legislative Committee (Ad Hoc) Report. George Beck

a. The Federal Noxious Weed Act has been amended and Senator Dorgan (ND) has agreed to sponsor the amended Act.

Publications Committee (Ad Hoc) Report. Tom Whitson

a. Last April (1992), we reprinted 12,500 copies of *Weeds of the West*. We have 3,700 copies of that printing remaining.
b. Since our first printing in 1990, we have sold 28,800 copies of *Weeds of the West* for a gross income of $403,200.00
c. Publications Committee will begin working with western states to assemble cooperative research/extension bulletins on weed science topics, provided that a demand is established in advance.

Editorial Committee (Ad Hoc) Report. Rod Lym

a. Please turn in computer disks of abstracts as soon as possible.

Herbicide Resistant Weeds (Ad Hoc) Committee Report. Charlotte Eberlein

a. The Herbicide Resistance Symposium was held Wednesday morning.
b. The Herbicide Resistant Weeds Committee sponsored an informal workshop at Elk River, Idaho on June 18 to 19, 1992, hosted by University of Idaho.
c. Resolution: "Whereas; weed resistance is being documented with increasing regularity, and whereas; the reversal of herbicide resistance occurs slowly, if at all, and whereas; herbicides are important weed management tools for crop production, be it therefore resolved that the Western Society of Weed Science does hereby encourage public and open acknowledgement of the existence of and potential for herbicide resistance by all concerned parties as part of good product stewardship. Be it further resolved that all concerned parties should adopt and promote integrated programs of weed management to prevent or delay selection for herbicide resistance." Motion was made to accept resolution. M/S/C

Weed Management Short Course (Ad Hoc) Committee Report. Barbara Mullin

a. The 1993 Noxious Weed Management (Introductory) Short Course will be held in Bozeman, Montana April 26 to 29, 1993.
b. The committee is developing an intermediate course for those who have already taken the introductory course.

New Business

a. Dedication of 1992 WSWS Proceedings to Dr. Wendell Mullison.
b. President's trip to Washington D.C. April 13 to 15, 1993 to meet with congressional staffers.
c. CSRS is planning a symposium for politicians, political staffers, and academic leaders to influence the priorities of future weed science research and funding by the federal government.
d. Incoming WSWS President Doug Ryerson presented a plaque of appreciation to Steve Miller for his year as President of the WSWS.

The meeting was adjourned by President Doug Ryerson at 8:39 a.m.

Submitted by:

Jesse M. Richardson, Secretary
Western Society of Weed Science

WESTERN SOCIETY OF WEED SCIENCE
FINANCIAL STATEMENT
MARCH 1, 1992 - FEBRUARY 28, 1993

INCOME	1992	1993	
Weeds of the West Book		$145,252.90	
Registrations	$7,794.00	10,560.00	
Spouse Registration		450.00	
Conference Bar-B-Que		2,350.00	
Monday Tour		260.00	
Membership Dues	860.00	20.00	
Sustaining Membership	200.00	5,400.00	
Proceedings	2,871.08	2,136.50	
Research Progress Reports	2,605.78	2,013.00	
WSWS History Book		360.00	
Bank Interest		4,277.74	
Complimentary Room Credit - Salt Lake	852.00		
TOTAL INCOME YTD			$188,263,00

EXPENSES			
1992 Conference			
Guest Speakers	1,472.05		
Grad Student Awards & Plaques	732.00		
Grad Student Room Subsidy	740.00		
Audio Visual	1,517.58		
Refreshment Breaks	1,415.45		
Spouse Breakfast	78.49		
Luncheon	3,121.38		
Registration Help & Typewriter Rental	106.00		
Refund of Registration Fees	60.00		
Miscellaneous Conf Expense	86.15		
Postage		1,180.19	
Post Office Annual Box Rent		49.00	
Telephone		208.38	
Office Supplies		40.44	
Annual State Filing Fee		5.00	
CAST Membership Dues		608.00	
Franchise Tax Board		65.71	
Tax Accountant		135.00	
Bank Charges		15.16	
Business Manager		3,300.00	
Weeds of the West Book		162,370.89	
WSWS History Book		6,234.17	
WSSA Congressional Fellow		2,000.00	
Printing			
Research Progress Report	3,420.45		
Proceedings	3,830.13	273.00	
Newsletters		820.73	
Stationery		622.45	
Programs		710.51	
Conference Planning Meetings		401.03	
Tours		900.00	
Conference Bar-B-Que		3,500.00	
Award Plaques		139.10	
Refund of Registration Fees		56.50	
Miscellaneous (Bulk Mail Handling, misc mileage, etc)		199.35	
TOTAL EXPENSES YTD			$200,414.29

CAPITAL	
1991-92 Balance Forward	$117,605.76
Current Loss	(12,151.29)
	$105,454.47

DISTRIBUTION OF CAPITAL	
Mutual Funds	$38,000.00
Certificate of Deposits	15,000.00
Money Market Savings	30,338.08
Checking Account Balance	22,116,39
	$105,454.47

1993 FELLOW AWARD
WESTERN SOCIETY OF WEED SCIENCE

Paul J. Ogg

Paul Ogg, a resident of Longmont, Colorado, is a Senior Field Agriculturalist in Research and Development with American Cyanamid Company, serving Colorado, Wyoming, western Nebraska and western Kansas. A native of Wyoming, Paul attended the University of Wyoming, receiving his B.S. and M.S. degrees in plant science (weed science). From 1970 to 1972, he worked on American Cyanamid Company's research farm in Fresno, California. In 1973 he was transferred to Monticello, Illinois, to serve as a research and development representative. He moved to Longmont, Colorado, in 1976, to assume the responsibilities of Regional Manager of Research and Development for some south central and western states. He was advanced to his present position in October 1985.

Paul has been active in the weed science societies and served the North Central Weed Science Society as chairman of several committees. He has had a long and productive commitment to the goals and activities of WSWS. He has served many assignments and committees, including chairman of the Site Selection and the Award committees, and chairman of the Education and Regulator Section, Secretary (1986-1987), President Elect, President (1991-1992), Past President, Nominations Committee and most recently, chairman of the Student Educational Enhancement Committee, an ad hoc committee. Paul was chairman of the Local Arrangements Committee for the WSSA meeting held in Denver last month.

1993 FELLOW AWARD
WESTERN SOCIETY OF WEED SCIENCE

Peter K. Fay

Peter Fay was born in New Jersey in 1941. Prior to starting his college career, he served in the U.S. Marine Corps infantry. He received a B.S. degree from the University of Maine in 1967, then spent two years working as a county agent in rice and vegetable production with the U.S. Peace Corps in the Philippines. He received his M.S. and Ph.D. degrees in weed science from Cornell University. Pete was leader of the Wild Oat Pilot Project at North Dakota State University in Fargo from 1975 to 1978. Then he moved to Montana State University where he taught for 15 years, conducting research on troublesome weeds in small grains, forages, and rangeland. He was the leader in developing and expanding the weed science curriculum at MSU. Currently he is Extension Weed Specialist at MSU.

Pete has trained 20 M.S. students and published more than 15 refereed journal articles. He has served the WSWS as President (1990 to 1991), Secretary, Member-at-Large, Research Section chairman, and served on numerous committees in both the WSWS and WSSA. Presently he is a member of the WSSA Board of Directors. In addition, Pete chaired regional and state committees on noxious weeds, and served as president of the Montana Weed Control Association. He has received numerous awards including the Distinguished Teaching Award (4 years), Teacher of the Quarter Award, and Professor of the Month Award at Montana State University.

1993-94 WESTERN SOCIETY OF WEED SCIENCE HONORARY MEMBER.
Jerry D. Caulder

1993-94 WESTERN SOCIETY OF WEED SCIENCE OUTSTANDING WEED SCIENTIST AND FELLOWS.
Standing (L to R): Sheldon Blank (Outstanding Weed Scientist-Private Sector); Ed Schweizer (Outstanding Weed Scientist-Public Sector); Paul Ogg (Fellow); Pete Fay (Fellow).

1993 HONORARY MEMBER AWARD
WESTERN SOCIETY OF WEED SCIENCE

Jerry D. Caulder

Dr. Jerry Caulder, a native of Missouri, received his M.S. and Ph.D. degrees in agronomy/plant physiology from the University of Missouri, Columbia. In 1989, the College of Agriculture at his alma mater selected him Alumnus of the Year. He served on many prominent committees for the WSSA in his early weed science career, and became well known for his role as master of ceremonies, moderator and invited speaker at WSSA, NCWSS, NNEWSS SWSS, and APWSS meetings, among others.

Grounded in a rural past, Dr. Caulder has emerged as a true leader in today's high technology agribusiness portion of corporate America. He contributed to the progress of herbicide technology over his 15 years at Monsanto Agricultural Company. In a short time he rose to the executive ranks in a variety of positions. After his departure from Monsanto, his vision and values spawned the emergence of Mycogen Corporation, a leader in agricultural biotechnology. He joined the corporation as president and chief executive officer in September 1984. In July 1989 he was elected chairman of the Board of Directors. The San Diego based company focuses on the discovery, development and sales of bioherbicides and bioinsecticides as alternative to chemical pesticides to control a variety of insects, weeds and other pests.

In addition to the success of Mycogen, Dr. Caulder has been an active leader in the formation of the agricultural biotechnology industry in the United States. His adroitness has been capitalized upon in a variety of situations. He has served and chaired various committees of the Office of Technology Assessment for the U.S. Congress, including new developments in biotechnology and genetically engineered organisms in the environment. While George Bush was serving as vice president, he asked Dr. Caulder to meet with him to discuss the future impact that biotechnology and agriculture could have on the American economy.

Dr. Caulder serves as consultant/speaker to various nonprofit "think tank" organizations and helped shape the White House policies on science and technology. Two of the more prestigious ones are the Brookings Institute of Washington, D.C., and the Keystone Group of Keystone, Colorado. In addition, he has also served as an expert witness to both houses of Congress on issues pertaining to agriculture and biotechnology.

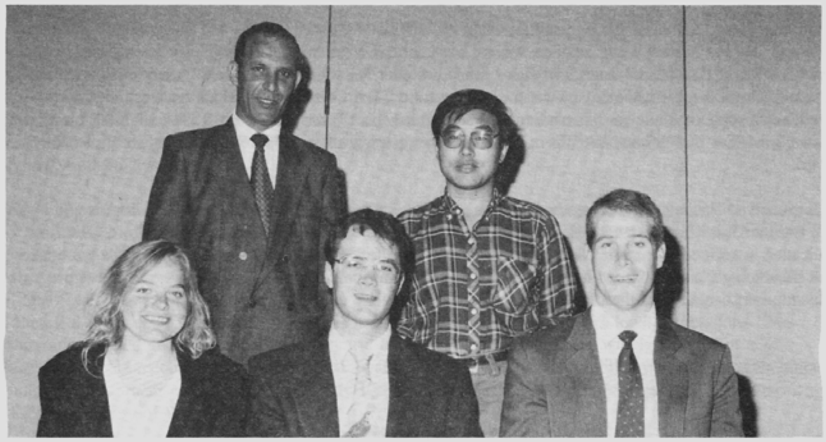
Dr. Caulder has been active on the international scene. He was asked to advise Chancellor Helmut Kohl of Germany on biotechnology and venture capital investments. Representing Mycogen, he participated in a session with members of the British Parliament to explore the international impact of biotechnology on agriculture. In 1990 he participated in a meeting of the World Economic Forum in Switzerland. He has also served as a biotechnology advisor in Japan. In addition to being profiled in Forbes and USA Today, he has been featured on several financial broadcast segments, including Wall Street Report and Stock Market Observer.

1993 OUTSTANDING WEED SCIENTIST AWARD
PUBLIC SECTOR

Edward E. Schweizer

Dr. Schweizer has been employed by the USDA/ARS for over 30 years as a Weed Scientist in Stoneville, Mississippi and in Fort Collins, Colorado. During his career he has developed new weed control technology for corn and sugarbeet production; led a team of scientists in three special research projects on integrated pest management and weed/crop modeling; and developed new knowledge and concepts on the biology and ecology of weeds and weed populations, on principles and mechanisms for their control by cultural, chemical, and integrated management methods, and on weed/crop modeling.

He is recognized internationally for his development of new weed technology for sugarbeet production and his basic contributions on weed interference in sugarbeets. Nationally, he is recognized for his leadership in



1993-94 WESTERN SOCIETY OF WEED SCIENCE PAPER AND POSTER WINNERS.
Student Paper (Seated L to R): Marianne Pedersen (1st); Kris Johnson (2nd); John Squire (3rd). Student Poster (Standing L to R): Abdul Mesbah (1st); Yanglin Hou (2nd).

1993-94 WESTERN SOCIETY OF WEED SCIENCE OFFICERS AND EXECUTIVE COMMITTEE.
Seated (L to R): Charlotte Eberlein, Secretary; Wanda Graves, Treasurer/Business Manager, Douglas Ryerson, President; Tom Whitson, President-elect; William Dyer, Research Section Chairman. Standing (L to R): John Evans, CAST Representative; Stephen Miller, Immediate Past President; Rodney Lym, WSSA Representative; Steven Dewey, Member-At-Large; Vanelle Carrithers, Education and Regulatory Section Chairman.

research on integrated weed management systems for irrigated agronomic crops and bioeconomic weed/crop modeling. He has served Weed Science Society of America, Western Society of Weed Science and American Society of Sugar Beet Technologists in many capacities over the years. His awards include the American Society of Sugar Beet Technologists Meritorious Award, USDA Certificate of Merit Award, the Award of Excellence as coauthor of two Outstanding Articles published in Weed Science in 1984 and 1990, election as fellows in WSSA in 1985 and WSWS in 1991, and the recipient of the 1992 WSSA Outstanding Research Award.

He received Bachelor of Science and Master of Science degrees from the University of Illinois and his Ph.D. from Purdue University in 1962. He has published 67 articles in refereed research publications. His first publication was titled "Structural Requirements of Amitrole for Physiological Activity". His last publication was titled "Reducing Herbicide Loading in Corn with Weed Management Models". In between these two publications is a history of the development of Weed Science.

1993 OUTSTANDING WEED SCIENTIST AWARD
PRIVATE SECTOR

Sheldon Blank

Dr. Sheldon Blank received a Bachelor of Science from Washington State University, a Master of Science and Ph.D. from the University of Minnesota in 1975. He has worked for Monsanto since 1975 with his initial assignment being Idaho and Utah. He spent two different time periods in corporate assignments in St. Louis. He moved to Kennewick, Washington in 1981 and has been responsible for Product Development activities in parts of Oregon, Washington, Idaho and Utah since that time.

His major accomplishments were in developing glyphosate products for annual weed control for reduced tillage in the production of wheat. This area involved decreasing glyphosate rates through the addition of ammonium sulfate and additional surfactants which resulted in reduced costs for the wheat farmer. He was instrumental in developing the "aid to tillage" concept as an economical method of controlling cheatgrass.

He developed the Landmaster field bindweed control program with resulting yield improvement for dryland wheat farmers. He developed the chemical mowing concept involving Roundup for use by orchard growers in the Pacific Northwest. In recent years he has been a leader in developing the glyphosate preharvest wheat market. His most recent activities have involved the technical evaluation of MON13200 in alfalfa and apples.

He has been a member of the Weed Science Society of America and on the Board of Directors for the Washington Weed Association. He has been and continues to be an active member of the Western Society of Weed Science. He has served in six different capacities on the Executive Committee. He was our President for the 1990 meeting.

1993 NECROLOGY REPORT

Wendell R. Mullison, age 78, died April 20, 1992. Dr. Mullison was born September 24, 1913, in Philadelphia, Pennsylvania. He received his B. A. degree at the University of New Mexico, and his Pd.D. from the University of Chicago. Dr. Mullison contributed broadly to the development of chemicals with applications to weed science. The 1993 Proceedings of the Western Society of Weed Science are dedicated to him in memory of his many accomplishments. (Page)

Bruce J. Thornton, age 97, died November 23, 1992. Mr. Thornton was born August 9, 1895, in Berthoud, Colorado, the son of pioneer parents. He received Bachelor and Master of Science degrees from Colorado State University, and did additional graduate work at the University of California, Berkeley. Mr. Thornton was a member of the teaching faculty at CSU, was a staff member at the CSU Experiment Station and was Head of the CSU Seed Laboratory. He retired in 1962 after 30 years of service. During his career he helped pioneer cultural and chemical weed control practices, as well as helped to establish several professional associations. Mr. Thornton also helped author seed and weed control legislation, and authored the widely used "Weeds of Colorado" text. He received many professional awards and held memberships in many professional societies, including the American Association for the Advancement of Science, the Weed Science Society of America, and the Western Society of Weed Science.

Paul G. Lauterbach, age 71, died March 13, 1992. Mr Lauterbach was born April 20, 1920, in Sac City, Iowa. He received his B.S. degree in forestry from Iowa State University in 1944, and then completed a career of 48 years with Weyerhaeuser Company. Paul was a key contributor in the development of industrial forest herbicide applications, including the use of phenoxy compounds, glyphosate and triclopyr. He also lead development efforts for large scale aerial applications of both insecticides and herbicides, and developed the first baseline vegetation management prescriptions that were used broadly in western forest production. Paul was an active member of the Council for Agricultural Science and Technology, and had participated in both the Weed Science Society of America and the Western Society of Weed Science.

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CROP INDEX

WEED INDEX

HERBICIDE INDEX

Common name or Code designation,
Trade name and Chemical name **Page**

Common name or Code designation,
Trade name and Chemical name **Page**

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