PROCEEDINGS

WESTERN SOCIETY OF WEED SCIENCE

ISSN: 0091-4487

Volume 38—1985

1985

PROCEEDINGS

OF

THE WESTERN SOCIETY OF WEED SCIENCE

ISSN: 0091-4487

VOLUME 38

PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 12, 13, 14, 1985

HILTON HOTEL

PHOENIX, ARIZONA

Cover photograph of jointed goatgrass (*Aegilops cylindrica* Host) courtesy of Dean G. Swan, Washington State University Cooperative Extension.

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WHERE DO WE STAND TODAY?

Stanley Heathman[1]

PRESIDENTIAL ADDRESS

Where do we stand today? As members of the Western Society of Weed Science, I believe we stand on solid ground. The financial picture for our society is excellent. A two year operational budget has been saved and set aside. Attendance at the annual meetings of WSWS has shown a steady increase for the past 10 years. From all appearances WSWS is fulfilling its role as viewed by its membership.

Perhaps all of us who belong and attend these meetings bring with us our own concepts of what WSWS means to us. Under our Constitution and By-Laws, Article II-Objectives, there are six sections specifically dealing with the purposes of WSWS. You can find these articles and the entire Constitution in the 1983 Proceedings, 36:212-219. I suggest to you that you read them. I strongly believe that you will find your interest in WSWS will be reflected in these objectives.

The strength and vigor of the WSWS is dependent upon meeting the needs of the membership. Each year you elect a group of officers to see to it that WSWS continues to function as it should. While these activities and functions are well prescribed and described in the Constitution and By-Laws, as well as the Operating Guide for Officers and Chairmen of WSWS, your officers also need your direct input. Because this is a dynamic society we live in, undergoing almost constant change, we must also constantly review what we are doing so that the activities of WSWS truly reflects the current and future needs. If you have any concerns regarding our Society, do not hesitate to contact anyone on your Executive Committee during our meeting here in Phoenix. Let us know your concerns.

More specifically, each year the new President of our Society appoints a Member-At-Large. His principal function is to represent the viewpoint of all factions of the Society. This past year Dean Swan has served us well as Member-at-Large. During the coming year the new President Harvey Tripple, will have a Member-At-Large to appoint. If you have any concerns during the coming year and if you are not sure of the appropriate person or committee to contact, talk to the Member-At-Large.

How do we stand in this nation in regard to agriculture? Agriculture appears to be in serious trouble economically. The ability of many farmers to survive the high debt load they have acquired in recent years is in doubt. Federal programs are designed to aid agriculture in the past have to be reviewed in the light of the current crisis. This nation can ill afford to see a large percentage of its agriculture base impaired because of the insolvency of its producers. It is not within the scope of this speaker to suggest solutions to this problem. However, I do not think I need remind you that when agriculture is in such a crisis, its impact will be felt throughout weed science.

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[1]Plant Science Dept., University of Arizona, Tucson, AZ.

Underfinanced farmers are often tempted to cut corners in their weed control programs. I believe we can look forward, among other things, to the using of lower than efficacious rates of herbicides and/or the elimination of prophylactic treatments, which will result in failed weed control programs. While many growers can and should look for ways to reduce weed control costs, there are better ways of reducing costs than these.

Cultural practices such as crop rotation, planting under a dry mulch and the well managed use of mechanical cultivation are the cornerstone of efficient weed control. But where herbicides are concerned, I believe we still have a long way to go in regard to their efficient application. While new and more effective herbicides are still an obvious need, we cannot count on their quick introduction into the market place to help save the day. A disproportionate amount of the resources needed for new developments in weed science are now being spent in defending the registration of some of our most valuable established pesticides. It is now extremely difficult, if not impossible, to achieve any new registrations for herbicides already on the market.

This would suggest to me that within the coming months, those of us who work with production agriculture, will be concentrating more on improved application techniques including: better adjustment and maintenance of equipment, precise and timely application scheduling, selection of the most appropriate available herbicide for the weed problem and better integration of the weed program into the other cultural practices. It should also be pointed out that as new technology is adopted by growers such as new varieties, different methods of irrigation, new nematicides or fungicides and different planting dates, old weed control programs may need to be revised. Less emphasis will be placed upon new product testing and development.

Perhaps the most important question to this audience in regard to our position in the world is "Where do we stand in the nation's eyes regarding the use of pesticides?" I believe we could all agree it is somewhere between bad and disastrous. It has been well documented that the general public is convinced that the use of pesticides is a direct threat to their health. The center of our problems is that the general public perceives pesticides used by anyone other than themselves, as having limited benefits accompanied by great risks. Who needs them!

We have an aroused populace who are very anxious about their exposure to pesticides and all other man-made chemicals. They are made anxious by constant exposure to horror stories in the press. The carcinogen of the month has been replaced by the carcinogen of the day. This level of hysteria is difficult to maintain. Currently a few scientists and scientific writers have been stimulated enough to critically analyze the facts and have tried to shed some light upon this almost mass hysteria. But the damage has already been done. Our representatives at all levels, city, county, state and national are being pressured to do something more about this perceived problem. They are being pressured by well financed and organized environmental groups who have a powerful image. Edith Efon in her book "The Apocalyptics" describes it as a "moral cartoon". The cartoon is this "the essential problem in regulatory science is a conflict between good and evil between regulators who seek selflessly to protect our lives and businessmen who seek selfishly to kill us all." How did we get into this distorted image? Partly because we let it happen. Yes, I

know, many of us have tried to speak up but never as a united group. But even when we do speak up and try to present the facts, or scientific evidence, we have found it has not been enough. We will never have sufficient facts to satisfy those who are convinced we are seeking selfishly to kill them all. Image can be everything. The person who attempts to defend a little poison, even if it is 1 part per billion, wears the black hat and those who will not accept any poison, sit on the high ground wearing the white hat.

We are wearing this uncomfortable black hat, mashed rather firmly on our heads because the press has put it there. When people look for information they most often turn on TV. The news media by its very nature, is limited to presenting news highlights not information in depth. So all we see on the tube is a vague outline of a problem. The sensational part of the story is more easily told than the tedious and often mundane facts which explain the event. TV is at its best in creating heat but often fails to shed enough light on the subject so that the public can make informed judgements on complex problems.

Unfortunately the other media forms are not always more effective than TV in presenting all of the facts. But even worse, I am not at all sure the general public really wants to know or would even bother to read the facts even if they were easily available.

The inherent negative image produced by the press for man-made chemicals is not unique to this area. It is perhaps a natural result from reporting the "news worthy" events to the public. People do seem to be most interested in watching, reading or listening about floods, famines and pestilence rather than the day to day success of people at work. The fact that American farmers represent less than 1% of the world's farmers, yet produce 46% of the world's corn and 17% of the world's wheat does not make headlines. Instead more frightening stories about 2,4,5-T, EDP and DDT make top news stories day after day. There is hope that some of this may change. Executive Vice President Louis D. Boccardi of The Associated Press commented recently on the negative tone of the press and I quote: "When a reader complains about too much bad news, do we dismiss the thought as a dreamer longing for a world that is not? Or should we not re-examine standards which, on some days, seem to foreclose from our audience any suggestion that anything, anywhere is being done right by anybody."

Our world is becoming increasingly dependent upon technology for its survival. World populations of tomorrow will not be properly fed, clothed or housed using old technology. We must make decisions regarding the safe and effective development of new technology. Some of this technology has and will raise serious questions regarding its acceptability in our lives. Biotechnology such as genetic engineering could be drowned in a sea of red tape before it ever gets off the ground. The American people have to make wise and courageous decisions regarding technology if we are to continue to prosper. The press must bear some responsibility in helping us all to make well informed and logical decisions. I quote from Mr. Boccardi of The Associated Press again. He was not calling for "cowardice, for doing only what the readers will love us for," but for a courageous look "at the new place of the media in the society and the obligations that place imposes on us."

As a citizen we are all asked to make decisions regarding the safety and benefits of technology that is out of our field of specializations.

For example, as weed scientists most of us feel comfortable making decisions regarding the safety, hazards and benefits in weed science. How comfortable do we feel when deciding if the use of atomic energy or genetic engineering is for the public benefit or not? We do need help from the press in learning the facts. How can we make honest judgements if we are only informed about the problems. The press does have an obligation to inform us as well as scare us on prime time.

Finally, I turn to our relationships with the EPA and other regulatory agencies at all levels of government. How do we stand with these agencies? Too often, on the outside looking in. Back in the 1970s when the EPA was first formed and when each state became involved somewhat in the regulation of pesticides, I felt that it might be impossible to co-exist with this agency and still maintain any real technological progress. The EPA seems to be full of lawyers with a cause, busily erecting barriers against dragons. True, there are a lot of lawyers in this country that need work. In Japan, I am told, there are fewer than 15,000 lawyers in the whole country. American universities graduate 35,000 new ones every year. The EPA was created during a time when the Congress was convinced that there was an imminent threat to our environment. The EPA's mission was to protect that environment. Inevitiably the EPA has become highly politicized constantly under pressure from all sides. Over the years it has failed to please almost everyone.

Despite the fact that the EPA is still unable to regulate the herbicide industry as I think it should, I am afraid I have come to the conclusion that the EPA and other regulatory bodies may be our last and best hope. What makes me say this was in some measure brought about by a speaker on the Education and Regulatory session last year in Spokane. A member of the National Audubon Society, Pam Crocker-Davis talked about "The Pesticide Controversy - A Citizen's Perspective." In her talk she gave us a tip and I quote. "Please do not base your arguments on pesticide safety on the fact it has been tested and registered with the EPA. It won't go down - and the conversation will end right there." In other words, she is totally convinced that the EPA registration process is a sham. She assumes anyone not opposed to pesticides is at least misinformed and at worst a liar. We, who devote our life to the study of weed control do not understand what we are doing.

Besides getting your blood pressure dangerously high, I want you to reflect on the implications of that remark. While Pam Crocker-Davis may not be your typical Jane Q. Citizen, she no doubt represents the thinking of some people in the environmental movement. They seem to be saying that they are completely unprotected from the ravages of pesticides. They will not accept or believe anything said or done by those in the scientific community who attempt to rationally discuss the use of pesticides. Do you feel that black hat being pushed down further on your head?

The only thing that would apparently satisfy them would appear to be the abolition of all uses of pesticides or a regulatory body that they would trust. I do not believe that we can afford the abolition of herbicides nor do I believe that this will happen short of a holocaust. What this does suggest is that we must have regulatory bodies that are perceived to be working in the public interest. Without a credible regulatory agency between industry and the environmentalists, weed science will continue to lose ground.

The loss of credibility of some control agencies at both the national and local levels is making our situation less tenable. The politicalization of the EPA has weakened its ability to gain the trust of our society. Our industry must have outside review for credibility. We must be willing to work with and support a strong vigorous, and fair EPA. It is our best hope. Without the image of credibility at the national level, we will see hundreds of EPA's at local, county and state levels and this will spell chaos.

I am not advocating total surrender to the EPA or environmental fears. I do not believe that the proper use of herbicides has or will result in significant damage to our environment. The increasing life span and excellent health of our population speaks for itself. We must continue to vigorously defend the essentiality of weed science in our modern day world. We must continue to do what we do best, generate accurate and unbiased data for the purposes of furthering weed science.

It does no good, however, if only those of us in this room are convinced of the purity of our profession. I do not believe that we can win the public over through the press. There are problems both real and imagined in the use of herbicides that should be addressed. Should we not be able and willing to sit down with bona fide groups and reason together. I know we have tried this before, but I do believe reason can and must prevail. Confrontation is a losing game, particularly when you are outnumbered. Sure, we can win them all over when we all face starvation, but that would be a hollow victory indeed.

It would appear that there is hope that with maturation and with more professional management the environmental movement will move toward a more rational and businesslike approach in addressing issues. We cannot co-exist as no-holds-barred adversaries and expect any real progress. We must reason together, that's where we should stand.

ALLELOPATHY: AN IMPORTANT MECHANISM OF PLANT INTERFERENCE

Alan R. Putnam[1]

Abstract. Allelopathy produces marked impacts in a variety of agricultural and natural ecosystems including influences on plant succession, patterning of plants, inhibition of nitrogen fixation and nitrification, and chemical inhibitors of seed germination and decay. The major challenges to weed scientists are to minimize the negative impacts of allelopathy on crop growth and yield, and wherever possible to exploit allelopathic mechanisms as additional pest control or crop growth regulation strategies. Secondary plant products, microbial products, or their synthetic analogs may provide the next generation of pesticides and growth regulants. Joint efforts of weed scientists, chemists, microbiologists, ecologists, and perhaps others, will be required to achieve maximum progress in this endeavor. Research on allelopathy offers unlimited opportunities to contribute both practical solutions to agricultural problems and fundamental knowledge regarding the chemistry and biology of interspecies relationships.

The term allelopathy was first used by Molisch in 1937 (20). Now the term generally refers to the detrimental effects of higher plants of one species (the donor) on the germination, growth, or development of plants of another species (the recipient). Allelopathy can be separated from other mechanisms of plant interference (allelopathy, allelomediation) in that the detrimental effect is exerted through release of chemical inhibitors (allelochemicals) by the donor species. Microbes associated with the higher plants may also play a role in production or release of the inhibitors (14).

Allelopathy is included in a higher-level order of chemical ecology. Whittaker and Feeny (34) have classified allelochemicals on the basis of whether the adaptive advantage goes to the donor or recipient. Allomones, which give adaptive advantage to the producer, include repellants, escape substances, suppressants, venoms, inductants, counteractants, and attractants. Allelopathic chemicals may be classified as suppressants. Some inhibitors from plants also induce intraspecific effects (autotoxicity).

Impacts on Agriculture

Impacts on agriculture were apparently recognized by Democritus and Theophrastus in the fifth and third century BC respectively, by deCandolle in 1832, and certainly more recently by many ecologists and agronomists (27, 28). Allelopathy has been related to problems with weed:crop interference (2), with phytotoxicity in stubble mulch farming (19), with certain types of crop rotations (7), and with orchard replanting (4) or forest regeneration (13). In some alleged allelopathic interactions, it is not proven whether reduced crop growth is a direct result of plant toxins, or whether the toxins may precondition the crop plant to invasions by plant pathogens. Rice (28) indicated that allelopathy may contribute to the weed seed longevity problem through at least two mechanisms. Chemical inhibitors in the seed may prevent seed decay induced by microbes or that the inhibitors function to keep seed dormant, but viable for many years.

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[1]Pesticide Research Center, Michigan State Univ., East Lansing, MI.

There is considerable evidence that allelopathy may contribute to patterning of vegetation in natural ecosystems (3). Distinct zones of inhibition are present under and adjacent to a variety of woody species, and often toxins from their litter are implicated (8). One might speculate that aggressive perennial weed species that quickly gain dominance may do so by allelopathic mechanisms.

Release of Allelopathic Chemicals

Chemicals with allelopathic potential are present in virtually all plant tissues, including leaves, stems, roots, rhizomes, flowers, fruits, and seeds. Whether these compounds are released from the plant to the environment in quantities sufficient to elicit a response, remains the critical question in field studies of allelopathy. Allelochemics may be released from plant tissues in a variety of ways, including volatilization, root exudation, leaching, and decomposition of the plant residues.

Reports on volatile toxins originate primarily from studies on plants found in more arid regions of the world. Among the genera shown to release volatiles are Artemisia, Eucatyptus, and Salvia (28). When identified, the compounds were found to be mainly mono- and sesquiterpenes. Work of Muller and associates (21) has indicated that these compounds may be adsorbed as vapor by surrounding plants, be absorbed from condensate in dew, or they may reach the soil and be taken up by plant roots.

Numerous compounds are also released by plant roots (29). The compounds are actively exuded or leaked, and may also arise from dead cells sloughing off the roots. Much of the evidence for root-mediated allelopathy has come from studies where nutrient solutions cycled by the root systems of one plant are added to media containing the indicator species. Recent research by Tang and Young (32) successfully utilized an adsorptive column (XAD-4) to selectively trap organic, hydrophobic root exudates while allowing nutrient ions and other hydrophilic compounds to pass through. They identified 16 compounds exuded from the roots of Bigalta limporgrass (Hemarthia altissima) representing a variety of benzoic, cinnamic, and phenolic acids.

Allelochemicals may be leached from the aerial portions of plants by rainwater or by fog-drip (33). Among compounds shown to be leached from plants are organic acids, sugars, amino acids, pectic substances, gibberellic acids, terpenoids, alkaloids, and phenolic compounds. Colton and Einhellig (5) suggested that leaf leachates of velvetleaf (Abutilon theophrasti Medic) are inhibitory to soybean (Glycine max (L.) Merr.). We have recently discovered specialized trichomes on the stems and petioles of velvetleaf plants which exude toxic chemicals.

After death of the plant, chemicals may be released directly by leaching of their residues. A variety of compounds may impose their toxicities either additively or synergistically. Microbes in the rhizosphere can produce toxic compounds by enzymatic degradation of conjugates or polymers present in the plant tissue. Examples of this phenomenon are the action by microbes on the cyanogenic glycosides of johnsongrass (Sorghum halepense (L.) Pers), and Prunus species to produce toxic HCN, and the corresponding benzaldehydes (6).

The toxicity arising from plant residues provides challenging problems and opportunities for agronomists and weed scientists. Where stubble-mulch farming has been practiced in the plain states for soil and water

conservation, toxins from the stubble have proven toxic to certain rotational crops (19). Since there is a movement toward conservation tillage (including no-tillage) practices which preserve surface plant residues, these can influence crop emergence, growth, and productivity, and have similar influence on weed emergence and growth. Our recent work indicates that management of selected crop residues e.g., rye, wheat and sorghum, can greatly reduce weed germination and growth (25).

Families of Allelochemicals

Inhibitors from plants and their associated microbes represent a myriad of chemical compounds from the extremely simple gases and aliphatic compounds to complex multi-ringed aromatic compounds.

The groups of compounds implicated in allelopathy have been divided into chemical classes by recent reviewers (24, 28). They can be arbitrarily classed as (A) toxic gases, (B) organic acids and aldehydes, (C) aromatic acids, (D) simple unsaturated lactones, (E) coumarins, (F) quinones, (G) flavonoids, (H) tannins, (I) alkaloids, (J) terpenoids and steroids and (K) miscellaneous and unknowns. Although many of these compounds are secondary products of plant metabolism, several are also degradation products which occur in the presence of microbial enzymes.

Swain (31) recently reported that over 10,000 low-molecular weight secondary products have already been isolated from higher plants and fungi. In addition, he proposed that the total number might approximate 400,000 chemicals. Some of these chemicals or their analogs could provide important new sources of agricultural chemicals for the future. There is considerable interest within industry on at least two approaches involving allelochemics for weed control. One involves the production of crops (perhaps through genetic engineering) which can either themselves suppress associated weeds or provide a source of chemicals. Another approach is to produce natural herbicides through batch culture with microorganisms. Two phosphonated amino acid herbicides have already been discovered using this approach.

Priorities for Allelopathy Research

Although allelopathic interactions have been observed for centuries, the science of allelopathy is in its infancy. Much needs to be accomplished, and it will require joint efforts of scientists from several disciplines. Although by no means a complete list, the following areas need intensive study.

Improved Methods for Assay and Characterization. Techniques used to characterize natural products evolve rapidly as more sophisticated instrumentation is developed. Plant physiologists and chemists should work closely together on this aspect, because good bioassays are essential at each step. There is no standard technique that will work effectively for every compound. Briefly, isolation of a compound involves extraction or collection in an appropriate solvent or adsorbant. Commonly used extraction solvents for plants are water or aqueous methanol in which either dried or live plant parts are soaked. After extracting the material for varying lengths of time, the exuded material is filtered or centrifuged before bioassay. Soil extraction is more difficult, since certain "harsh" methods may produce artifacts.

Chemical separations may first be accomplished by partitioning on the basis of polarity into a series of solvents from non-polar hexane to vary polar compounds like methanol. Compounds may also be separated by molecular size, charge, or adsorptive characteristics, etc. Various chromatography methods are utilized, including columns, thin layer (TLC), gas-liquid (GLC), high performance liquid (HPLC), and more recently, direct countercurrent (DCC) chromatography. HPLC and DCC has proven particularly useful for separations of water soluble compounds from relatively crude plant extracts. Although at one time the major effort toward compound identification involved chemical tests to detect specific functional groups, characterization is now usually accomplished using a series of spectroscopic analyses. Initially, ultraviolet spectroscopy (UV) is useful in this regard to detect specific functional groups. More recently, infrared (IR) spectroscopy and nuclear magnetic resonance (NMR) have helped immensely in determining natural products structure by indicating the functional groups and relative positions of atoms. Mass spectrometry is a relatively recent addition to the analytical arsenal that provides additional clues as to molecular size and composition. It can quickly provide confirmation of complex organic molecular structures. Tandem Mass Spectrometry (MS/MS) or GC-MS are recent developments which also allow analyses of mixtures of compounds. Effective studies of allelopathy must now involve natural products chemists who can quickly provide structure elucidation using their powerful instrumentation.

Factors Affecting Allelochemical Production or Release. This area of research should prove fruitful for the plant physiologists and biochemists who are interested in regulation of plant metabolism. Studies to date have been limited to only a few compounds.

Plants appear to vary in their production of allelopathic chemicals depending upon the environment in which they are grown and in particular, in response to stresses that they encounter. One particular difficulty faced by researchers is that greenhouse-grown plants may produce limited quantities of inhibitors. Ultraviolet (UV) light is absent in closed greenhouse, and several investigations have shown that UV light greatly enhances the production of allelopathic chemicals (28). For example, when greenhouse light was supplemented by UV, sunflower (Helianthus annuas L.) produced much more scopolin and chlorogenic acids (16).

Nutrient deficiencies may also influence the production of allelochemics. The compounds studies in great detail have been the phenolic compounds and scopolin-related chemicals. Deficiencies of boron, calcium, magnesium, nitrogen, phosphorus, potassium, and sulfur have all been reported to enhance the concentration of chlorogenic acids and scopolin in a variety of plants (28). In other species, chlorogenic acids have decreased in plants that are deficient in magnesium or potassium.

The type and age of plant tissues are extremely important since compounds are not uniformly distributed in the plant. Between species, there are great differences in ability to produce allelochemics. Within species, differences may exist in the amount of toxin produced by different genotypes. For example, various oat lines show differences in their ability to exude scopoletin and related compounds (10). Some cucumber (Cucumis sativus L.) accessions were found to greatly inhibit weed germination, while others had no effect, or even stimulated growth (26). The implications of all these findings are that we may either select or breed plant types that are more allelopathic, or perhaps enhance inhibitor production by exerting the proper stresses on the plants.

Mode of Action. Mode of action research has caused similar challenges for investigators working with either natural products or synthetic pesticides. The major difficulty is to separate secondary effects from primary effects. Although responses can be measured in isolated systems, there always remains the critical questions of whether the inhibitor reaches that site in the plant in sufficient concentration to specifically influence that reaction, and whether other processes may be affected more quickly. At this time, allelochemicals have been reported to inhibit nutrient uptake by roots, cell division, extension growth, photosynthesis, respiration, protein synthesis, enzyme activity and to alter membrane premeability (28). Little is known about their action at the molecular level.

Ecological Studies. Plant succession, particularly in old fields and cut-over forests has intrigued ecologists for many decades. The appearance and disappearance of species and changes in species dominance over time has been attributed to numerous factors including physical changes in the habitat, seed production and dispersal, competition for resources, or combinations of all these. Rice and co-workers (28) have presented extensive evidence that allelopathy may play an important role in the disappearance of the pioneer weeds (those most rapidly invading old fields). Additional findings in this area could help us manage vegetation more effectively.

Certain reforestation problems have also been linked to allelopathy. For example, there are logged-over sites on the Allegheny Plateau in Northwestern Pennsylvania that have remained essentially treeless for up to eighty years (13). Several herbaceous weed species have been shown to produce toxins that inhibit establishment of the black cherry (Prunus serotina Ehrh.) seedlings that normally reinfest these sites. Among the more active are goldenrods (Solidago) and Aster species. We wonder why that idea could not be exploited for vegetation management on right-of-way lands.

In many ecosystems, plants tend to pattern themselves as pure stands or as individuals spaced in rather specific densities or configurations. Many desert species show obvious zones of inhibition around which few, if any, aliens are allowed to invade. These patterns often cannot be adequately explained by competition alone, and are probably caused by a combination of factors including allelopathy. The phenomenon happens with herbaceous plants as well as woody shrubs and trees.

Muller reported that black mustard (Brassica nigra (L.) Koch.) can form almost pure stands after invading annual grasslands of coastal southern California (22). This was attributed to inhibitors released from the dead stalks and leaves which do not allow germination and growth of other plants. These observations provide agronomists hope that similar results could be exploited with crops, specifically to achieve almost pure stands of crops (over weeds) by use of an allelopathic mechanism.

Positive and Negative Impacts on Weed Science. There is considerable evidence now accumulated to suggest that some of the more aggressive perennial weed species, including quackgrass (Agropyron repens (L.) Beauv.) (12), Canada thistle (Cirsium arvense (L.) Scop) (35), Johnsongrass (23), and yellow nutsedge (Cyperus esculentus L.) (9) may impose allelopathic influences, particularly through toxins released from their residues. There are also several annual weed species in which allelopathy is implicated. Perhaps best documented is giant foxtail (Setaria faberi Herrm.) whose residues have been shown to severely inhibit the growth of corn (Zea mays L.) (2).

Extracts of several important weed species were found to inhibit the nodulation of legumes by Rhizobium (28). Among those were Western ragweed, large crabgrass, prostrate spurge and annual sunflower. Our recent studies indicate that quackgrass released compounds that are inhibitory to nodulation and nitrogen fixation on a number of legumes. Adverse effects of weeds on N-fixation appears to be an agricultural problem that deserves much more research attention.

The classic seed burial studies of W. J. Beal and his successors have shown seeds of at least one weed species, Moth Mullein (Verbascum blattaria L.) can remain viable in soil for a period of 100 years, whereas three continued to germinate after 80 years of burial (15). Weed seeds not only resist decay by soil microbes, but they vary in dormancy characteristics. There is considerable evidence that chemical inhibitors are responsible for both phenomena. Unsaturated lactones and phenolic compounds in particular, are potent antimicrobial compounds and are present in many seeds (28). Fruits and seeds are also known to contain diverse germination inhibitors including phenolic compounds, flavonoids and/or their glycosides and tannins. Unique methods to destroy inhibitors could provide an excellent weed management strategy.

Recently, some weed scientists have attempted to directly exploit allelopathy as a weed management strategy. One approach has been to screen for allelopathic types in germplasm collections of crops, the idea being to ultimately transfer this character into cultivars by either conventional breeding or other genetic transfer techniques. Superior weed suppressing types have been reported from searches of cucumber (26), oat (10), sunflower (17), and soybean collections (18). When thoroughly researched, this idea may have potential for crop plants that are maintained in high density monocultures i.e. turfgrasses, forage grasses, or legumes.

Another approach has been to utilize allelopathic rotational crops or companion plants in annual or perennial cropping systems (25). Living rye (Secale cereale L.) and its residues have been shown to provide nearly complete suppression of a variety of agroecosystem weeds (1). Similarly, residues of sorghums, barley, wheat and oats can provide exceptional suppression of certain weed species (25). These approaches could keep several weed scientists busy for a number of years.

Allelopathic plants may also provide a strategy for vegetation management in aquatic systems. The diminutive spikerush (Eleocharis coloradoensis) has been reported to displace more vigorous and unwanted aquatic plants, i.e. pondweeds (Potamogenton species) and Elodea in canals and drainage ditches. Frank (11) attributed this to allelopathic effects, and more recently the phototoxic compound dihydroactinidiolide (DAD) was isolated and characterized from the spikerush plant (30). This chemical has since been shown to be inhibitory to pondweeds.

Another payoff from allelopathy research may be the discovery of novel chemistry that could be useful as pesticides or precursers of pesticides. Both higher plants and microorganisms are rich sources of diverse chemistry. Some excellent leads have already been made in this area.

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BOUNTY PROGRAMS - AN EFFECTIVE WEED EDUCATION TOOL

C.A. Lacey[1], C. Egan[2], W. Pearson[2], and P.K. Fay[1]

Introduction

Weeds are a major threat to the productivity of rangeland in the western United States. For example, leafy spurge (Euphorbia esula L.) currently occupies over 2.5 million acres with severe infestations in North Dakota, Montana, and Wyoming. Spotted knapweed (Centaurea maculosa L.) was introduced to North America in 1893 and is now reported to infest 8 million acres in Montana, Oregon, Washington, and Idaho. Current studies indicate that millions of additional acres of range and pastureland are highly susceptible to invasion by introduced weeds.

The ecological nature of rangeland contributes to the problem of weed invasion. In comparison to lands that are used for intensive agriculture, rangeland is usually managed extensively and is relatively inaccessible. These conditions enable weeds to spread and infest large acreages before they are recognized. Large-scale use of herbicides is restricted by ecological concerns and low economic returns. Therefore, the key to weed control on rangeland is early detection and treatment.

Creative educational programs that promote awareness, identification, and control are needed to stop the spread of weeds on rangeland. In 1984, a weed "bounty program" was implemented in Stillwater County, Montana, in an attempt to stop the invasion of spotted knapweed. This paper evaluates the effectiveness of that program and presents guidelines to aid development of similar programs in other states.

Approach

The weed bounty program in Stillwater County offered rewards for locating and controlling spotted knapweed infestations on rangeland. The objectives of the program were: (1) to increase public awareness of spotted knapweed; (2) accurately locate and map all spotted knapweed infestations; and (3) control knapweed infestations that were reported.

Guidelines were developed by the county extension agent and the weed supervisor to meet the objectives. First, they wanted youth involvement. As an incentive, young people were paid a $5.00 bounty for reporting each spotted knapweed infestation that was not previously plotted on the county weed map. An additional $50.00 was paid if the "bounty hunter" could persuade the landowner to control the infestation. Spotted knapweed "wanted posters" and newspaper articles carried photographs of the plant to help youth identify the plant. Live plants were also on display at the county extension office.

The second guideline concerned weed infestations. Although infestations of any size could be reported, only one claim could be filed per ranch unless infestations were at least 1/4 mile apart.

These two guidelines insured that all infestations were reported to the county extension agent or weed supervisor, and located on a map. They also encouraged the "bounty hunter" to work with the landowner to control the infestation. To aid their effort, county spray equipment and control

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[1]Plant and Soil Sci. Dept., Montana State Univ., Bozeman, MT.

[2]Stillwater Co. Ext. Agent & Weed Supervisor, Columbus, MT.

information were provided to landowners and "bounty hunters". Throughout the program the county agent and weed supervisor were available to confirm infestations, provide technical assistance, and evaluate control efforts.

Funds for the bounty program were obtained as an "educational appropriation" from the county weed control budget. The program was administered by the county extension agent and weed supervisor.

Program Results

The first year of the pilot bounty program was very successful. Over 65 people were directly involved with the weed control effort as a result of the program. The participants included 14 youth, in addition to parents, agricultural producers, and state and federal employees that worked with the youth in controlling spotted knapweed infestations.

Thirty-four spotted knapweed infestations were located and recorded on the county weed map and created an accurate map for spotted knapweed in the county. Landowners and "bounty hunters" controlled 20 of the infestations which were located on private, state, railroad and federal lands. Publicity concerning the program increased weed awareness on both a county and regional basis.

The cost of implementing the program in 1984 was $1170.00. This included the $5.00 "finders" fee and the $50.00 bounty paid for each infestation controlled. By utilizing youth, rather than county employees, to map and control these infestations, the program actually saved the county weed control budget an estimated $4500.00. There will also be long-term financial benefits achieved through the education and involvement of youth in the weed control effort.

The success of the weed bounty program in Stillwater County as an educational tool is reflected in the following statments made by people who participated in the program:

"...I learned how to identify spotted knapweed and how it spreads to infest new areas."

"...I think it's a very good program for everyone. It does the county a lot of good and it's an easy way to make money."

"...Once you become a 'weed fighter' you can't drive down the road without looking for weeds!"

The success of the program can also be measured through its endorsement by other extension agents in Montana. The enthusiastic response from personnel in other counties is a strong testimonial of the over-all effectiveness of a bounty program.

The personnel in Stillwater County are proposing changes for the 1985 program. First, participation will be limited to youth from 12 to 18 years of age. This will exclude young children and enhance the educational aspects of the program. Second, bounties will be restricted to the finder fee of $5.00 on weed infestations located on county owned land. Without this provision, the county would have to control infestations reported on their land (at a cost to the county) and in addition, pay the "bounty hunter" $50.00 for having the infestation controlled.

Guidelines for Establishing Bounty Programs

Based on the results of the weed bounty program in Stillwater County, Montana, the following guidelines have been established to aid the development of similar programs in other areas.

** Success of the program will be influenced by the nature of the target weed. The selected weed should be a potential threat to the area and common enough to promote enthusiasm for the program, especially the first year the program is implemented.

** The county extension agent and weed supervisor must be willing to commit time and energy to the program, especially the first year.

** Utilize bounty programs as educational tools for youth.

** Publicize the program through a variety of media channels to promote enthusiasm among youth.

** The amount of bounty paid on a weed will be determined by the number of infestations in the county. For example, weeds that are just starting to invade an area should have a larger bounty than weeds that are more common.

Summary

The weed bounty program is an educational tool that can be used to promote awareness, detection, and control of problem weeds on rangeland. The success of a bounty program is influenced by: 1) the enthusiasm and innovativeness of the county extension agent and weed supervisor, 2) the choice of weeds selected for the bounty program, and 3) good media coverage of the bounty program. In Stillwater County, enthusiasm and involvement of the extension agent and weed supervisor and a responsible media generated community support that made the bounty program an outstanding success.

WORKING TOGETHER - DOES IT REALLY WORK?

Barbra Mullin[1]

Abstract. A weed awareness program initiated by Montana State University in 1980 has had a great impact on public interest in the problems associated with noxious weeds and their control in Montana. This interest has spurred citizens in many communities to develop local coordinated weed control programs involving all landowners within a designated area. The goal of this type of approach to noxious weed management is the implementation of weed control on all lands within an area by all landowners, thus slowing the spread of noxious weeds. Since nearly 30 percent of the land area in Montana is controlled by federal land agencies, cooperation from these agencies is imperative for the success of the program. When local agency personnel show that all landowners are attacking the problem in an organized manner they can justify the expenditure of funds for noxious weed control on federal lands in the area. Indications from regional Forest Service officials show that this approach to weed management will aid in funding the Carlson-Foley Amendment at the national level.

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[1]Montana Department of Agriculture, Helena, MT.

Due to variations in weed problems and environmental considerations across Montana, each community has developed a program unique to its own area. These programs range in size from several acres to several million acres. Often programs have been spearheaded by local landowners, some by extension personnel or a local weed district. What each group has in common with others like it is the enthusiasm of all participants and the ability to get all landowners actively controlling weeds. Development of a statewide program to encourage formation of these local efforts and the continuation of those already in operation is the goal of the Montana Weed Control Association, the Department of Agriculture, the Agriculture Experiment Station, and the Cooperative Extension Service. Working together is working in Montana. The effort must continue.

BIOTECHNOLOGY, WHAT IS THE BIG DEAL?

Norton D. Addy[1]

I was asked to present some information concerning Biotechnology and its application to the field of plant science specifically and to agriculture in general. The best way for me to accomplish this task is to describe the various areas of biotechnology that are being practiced in Plant Genetics, Inc., a biotechnology company.

First, it would be helpful to remove some of the glitter and aura surrounding the term 'Biotechnology.' Biotechnology can be defined in the context of its use today as being a collection of biological techniques resulting from several disciplines of biological science. Or in short, a grouping of new or different biological techniques.

Plant Genetics, Inc., which began operations in 1981, is considered an agricultural biotechnology company. Located near the University of California in Davis, the firm occupies approximately 20,000 square feet of office and laboratory space.

Just six miles away from its headquarters is the main research field station. The station has over 80 acres available for field trialing and 25,000 square feet of greenhouse space for research, development and production.

Other major facilities include the Pacific Coast research station in Watsonville, California for development and testing of high value vegetable crops. The company has two laboratory and greenhouse facilities in the state of Idaho. The newest facility is a 5,000 square foot tissue culture production laboratory located in Sacramento, California.

PGI recognizes that plant breeding is the science that has brought agriculture to its present state of development. The theme of plant breeding is present in all of the company's core technologies, which are molecular biology, cell biology and tissue culture, plant breeding and plant delivery systems (figure 1). With the emphasis on an irrigated science approach, our plant breeders have access to both traditional field selection techniques as well as the newer molecular and cellular methods of biotechnology. This breeder group works closely with cell biology to incorporate variety improvements through somatic embryogenesis.

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[1]Director, Product Development, Plant Genetics, Inc., Davis, CA.

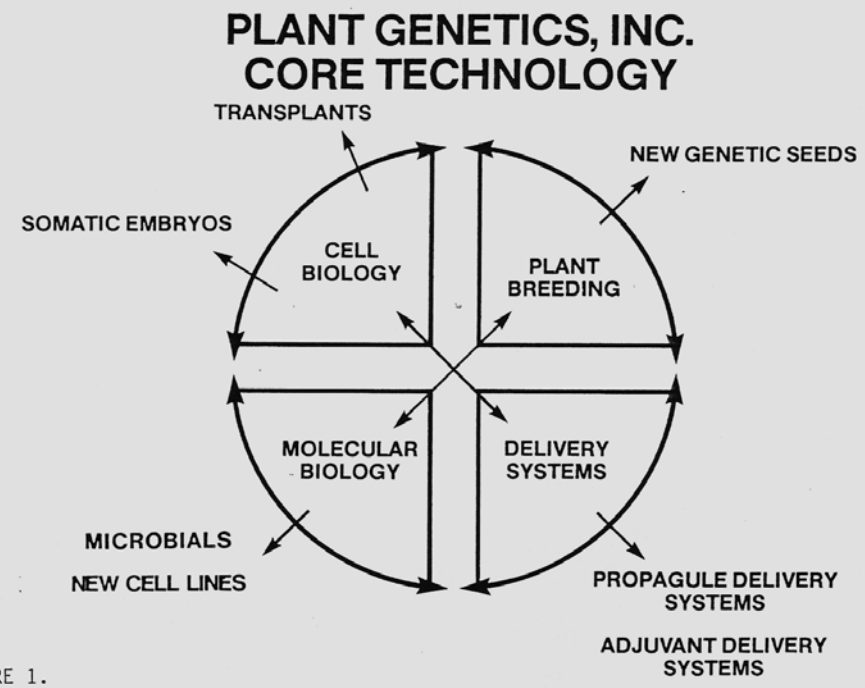


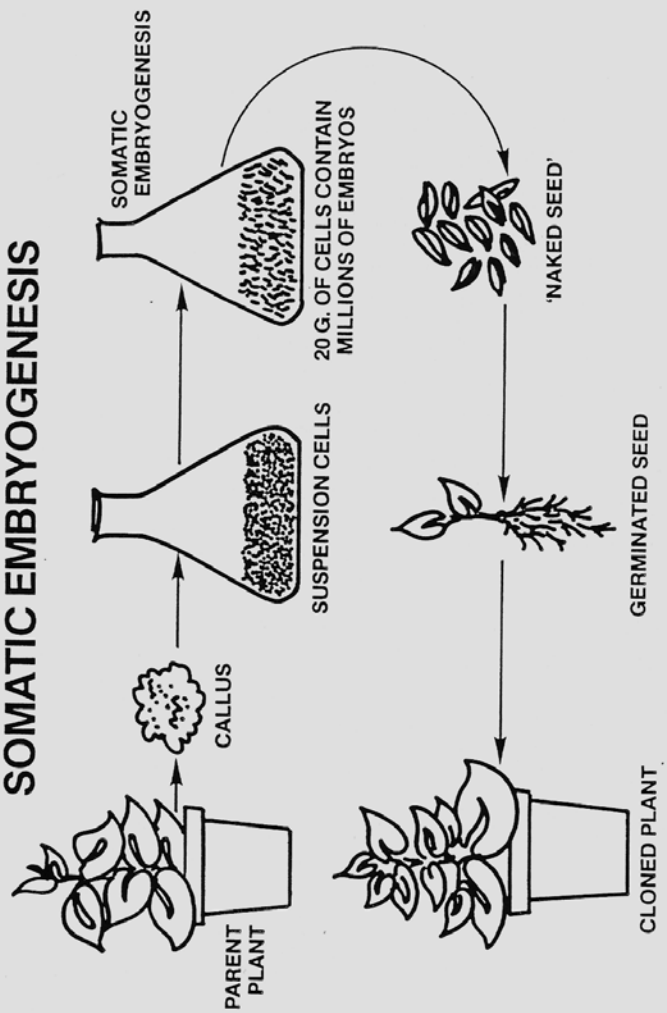
FIGURE 1.

One very important part of the plant breeding program is the use of cell cloning or creation of somatic plant embryos (figure 2). The process begins by selecting stem tissue from an appropriate plant variety and planting the tissue on nutrient media. After some weeks in the medium, the tissue has grown a large number of individual cells, each containing the same identical genetic code of the original plant. When this process is carried out in a liquid culture, the cells can be stimulated to produce hundreds of thousands of embryos and this is called liquid culture technique. From advances made in solid and liquid cultures, company scientists are transferring somatic embryo technology to fermenters for eventual scale-up.

Individual cells that have differentiated into embryos are encapsulated in hydrated gel capsules called GEL-COAT®. Thus the differentiated embryos have become synthetic somatic seeds with their artificial seed coat (figure 3).

GEL-COAT is not only an outstanding encapsulation system for somatic embryos, but also can be used to deliver agricultural chemicals, plant growth regulators, and fertilizer. Thus, again we are describing an integrated system where the main objective is to deliver the new improved plant material to the field but it is also possible to enhance the performance of the embryo by including various support adjuvants.

FIGURE 2


SOMATIC EMBRYOGENESIS
SOMATIC EMBRYOGENESIS
20 G. OF CELLS CONTAIN MILLIONS OF EMBRYOS
SUSPENSION CELLS
CALLUS
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GERMINATED SEED
CLONED PLANT

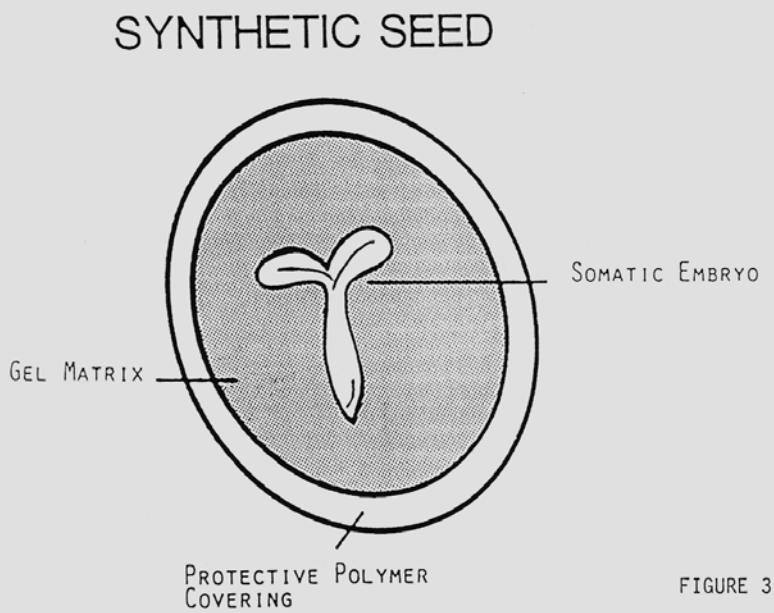

FIGURE 3.

Returning to the subject of plant breeding, how are we using the delivery of somatic embryos to improve crop varieties? Back at the stage of cell culture where we have a large number of cells to choose from we apply various controlled methods of mutagenesis. We now have a mixture of cells with slightly different genetic structure. These cells are then exposed to a selection agent such as a herbicide, salt, disease toxin or other agents. Surviving cells will then be removed and allowed to differentiate into embryos and from there to viable plants. These resulting plants now offer possible germplasm that can be field tested and evaluated for various performance charactertistics by the traditional plant breeder. Using this method and others, we intend to introduce improved varieties derived from known parent stock.

So what is the big deal? The utilization of new and refined biological techniques to bring more variation and improved performance of existing plant varieties. This will be accomplished through the use of an integrated approach, with the application of a number of related sciences.

Thus we have biotechnology, the use of current biological techniques to offer new solutions to the field of agriculture.

A TOXICOLOGICAL AND ENVIRONMENTAL REVIEW OF PICLORAM

Wendell R. Mullison[1]

Summary

Introduction. This article was written to fulfill the need for a review summarizing and referencing the toxicological and environmental data about picloram. The following summary discusses the four general issues of toxicology, degradation, movement, and dissipation of picloram. The review that follows discusses the literature on these subjects in greater depth.

Picloram, 4-amino-3,5,6-trichloropicolinic acid, is an organic compound that is a selective herbicide of the plant growth regulator type. It is used to control many unwanted vines, broadleaved herbaceous weeds and woody plants. Most grasses are quite resistant to picloram.

Toxicology. The mammalian toxicity of picloram is low. The acute oral LD_{50} ranging from 2000 to 8200 mg/kg of body weight for rabbits, mice and rats. While LD_{50}'s have not been established for larger animals such as sheep and cattle, data exists that shows picloram also has a low degree of toxicity to these species.

Commercial formulations of picloram vary in their effects on eyes and skin and their labels carry different appropriate eye and skin precautionary statements. Undiluted picloram acid caused slight to moderate conjunctival irritation but was essentially nonirritating to the cornea in eye tests with rabbits.

Picloram is not a skin sensitizer and very little is absorbed through the skin. The inhalation toxicity of picloram to humans is considered to be in the range of house dust. Ingested picloram is rapidly excreted unchanged in humans (87% in 72 hours) as is also true in large and small animals.

Studies with rats and rabbits show that picloram did not cause teratogenesis or other adverse reproductive effects when administered orally. Three generation reproduction studies have also shown no reproductive hazards as measured by fertility indices, gestation, lactation, viability and birth defects.

The National Cancer Institute conducted a two-year feeding study with picloram on rats and mice at high dosages (7,437 and 14,875 ppm for rats and for mice 2,531 and 5,062 ppm). Although picloram was toxic to both rats and mice at these high dosages, the conclusion was that picloram did not cause cancer in male rats or male and female mice. The authors also stated "that under the conditions of the bioassay the findings are suggestive of the ability of the compound to induce benign tumors in the liver of female Osborne-Mendel rats." A new life time feeding study on rats was initiated by Dow in 1982. To date, no unusual results have been detected. The study is planned to be completed in 1985.

The toxicity of picloram to birds is low since it has an acute oral LD_{50} to chickens of 6000 mg/kg and the eight-day dietary LD_{50} is between 10,000 and 385,260 ppm for Mallard ducks and Bobwhite quail. Japanese quail fed 1000 ppm in a three-generation reproduction study showed no ill effects as measured by food consumption, egg production, hatchability, survival, fertility and body weight. Ornithologist E.E. Kenaga, after studying the bird toxicity data, said TORDON herbicides are no hazard whatsoever to birds.

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[1]Consultant, The Dow Chemical Co., Agr. Products Dept., Midland, MI.

There have been many aquatic studies with picloram on fish that live in both warm and cold water as well as other aquatic species living in both marine and fresh water habitats. These extensive studies show that picloram has a low order of toxicity to such organisms. As picloram is not applied to water, the possibility of it getting into streams in significant amounts from normal usage is unlikely. Experiments on both fish and daphnia show that there is no biological magnification with picloram. Experiments have also shown no adverse effects of picloram on honey bees.

The Safe Drinking Water Committee of the National Research Council established a Suggested No-Adverse-Response Level for picloram of 1.05 ppm in drinking water. They also said "the committee found no reports of adverse effects in humans."

Degradation in Soil and Water. Degradation of picloram is due largely to two phenomena: photo-degradation when exposed to sunlight and microbial degradation in soil, mostly by numerous indigenous soil microorganisms.

Picloram is rapidly degraded in water by sunlight often completely disappearing within 5 to 20 days. The rate of loss in water depends not only on the amount and intensity of sunlight but also on the water depth and presence of extraneous particulate matter that obscures the sunlight. Photodegradation, however, can occur even under hazy sunlight and in cloudy water.

Photodecomposition is particularly important when picloram on the top soil surfaces is exposed to sunlight. When picloram is applied to bare soil in areas with much sunlight and little rainfall, loss through photo-decomposition can be significant. Less loss occurs if rains occur immediately after application and moves the herbicide into the soil. In this case photodecomposition does not take place but decomposition by microbial action does. Many studies have shown the importance of soil organisms such as bacteria and fungi in degrading picloram in the soil. The compound is not considered a good energy source for microorganisms but it is co-metabolized with other available energy sources such as organic matter. The soil microbial population most efficient at decomposing picloram is the population that uses the less easily decomposable soil organic matter as an energy source. The rate of degradation will decrease as the oxygen supply diminishes and under complete anaerobic conditions it will stop. Sterilization of the soil also inhibits or greatly reduces decomposition.

Picloram in the soil has very minimal, if any, measurable effects on numbers and kinds of soil microorganisms, microbial metabolism, carbon dioxide evolution, or nitrogen transformations. When picloram degrades, opening of the molecular ring structure takes place first after which the decomposition products are rapidly broken down to carbon dioxide. Experiments using radioactive tracer techniques have shown that the major degradation product of picloram is carbon dioxide.

To conclude, picloram is decomposed in both soil and water and the resulting degradation products are harmless to living organisms and the environment.

Picloram Movement in Soil. Picloram can move downward or upward in the soil depending upon the movement of the soil water. The downward movement or leaching is more likely in sandy or gravelly soils low in organic matter than in heavy soils relatively high in organic matter. In sandy or sandy loam soils receiving heavy and prolonged rains, picloram occasionally has moved downward 3 feet or more. Classical columnar laboratory leaching experiments have shown that picloram has the potential

to move readily in the soil. Nonetheless, in most of the numerous field experiments conducted, residual picloram has only been found within the top 1 foot layer of soil. Usually leaching is not a serious factor and picloram remains in the top layer of good agricultural soils. There have been no authenticated reports of groundwater contamination from leaching of labeled rates of picloram through undisturbed soil profiles.

As with most herbicides, relatively small amounts of picloram can be moved off a treated area in surface runoff water. This is a physical phenomenon. Amounts so moved vary with rate of application, duration and intensity of rainfall, slope and type of soil surface. The greatest movement usually occurs in the first major runoff when application is followed by heavy rain. The amount of picloram in runoff water has been shown to be inversely related to the distance the water passes over untreated areas. Usually, runoffs from later rains contain only very small amounts of picloram or none at all. Well contamination has not been a problem with picloram. For example, studies in Texas have shown that picloram was not detected in shallow domestic water wells during a two-year sampling program following application of picloram to surrounding areas at rates of 1 pound per acre.

Dissipation in the Soil. Picloram applied to the soil dissipates with time. This is caused by photodegradation, microbial degradation and leaching. The rate of disappearance is dependent, therefore; on the application rate, climatic factors including sunlight, rainfall, soils type, soil temperature, soil moisture, soil organic matter and last but not least the soil microbial population. The duration of its activity in soil is greater than some herbicides such as phenoxies, about equivalent to certain substituted urea and triazine compounds, and less than fenac and prometone. Picloram has a vapor pressure of 6.2×10^{-7} mm at 35°C, and therefore, losses by volatilization are negligible.

Temperature and moisture conditions that are favorable for plant growth are the two most important climatic factors that determine the rate of degradation of picloram in soil. When picloram is applied at 0.5 lb/A or less under conditions favorable for plant growth in a temperate climate, residue levels in soil become low enough in 1 to 1.5 years to allow planting of many crops. At rates of 2 or 3 lb/A (these are not labeled rates for agricultural uses) in certain situations, especially in cold or dry soil, residues can affect susceptible plant species four or five years after application. The time required for decomposition to a negligible level in the soil (0.01 ounce/acre or 0.625 ppb which is generally considered to be safe for most crops sensitive to picloram) may vary from 4.5 months to 4 years depending primarily on temperature and moisture. The following crops are particularly sensitive to picloram residues in the soils: cotton, legumes, potato, safflower, sugarbeet, tobacco and tomato. Tobacco, beans, and potatoes are species extremely sensitive to picloram and may show some herbicidal response at slightly lower soil levels than 0.6 ppb. Most grasses and grass crops like wheat or corn are tolerant to moderate soil residues which would damage less tolerant species. The rate of disappearance is generally accelerated in southern as compared to northern areas of the United States due to the warmer and moister soils.

In conclusion, there has been a great amount of research devoted to the toxicology, behavior, and various environmental characteristics of picloram. These scientific experiments have been performed by governmental and academic research workers both in the USA and abroad as well as by industrial scientists. This large body of information clearly shows

that the use of this herbicide according to the label directions will present no significant hazard to soil, aquatic fauna or flora, wildlife, livestock, pets or humans.

Introduction

The first published paper on picloram, 4-amino-3,5,6-trichloropicolinic acid, appeared in a 1963 Science article(1). Granting of a United States Federal registration and the first commercial sales also took place that same year.

Picloram is an organic chemical compound, which has excellent herbicidal activity as a plant growth regulator and is used as a selective herbicide to control many unwanted vines, broadleafed herbaceous weeds and woody plants. It is manufactured solely by The Dow Chemical Company and is sold in the USA as a herbicide under the trademark of TORDON or GRAZON. GRAZON formulations are designed for controlling unwanted plants on southwestern pastures and rangelands, whereas TORDON formulations are used for all other labeled uses such as rights-of-way, forestry, pasture and small grains.

Picloram is usually formulated as the potassium or triisopropanolamine salt to make commercial formulations convenient for use. Various formulations are used for the control of unwanted vines, broadleaved weeds and woody plants on rights-of-way for telephone lines, electrical power lines, pipelines, highways and railroads. Picloram may also be used for spot treatment of multiflora rose and other woody plants growing on Eastern pastures. Picloram has several Special Local Need (SLN) labels in certain states for use in pastures, rangeland, and small grains. It is also used in forestry, particularly for forest site preparation and timber stand improvement.

Picloram often controls weeds that are resistant to other herbicides. A few noxious and other difficult to control broadleaved weed species that picloram is particularly useful in controlling are: Canada, musk and star thistles, leafy spurge, Russian and spotted knapweeds, lupine, loco weed, field bindweed, and prickly pear. Some difficult to control vine species controlled with picloram are kudzu, honeysuckle, poison ivy, and trumpet creeper. Examples of some tree species controlled by picloram are alder, aspen, maple, sweet gum, sassafras, locust, cherry, and elm. The major uses of picloram are for controlling weeds on rights-of-way, range and pasture land, and in forestry. Most grasses are quite resistant to picloram.

Plant auxins are naturally occurring compounds that regulate plant growth. Synthetic chemicals that have this property are called plant growth regulators. Picloram is another of the synthetic plant growth regulators such as 2,4-D that act as natural auxins in controlling plant growth (2).

Picloram may cause physiological effects in plants, such as decreased water uptake and transpiration, the production of ethylene, exudation of carbohydrates and reducing sugars, and changes in nucleic acid metabolism.

Picloram has a dramatic effect on the growth of various plant tissues. At low levels, epinasty occurs and leaves develop in an atypical fashion showing a cupping effect and having narrowed midribs. Thickening of the leaf and a distinct puckering of young developing leaves may also occur. Stems of treated plants may thicken and split and adventitious roots start to develop. Plant growth stops, the roots deteriorate and the plant dies.

Picloram tends to move to the young actively growing parts of the plant such as the young leaves and the growing points of the stem and roots. Normal tissue development is prevented and development of adventitous roots in unusual areas often takes place. Cell permeability may also be affected and leakage of picloram, carbohydrates and reducing sugars has been detected (2).

A thorough Canadian review (3) gave a technical discussion of this subject and two particularly interesting points are mentioned. First, the increased activity of the picloram, when compared to 2,4-D, is due to the resistance of picloram to metabolic breakdown in plants. Second, is the suggestion that picloram may chelate with metal ions in plants leading to the inhibition of metallic enzymes such as the peroxidases. Peroxidases have been shown to be associated with auxin metabolism. If this idea is correct, it would explain both the herbicidal and growth-promotive actions of picloram. This disturbance of the normal physiological functioning of the plant and the abnormal tissue stimulation and maturation results finally in the death of susceptible plants. Some properties of picloram are given in Table 1.

Table 1 Some Physical and Chemical Properties of Picloram

Chemical Name:	4-amino-3,5,6-trichloropicolinic acid
Physical state and color:	white powder
Melting point:	decomposes before melting
Decomposition temperature:	approximately 215° C (419° F)
Vapor pressure:	6.2×10^{-7} mm Hg at 35° C
Water solubility:	430 mg/l at 25° C
Bioconcentration factor:	less than one
Hydrolysis:	1/2 life of 18 years (at 1 ppm at pH 5,7,9 and 25° C)
Photolysis:	1/2 life of 7 days

These data show that picloram will be decomposed at a relatively low temperature so, therefore, it would be destroyed in a brush fire and that photolysis can be a significant route for degradation of picloram. Table 1 also shows that the vapor pressure of picloram is so slow and the rate of hydrolysis so slow that practically speaking, it may be considered to be non-volatile and does not hydrolyze in water. The bioconcentration factor of less than one shows that picloram will not bioconcentrate in the food chain. The degradation behavior of picloram in soil is shown in Table 2.

The most important route for degradation of picloram in soil is by the action of soil microorganisms. Another important point shown by these data is that the degradation of picloram in soil is concentration dependent: that is, as the concentration of picloram in the soil increases, the degradation rate decreases.

Table 2 The Degradation of Picloram in Soil at 25°c and 75% of 1/3 Bar Moisture

Aerobic Degradation in Soil	
Concentration	1/2 life in days
0.0025 ppm*	18
0.025 ppm	29
0.25 ppm	150
2.5 ppm	300
Anaerobic Degradation in Soil	None
Tank mixture with 2,4-D:	No effect on degradation in soil
Adverse effects on soil microorganisms at label rates:	None

*Using the generally accepted figure that a three-acre-inch layer of soil weighs one million pounds, one pound per acre distributed in the top three inches of soil would be one part per million.

Toxicology of Picloram

Picloram has low acute oral toxicity to warm blooded animals (5, 8). The acute oral toxicity of pesticides is usually measured in terms of the amount administered in a single oral dose that will kill 50% of the population of the test animals. This is called the acute oral LD_{50} and is often written as the LD_{50}. These values are normally givne in terms of milligrams per kilogram of body weight (mg/kg). Some acute toxicological information on picloram (4) is given in Table 3.

Table 3 Some Acute Oral LD_{50}'s for Picloram

Species	Milligrams per Kilogram (mg/kg)
Rats (female)	8200
Mice (female)	2000-4000
Rabbits	2000
Guinea Pig	3000
Chickens	6000
Sheep	>1000
Cattle	>750

To better put this data in perspective, the acute oral LD_{50} for table salt in rats is 3000 mg/kg. Also note the information in Table 4.

Table 4 Estimated Acute Oral LD_{50} Values for People[a]

Material	Dose in Pounds for 154 Pound Person
TORDON 22K Weed Killer 21.1% picloram (2 lb/gal.)	1.3
Aspirin	0.3
Table salt	0.7
Household bleach	0.7
Sugar	4.2
Whiskey (86 proof blended)	5.0

[a]This is based on laboratory rat data and assumes healthy adults would have the same toxic reaction as rats.

Eye Toxicity. Picloram itself and a formulation containing 25% picloram as the potassium salt was slightly to moderately irritating to the eye (5). Undiluted picloram acid (6) caused slight to moderate conjunctival irritation and was essentially nonirritating to the cornea in tests on rabbits.

The eye toxicity warning statements from the labels of formulated picloram products vary due more to other constituents in the formulations than to the forms of picloram present.

Animal Skin Toxicity. Rabbit skin tests showed a very slight response when exposed to a confined dermal application of both the undiluted acid and the undiluted formulation of the potassium salt of picloram (5). Undiluted picloram applied to shaven skin on rabbit bellies nine times over a 11-day period caused a slight scaling and reddening of the skin in one of three rabbits. Similar tests with undiluted TORDON 22K gave a slight irritant reaction but the animal's skin healed without a scar.

Human Skin Toxicity Tests. A group of 50 human volunteers subjected to dermal applications of a five percent aqueous solution of the commercial formulation TORDON 101 Mixture (5.7% picloram 21.2% 2,4-D as amine salts) showed no irritation or sensitization (40).

A test was conducted on a group of 69 human subjects who had volunteered for a patch test with TORDON 101 Mixture to determine whether it casued primary skin irritation or skin sensitization (42). Following administration of a five percent water solution of this product, 63 of the subjects showed little or no irritation or sensitization. Although little or no skin irritation developed, five of six subjects affected showed moderate sensitization and one showed mild sensitization. The active ingredients, however, did not produce an allergic response to TORDON 101 Mixture. Nearly always, regardless of the substance in question, some people can be found that are allergic to it and such a response is not uncommon. For example, some individuals are allergic to milk and milk products, and some babies are allergic to mother's milk.

In a similar test (41) on 29 human volunteers using a five percent water solution of TORDON 22K (24.4% of the potassium salt of picloram) there was no evidence of allergic contact inflammation of the skin or skin

irritation. Therefore, it was concluded that TORDON 22K is not a strong sensitizer nor likely to cause skin irritation.

Inhalation Toxicity. White rats subjected to vapors of TORDON 22K and TORDON 101 Mixture had no observable adverse effect during the exposure or for two weeks after the treatment (5). The inhalation toxicity of picloram (7) is considered to be in the range of house dust which is minimal or only slightly toxic if one considers its Threshold Limit Value (TLV). TLV's are established by the American Conference of Governmental Industrial Hygienists (241).

Toxicity to Large Animals. Picloram was administered to sheep and cattle to determine its acute toxicity (39). It was found that picloram in a single dose of 540 mg/kg given orally to cattle and 720 mg/kg for sheep was not toxic. Further, 7.2 mg/kg of picloram plus 27 mg/kg of 2,4-D aministered daily for 30 days caused no apparent signs of toxicity in sheep. A calf given 72 mg/kg of picloram and 257 mg/kg of 2,4-D in a single oral dose also showed no signs of toxicity but a calf given 108 mg/kg of picloram and 400 mg/kg of 2,4-D lost 6 kg in 4 days but showed no other signs of toxicity. Sheep given 72 mg/kg of picloram for 30 daily doses were not adversely affected. The conclusion was picloram would not cause any toxic effect upon animals grazing treated pastures.

Animal and Plant Residue Studies. Picloram residues were measured in the blood and urine of sheep fed for a week on a diet containing 220 ppm of picloram (8). The blood showed a maximum level of 0.25 ppm picloram which fell to a maximum of 0.01 ppm within 96 hours after the treatment was stopped. Picloram residues in the urine behaved in a similar fashion falling from maximum levels of 880 and 350 ppm to 52 and less than 1 ppm within 96 hours after the treatment ceased.

In an experiment conducted by Kutschinski (9), dairy cows were fed picloram at various rates from 10 to 1000 ppm in their diet. The top dosage of 1000 ppm was equivalent to a dosage of 18 mg/kg/day. No measurable residues (less than 0.05 ppm) were found in the milk after two weeks feeding at 10, 30, and 100 ppm. Dietary levels at 300 and 1000 ppm resulted in average residues of 0.05 and 0.19 ppm respectively, after two weeks' exposure. Picloram residues in milk declined rapidly and became undetectable (less than 0.02 ppm) within two to three days when the cows were taken off the dietary level of 1000 ppm.

A similar experiment by Kutschinski and Riley (10) reported the results for young beef cattle fed picloram for two weeks or more at dietary levels from 200 to 1600 ppm (2.6 mg/kg/day to 23 mg/kg/day). The concentration of picloram in the blood reached a maximum of 0.18 and 1.18 ppm at the dietary levels of 200 and 1600 ppm respectively, within three days after the treatment started. Residues in the tissues were proporitonal to the dietary levels of 200 and 1600 ppm fed the animals being 0.05 to 0.32 ppm in the muscle, 0.12 to 1.61 ppm in the liver, 2.0 to 18.0 ppm in the kidney and 0.06 to 0.45 ppm in the peritoneal fat. These residues decreased to 0.06 ppm in the kidney and below 0.05 ppm in all the other tissues within three days after withdrawal from the highest dietary feeding level of 1600 ppm.

In residue studies from liquid TORDON fromulations sprayed on grass pasture (11), one pound of picloram applied as a spray resulted in a residue of 200 ppm immediately after application. This decreased rapidly to less than 50 ppm in two weeks. Livestock grazing on pasture or rangeland treated with TORDON herbicide using recommended application rates would not be exposed to such a high dietary level as 1600 ppm. The highest

amount of picloram recommended on the label for control of weeds on rangeland is 2 lb/A.

Six months and one year after the application of 1 lb/A of picloram to grass and yaupon in Texas, no picloram could be found in aerial plant parts (116). One year after retreatment 0.04 to 0.26 ppm picloram were found in the aerial plant tissues.

Hall and Brady (153) sprayed "to wet" the foliage of young trees with a 0.75% solution of the potassium salt of ^{14}C carboxyl labeled picloram. Twenty-one weeks after application they found 91% of the picloram had disappeared from the plant tops compared to what had been found the first week after spraying. There were no differences in the amount of picloram found in the plants between resistant and susceptible species. The picloram was found unchanged or complexed with plant sugars and amine acids which readily was recovered as picloram.

Mutagenesis. Picloram in the Ames Salmonella test and two other microbiological tests was not a mutagen (12, 14).

Bignami et al. (13) tests picloram and an unidentified TORDON formulation for mutagenic activity with Aspergillus nidulans and none was found. The authors considered the negative results in one test (meitic non-disjunction) very important. This type of abnormal chromosome behavior is one of the major causes of genetic defects in man so the fact that it did not occur with picloram is important. Morpurgo et al. (16) also found that picloram and the triisopropanolamine salt of picloram had no mutagenic activity in Aspergillus nidulans. This report confirms an earlier test (13) on this species. In a new soil bacterial test system, Streptomyces coelicolor picloram did show mutagenic activity (14). This is the first report of genetic activity for picloram. Since this is a new test, its significance to man is not yet known.

In male and female rats dosed with picloram at 0.02, 02., and 2 g/kg of body weight, there were no significant differences between the results of any of the treatments (15). In fact there were very few cytogenetic aberrations (0.82%) of the bone marrow cells for any of the treatments including the controls 24 hours after treatment. In addition, none of the animals showed adverse effects.

Picloram is not a mutagen in mammals, and all the scientific evidence with one exception (14) shows that picloram is not mutagenic in micro-organisms.

Pharmacological Effects. Brisco (17) reported that picloram had been run through some general screening tests to determine if it had significant properties to be useful as a drug and none were found. Some of the tests run were to determine its potential as an analgesic like aspriin, effect on producing sleep, cardiovascular effects and other pharmacological effects.

Pharmacokinetics. Fisher et al. (18) studied a lactating Holstein cow fed picloram at a level of 5 ppm in the diet for four days. Due to technical difficulties the milk was not analyzed. However, 97.7% of the picloram was eliminated unchanged in the urine by the end of the fifth day.

Redemann (20) administered radioactive picloram, ^{14}C on the carboxyl group, to dogs and approximately 90% was excreted unchanged in the urine. The other 10% could not be traced. In an additional study, he found that carboxy labeled ^{14}C and ^{14}C ring labeled picloram was not metabolized in rats and in 12 hours was excreted unchanged in the urine (21).

Redemann's work has been confirmed in a later experiment (19) where ^{14}C ring labeled radioactive picloram was administered to rats both

intravenously and orally. In the oral experiment, two doses were used. The data indicate picloram absorption is dose dependent. Most is eliminated in urine, small amounts in feces and none in expired air. In this case 83% of the picloram was excreted unmetabolized in the urine and 15% in the feces in 72 hours. In the intravenous experiment, 75% of the picloram was excreted unchanged in the urine within six hours. Within 48 hours after treatment the concentration of radioactivity in all tissues, except that in the gastrointestinal tract, was at or below the limit of detection.

In a pharmacokinetic study (22) human volunteers were given an analytical grade of picloram by both dermal and oral administration. It was found that 76% of the orally given picloram was excreted in the urine during the first six hours and more than 87% was excreted in 72 hours. With the dermal application, only a small fraction, 0.18%, of the picloram applied to the skin was absorbed. This clearly indicates that picloram does not readily penetrate human skin and that it is improbable that acutely toxic quantities of picloram would be absorbed through the skin.

Thus in three species of mammals: dogs, rats, and man, there is experimental data showing the major quantity of ingested picloram was rapidly excreted unchanged.

It is worth noting that picloram has a very bitter, lingering taste that was not masked by grape juice in which it was given to human volunteers. It is unlikely, therefore, that a person would unknowingly swallow acutely toxic quantities of picloram.

Three-Generation Reproduction and Teratology Data. Rats were fed picloram at dietary levels of 300, 1000, and 3000 ppm for a three-generation reproduction and teratology study (24). There were two litters per generation. Picloram had no adverse effect on reproduction in rats even at the 3000 ppm dietary level.

The fertility index was reduced 42% in one litter of the F_1 generation in the female rats on the 0.3% picloram diet but all other indices and criteria were normal. Because of the proven fertility of the 0.3% male rats and the normal fertility of the surrounding generations, this effect was considered to be an artifact in the study.

This three-generation reproductive study was also designed, as is often done, to be used as a teratology study. No teratogenic effects were observed.

In another teratology study (25) picloram was not teratogenic to rats when the mother was given 500 to 1000 mg/kg/day on days 6-15 of gestation, the most critical days of pregnancy for the development of teratological effects in the rat. It should be noted this non-teratological effect was true even though the doses of 750 to 1000 mg/kg/day administered were so high that they were toxic to the maternal animals. Picloram was slightly toxic to the fetus, as shown by delayed hardening of the breast bone which is usually associated with maternal toxicity. Survival after birth and post birth development were not affected by these doses of 500 to 1000 mg/kg/day.

In a recent teratology investigation oral administration of 40, 200 and 400 mg/kg/day of the potassium salt of picloram, during the origin and early development of body organs was not embryotoxic or teratogenic in New Zealand white rabbits (242).

In considering the above data and the chronic studies subsequently reviewed in this paper, the following point is sometimes overlooked. Lifetime feeding, teratology, and multigeneration reproduction studies are

necessary for registration. The dosages used for these registration experiments are very high and have little connection to what ordinary people might be exposed to in the "real world." This is deliberately designed to be a worse case situation to insure that no harmful effect is overlooked. Thus, when these test results are favorable, there is an additional safety factor which has been built into the toxicological testing used for registration.

Subchronic Rat Toxicity Studies. A two-week feeding study with picloram on rats at doses of 0, 20, 60, 200, 500, 1000, and 2000 mg/kg/day showed that the liver was the primary organ affected by picloram (28). Liver weights were significantly increased in female rats at 500, 1000 and 2000 mg/kg/day and for male rats at 1000 and 2000. Relative liver weights were increased in male rats at all dose levels below 1000 mg/kg/day but the effects were not dose related. Slight microscopic changes were noted in the livers of rats given 1000 and 2000 mg/kg/day but no microscopic treatment-related liver or kidney lesions were noted in the rats given 20, 60 or 200 mg/kg/day. Males appeared to be more sensitive than females based on the increased liver weights at lower dosages. The no-observed-effect-level (NOEL) was judged to be 200 mg/kg/day for female rats but an unequivocal NOEL was not established for male rats.

An early 90-day feeding study on rats (29) made mention of some kidney effects of picloram which did not seem to be in accord with other information on toxic effects of picloram. Once there was some concern as to whether there were any microscopically observed effects in the kidney. To settle this question, it was thought worthwhile to get an opinion on this matter using today's standards. Slides of the liver and kidney were therefore, reexamined by two pathologists who indicated that there were no effects from picloram on kidneys caused by any dose in this study. Dietary levels of 1000 ppm (50 to 75 mg/kg/day) and below were tolerated with no observed adverse effects as judged by general behavior and appearance, mortality, food consumption, blood chemistry, average body and organ weights and gross and microscopic examination of tissues. At higher dietary levels of 3000 and 10,000 ppm adverse effects were noted with the liver being the organ affected.

A 90-day feeding study on rats (32) was run at 0, 30, 100, 300, 1000, and 3000 ppm of the triisopropanolamine salt of picloram. This salt is 55% picloram on an acid equivalent basis. No adverse effects were noted even at the top level of 3000 ppm (225 mg/kg/day) as judged by general behavior and appearance, growth, mortality, food consumption, blood chemistry, average body and organ weights and gross and microscopic examination of the tissue. The author concluded the toxicity on an acid equivalent basis was about the same for both the acid and the amine salt.

In a 13-week feeding study with picloram on rats at dosage levels of 15, 50, 150, 300 and 500 mg/kg/day, each rat was examined externally and internally for gross patholgoic alterations (31). The primary organ affected was the liver at doses of 150, 300 and 500 mg/kg/day. The livers were enlarged but there were minimal microscopic changes. Male rats were more affected than female rats at 300 and 500 mg/kg/day doses. This effect was shown by increased weight of the kidney but there were no histopathologic changes in the kidney tissues. The NOEL level for picloram was established as 50 mg/kg/day.

It is most interesting that the results from this 1982 90-day feeding study (31), are very similar to the earlier study of similar duration (29) done eighteen years ago. The target organ, the liver, the types of histopathologic effect and the no-observed-effect dose level are essentially the same as reported in the earlier study. The fact that modern tests usually confirm older toxicological data is reassuring and should give one greater confidence in relying on other vintage toxicological data.

Subchronic Toxicity Studies on Other Animals. In a 13-week feeding study of picloram on mice at 0, 1000, 1400, and 2000 mg/kg/day, liver weights were increased at all dose levels in female mice and male mice at 1400 and 2000 mg/kg/day (33). The liver was the primary organ affected. A no-observed-effect-level could not be determined from this test and is, therefore, considered to be less than 1000 mg/kg/day. Although treatment related effects were reported at all dose levels, the observed liver changes were considered to be reversible in nature.

Barna-Lloyd et al. (34) determined the palatibility of picloram in the diet of beagle dogs. Dose levels were 250, 500, 1000 mg/kg/day for 7 and 14 days. No overt signs of illness were seen at any dosage, but dogs given 500 and 1000 mg/kg/day sharply decreased (about ½) their consumption of food. Picloram is unpalatable to beagle dogs at doses at least as low as 500 mg/kg/day. Dogs will not eat diets containing 500 mg/kg/day or higher as readily as they will eat control diets containing less picloram. Presumably the lingering bitter taste previously noted in man is also detected by dogs.

A short (30 day) probe study on dogs was conducted to determine dosages to be used in a six-month dietary study (36). Dosages used were 125, 250 and 375 mg/kg/day. Differences were noted between the controls and all treatments. The liver was the primary organ affected. The major differences were: decreased food consumption in males and females for all treatments, decreased weight gain in males and females at 375 mg/kg/day and increased liver weights in males and females of the 250, and 375 mg/kg/day group and in the females of all treatments. A few minor changes were seen in the microscopic examination of the liver at the top dose level but not in any of the other treatments.

In a six-month dietary study with picloram on dogs at dietary levels of 0, 7, 35, and 175 mg/kg/day, no observed adverse effects were found for female dogs at 35 mg/kg/day and for male dogs at 7 mg/kg/day (35). Body weights, organ weights, food consumption, blood chemistry, urinalysis and microscopic examination of tissues and organs were the criteria used in this study. It was also concluded that the NOEL was 7 mg/kg/day.

Bucek and Colby (37) conducted a six-week swine feeding trial to determine the effect of picloram on growth and fattening. The addition of 10 mg of picloram per pound of feed increased weight gains by 0.2 lb and improved feed efficiency by 0.17 lb over that of pigs fed the control rations. This would suggest that picloram is a growth promoting agent for swine.

An experiment (38) to explore the same possible effect was done on cattle. Two steers were fed picloram, one at 72 and one at 154 mg/kg/day for 31 days. Both animals gained on the diets with picloram at these dosages although the dosage at 73 mg/kg/day appeared definitely to be superior. Both animals appeared to be normal when slaughtered. The number of animals in this case is too small to be conclusive but it is suggestive and no toxic symptoms were noted.

Chronic Toxicity Studies. A National Cancer Institute two-year feeding study (27) with picloram was conducted on rats and mice at high dosages. The dietary dosage levels for rats were 7,437 and 14,875 ppm and for mice they were 2,531 and 5.062 ppm. Although picloram was toxic to both mice and rats at these dosages, it was concluded that picloram does not cause cancer in male rats or male and female mice in this experiment. The authors concluded "that under the conditions of the bioassay the findings are suggestive of the ability of the compound to induce benign tumors in the livers of female Osborne-Mendel rats."

McCollister and Leng (8) studied albino rats and beagle dogs fed picloram in two-year feeding studies at the rate of 15, 50, and 150 mg/kg of body weight/day. After two years continuous feeding at these dosages, there was no observed adverse effect seen in either species as determined by body weight, food consumption, behavior, mortality, blood chemistry studies and urine analyses. Neither gross nor microscopic changes were noted in the tissues studied. There was no difference in the number of tumors found in the treated and the control animals indicating that picloram did not cause cancer. These tests were run at Industrial Biotest Laboratories (IBT) and as the raw data has been destroyed by IBT, these results, although believed to be correct have not been used in registration proceedings.

A new two-year feeding study in nuts was initiated in 1982. The dietary feeding levels were 0, 20, 60 and 200 mg/kg/day. General observations, body weights, food consumption, clinical laboratory studies, gross pathology and histopathology were obtained after 6 and 12 months (26). There were no overt signs of toxicity and no significant differences in body weights, food consumption or the parameters examined in the clinical laboratory studies. Some liver weight changes were seen and an apparent increase in pigment in the kidney but these were not dose related so they were not considered to be true adverse effects. The progress report to date supports the earlier study.

Human Toxicity. Nolan et al. (251) administered the sodium salt of picloram by both the oral and dermal routes to male volunteers. Over 75% of the picloram given orally was excreted within six hours and 90% in 72 hours. Picloram was absorbed very slowly through the skin and only a small fraction (0.2%) was absorbed. Picloram, therefore, has a very low potential to accumulate in man during repeated or prolonged exposures and it is unlikely that acutely toxic quantities would be absorbed by dermal exposure.

Recently the Safe Drinking Water Committee (30) of the National Research Council established a Suggested-No-Adverse-Response-Level (SNARL) for picloram in water of 1.05 mg/liter which is 1.05 ppm. This assumed a 70 kg person would drink two liters of water daily; used a safety factor of 1000; and assumed 20% of the human exposure would come from this water. Thus the total safe daily dietary exposure from all sources was assumed to be 10.5 mg for a 70 kg person. It is also worth noting that this committee in their toxicological review of picloram said "The committee found no reports of adverse affects in humans."

Effects of Picloram on Microorganisms. Dosages of picloram as high as 1000 ppm (applied as the potassium salt) did not appear to significantly affect carbon dioxide production from soils, urea hydrolysis or gross counts of soil bacteria and fungi (142). Some 12 different soils were used in this work. In vitro studies were done on 46 different soil microorganisms and with one exception concentrations of picloram as high as 1000 ppm

did not retard their growth and development. A concentration of 100 ppm picloram had no apparent affect upon the organism that was the exception. The authors concluded that while it can't be said that life processes of soil microorganisms are not in any way affected by very high concentrations of picloram it seems certain that if there are effects they must be very subtle.

Breazeale and Camper (123) studied the effect of herbicides on the growth rates of three species of soil bacteria. They found that picloram at 50 ppm had no effect on two out of the three but did slow the growth response 28.8% for the third.

Thorneburg and Teverdy (215) developed a rapid screening test method to determine the effect of pesticides on the nitrification process in the soil. A number of herbicides were tested including picloram at 6 and 12 ppm. At these concentrations, picloram had no inhibiting effect on the nitrification process.

In a laboratory study on a heavy clay Canadian soil to determine the effect of picloram on the nitrifying soil bacteria, there was no effect on carbon dioxide evolution or oxygen uptake by low concentrations (30 ppm and less) of picloram (147). The author concluded "it can be stated that picloram does not inhibit nitrate accumulation or the gross metabolism of Regina heavy clay soil at doses likely to be encountered in agricultural usage."

The effect of picloram as the potassium salt was studied on the soil microbial population of three soils in the Willamette Valley in Oregon at concentrations of 1 and 10 ppm (217). Picloram had only minor effects on numbers and kinds of soil microbes and climatic changes and cultural practices would have much more extensive effects. There was no effect of picloram in the only soil that had good nitrifying power (the ability to change ammonia and nitrites to nitrates). On nitrogen changes, sulfur oxidation, soil respiration, and organic decomposition there were no significant effects that were sufficient to be considered important to soil fertility. Picloram at rates up to 50 ppm did not adversely effect the growth of the fungus Aspergillus niger (43).

Dubey (129) investigating the effect of picloram on the nitrification process of three tropical soils in Puerto Rico, reported that picloram at 2 ppm caused a weak inhibition of nitrification and that 20 and 100 ppm caused complete inhibition except in soils with a high nitrifying capacity. These results are at variance with the other research work reported on this subject.

Arvick et al. (44) studied the effect of picloram and 2,4-D in an approximate 1:4 chemical mixture (TORDON 101 Mixture) on a natural population of soil algae. The dosages of picloram used in field plots were 0.25, 0.50, and 1.0 lb picloram/acre along with 1.0, 2.0 and 4.0 lb of 2,4-D. These rates caused no change in the consumption of the soil algae population over an 18-month period. Sixteen species of algae were identified. In laboratory experiments, growth of algae colonies was adversely affected by 250 ppm picloram and 2000 ppm 2,4-D but this would require an application rate at least 125 times the highest dosage generally used in the field (2.0 lb picloram/acre). At the labeled use rates, no adverse effects were seen in either laboratory or field experiments in the growth of algae.

Three soil microorganisms, one yeast and two molds were able to decarboxylate picloram when present in higher concentrations than one percent (208). The yeast, Rhodotoruls glutinis was able to decarboxylate over 19 percent of the picloram in 28 days as measured by $^{14}C_2$ evaluation. Aspergillus tamarri and Trichoderma sp. were able to decarboxylate over 6 and 11 percent of picloram, respectively. All three organisms could utilize picloram as their soil source of food (carbon) but grew faster when small amounts of the sugar dextrose was present.

In soil incubated under moist conditions and subsequently treated with picloram, 3.5 times as much carbon dioxide evolved as when picloram was applied to the same soil without the moist incubation pre-application treatment (229). These data suggest that the autochthonous soil microbial population is most efficient at decomposing picloram. This is the population that uses the less easily decomposable soil organic matter and grows relatively slowly as contrasted with the zymogenous microorganisms which grow rapidly and utilize the more readily available organic matter and are responsible for the major production of CO_2.

Wildlife Toxicology

Fish Toxicity. One of the first fish toxicity tests on picloram was conducted by Winston (74) using two formulations. One contained 11.6% of the potassium salt of picloram and the other contained 7.9% of the triisopropanolamine salt of picloram and 39.6% of the triisopropanol amine salt of 2,4-D. These were tested on green sunfish and the pugnose minnow. The 96-hour TL_m value for the potassium salt on green sunfish was 25.9 ppm and for the pughose minnow it was 16 ppm. The corresponding 96-hour values for the triisopropanolamine salt of picloram in combination with the corresponding salt of 2,4-D were 11.9 and 10.5 ppm. (The TL_m is the median tolerance limit or the concentration of the material at which 50% of the animals under test for a specific interval of time will survive. This test has largely been supplanted by the LC_{50} which is the concentration at which 50% of the test population will die under the conditions of the experiment.)

Later Winston (75) reported for the same formulations the 96-hour TL_m values for the triisopropanol amine salt of picloram (with 2,4-D) was 5.1 ppm for the fathead minnow, 19.0 ppm for brook trout, 18.2 ppm for brown trout and 11.9 ppm for rainbow trout. The maximum concentration of this formulation that had no observed ill effects on these species after a 96-hour exposure as being 4.7 ppm for the fathead minnow, 7.9 ppm for the brook trout, 7.9 ppm for the brown trout, and 7.9 ppm for the rainbow trout. In tests with the potassium salt of picloram the 96-hour TL_m value for fathead minnow was 29.2 ppm, for green sunfish 90.7 ppm, for black bullhead 69.1 ppm, brook trout 69.1 ppm, brown trout 21.6 ppm and rainbow trout was 21.6 ppm. The maximum concentration which caused no observed ill affects after a 96-hour exposure were 21.6 ppm for the fathead minnow, 38 ppm for the green sunfish, 69.1 ppm for the black bullhead, 69.1 for brook trout, 21.6 for both brown and rainbow trout. Recent (5/11/84) unpublished data obtained in Dow's Aquatic Toxicology Laboratory have shown that the 96-hour LC_{50} for TORDON 101 on rainbow trout, fathead minnow, and bluegills was in the range of 60-80 ppm.

Alexander and Batchelder (45) conducted a fish toxicity study on picloram with rainbow trout, bluegills, and channel catfish. The potassium

salt of picloram was used, and it was found that rainbow trout and channel catfish were more susceptible to picloram than bluegills. The TL_m values for these three species were 13, 14 and 24 ppm, respectively when exposed for 96 hours. Later, Batchelder (46) found that the LC_{50} for picloram on rainbow trout after a 96-hour exposure was 5.5 ppm and for bluegills it was 14.5 ppm. The rainbow trout was used as an example of a cold water fish and the bluegill for a warm water fish. This data indicates that the potassium salt of picloram is "slightly toxic" (241) to these species.

The toxicity of the triethylamine salt of picloram was determined by Duddles (52) for three species of fish. The 96-hour TL_m values for rainbow trout, channel catfish and goldfish were 41.4, 75, and 62 ppm respectively.

Duddles (53) also found that the isooctyl ester of picloram had a TL_m value of 13 ppm after a 96-hour exposure for channel catfish.

Butler (47) reviewed several reports on pesticide toxicity to aquatic organisms and listed no effect on phytoplankton growth from the use of TORDON 101 Mixture. He found 8.4% reduction from the potassium salt of picloram after a four-hour exposure. In other tests, there was no slowing or stopping of the growth of oysters or no mortality of adult shrimp or of juvenile fish when exposed to TORDON 101 Mixture.

Cope, of the Fish and Wildlife Service (48) reported the 96-hour LC_{50} at 65°F for bluegills using the potassium salt of picloram, was 25 ppm. For rainbow trout the 96-hour LC_{50} at 65°F was 24 ppm; the crustacean 96-hour LC_{50} value at 70°F was 27 for a small crustacean. The LC_{50} value at 96 hours for two gruops of goldfish is 14.1 and 31.6 ppm (49); and the LC_{50} value at 48 hours for bass was reported as 13.1 ppm.

Hardy (60) in a laboratory study using TORDON 101 Mixture at a concentration of 100 ppm found there was 100% mortality of goldfish after a 24-hour exposure. He also found that 530 ppm caused 95% mortality of daphnia after 24 hours exposure. At the end of 72 hours 530 ppm of TORDON 101 Mixture caused 100% mortality of snails. Pugnose minnows and green sunfish were also tested and the 96 hour TL_m values were 133 and 150 ppm respectively. Swabey (73) gave the 96-hour TL_m of 35.1 ppm for the lake emerald shiner exposed to TORDON 22K.

Bionomics EG and G Bionomics under contract with the Dow Chemical Company found TORDON 10K Pellets had a 48-hour EC_{50} value of more than 1000 ppm for oysters (61). The 96-hour EC_{50} value for pink shrimp was 1230 ppm and the crab had a 96-hour EC_{50} value of more that 1000 ppm. (The EC_{50} is the median effective concentration that results in 50% of organisms in the experiment showing the response being tested. Smolting is the maturing of two-year old salmon as they turn to the silvery-gray color of the adult.)

TORDON 22K had a 48-hour EC_{50} value on Eastern oysters of more than 10 and less than 18 ppm, a 96-hour EC_{50} value of 125 ppm to pink shrimp, and more than 1000 ppm EC_{50} to the fiddler crab (62). TORDON 101 Mixture was found to have a 48-hour EC_{50} value on Eastern oysters of more than 10 and less than 18 ppm (63). For pink shrimp the 96-hour EC_{50} value was 306 ppm and for fiddler crabs it was more than 1000 ppm.

Hughes and Davis (64) found the 48-hour TL_m value for picloram to be 43 ppm for bluegills, and later the 48-hour TL_m for the potassium salt of picloram as 50 ppm for bluegills (86).

Lors et al. (65) in a study on two-year old Coho salmon found the 24-hour LC_{50} of picloram as TORDON 22K was 17.5 ppm and for TORDON 101 Mixture it was 20 ppm. Gill, liver and kidney tissue were sampled and a histopatholgocial examination was made. A necrosis around the liver bile duct was seen which sometimes occurs in fish toxicity studies in both the

treated and control groups. No accumulation of picloram of 2,4-D was noted in salmon exposed for 15 days to 1.8 ppm of TORDON 101. The authors concluded that this would appear to have no effect on the smolting and migration of salmon (smolting is the maturing of two-year old salmon as they turn to the silvery-gray color of the adult.)

McCarty (67) evaluated the potassium salt of picloram for acute toxicity to daphnia and found the 48-hour LC_{50} was 226 ppm. This indicates the potassium salt of picloram is "practically nontoxic" (243) to daphnia, a fresh water invertebrate species. The 48-hour LC_{50} of technical grade picloram to daphnia was 34.4 ppm (79).

The Bureau of Sport Fisheries and Wildlife (69) reported the 96-hour TL_{50} value for the isooctyl ester of picloram as being 1350 ppm for channel catfish and 4000 ppm for rainbow trout. The 96-hour LC_{50} value for an emulsifiable concentrate of picloram was given as 27 ppm for the crustacean Gammarus lacustris (70) and the 96-hour LC_{50} value was 48 ppm for the larval stage of the California stone fly (71).

A report by Scott et al. (72) of the Fish and Wildlife Service stated that concentrations of picloram at 1.3 ppm for 48 hours decreased the survival of cutthroat trout fry (young recently hatched fish); a concentration of 0.6 ppm decreased fry growth by 25%. No adverse effects were observed when concentrations were below 0.3 ppm. Picloram concentrations in runoff and stream water have been greater than 0.3 ppm when rainfall occurred within 30 days of application and in one study it was 2.7 ppm. It was concluded that controlling weeds along stream banks could, therefore, be a serious threat to a fishery. These researchers were apparently unaware that the labeled use instructions for TORDON formulations prohibit their application along stream banks so this concern should not exist.

In an experiment to simulate field runoff conditions to determine the toxicity to cutthroat trout, picloram increased the mortality of young trout (fry) in concentrations above 1.3 ppm and reduced their growth in concentrations above 0.61 ppm (76). No adverse effect was found in concentrations below 0.29 ppm. Cope (78) using TORDON 101 Mixture found the 96-hour TL_m on rainbow trout was 70 ppm and concluded that it was unlikely that serious adverse effects to sport fish would result from the normal use of this product.

In a three-generation reproduction test in water containing 1 ppm picloram, guppies in all three generations grew and appeared normal in development, behavior and reproduction (80). One ppm of picloram did not retard the growth of algae and daphnia. Daphnia seven weeks after the beginning of this experiment had 1.21 ppm picloram in their tissue whereas the aquaria water in which they were grown had a concentration of 1.25 ppm indicating no biomagnification was taking place.

Sergeant et al. (81) found that 120 ppm of analytical grade picloram was "nontoxic" to fish. No effect in 41 hours on green sunfish was based on their swimming behavior. But on the other hand, the technical grade of picloram and the potassium salt had an effect after 5 minutes. Their interpretation was that the differences in behavior were based on some impurity in the technical picloram and the commercial formulation. They noted the treated fish recovered when placed in pond water without the herbicide. Histopathological studies showed some changes in the liver tissue that are a common response to a variety of drugs at a concentration

of 24 ppm. The impurity 2-(3,4,5,6-tetrachloro-2-pyridyl) guanidine was toxic to fish. They stated pure picloram was "virtually without effect on fish" but toxicity of different formulations vary. The authors concluded "the toxic concentrations reported in the study are 100-1000 fold higher than what would be expected in terms of water pollution resulting from runoff of treated soil or vegetation."

Aquatic tests with bluegills were run on three different samples of picloram containing various amounts of a guanidine, 0.05, 0.221, and 0.25 percent (68). The 96-hour LC_{50} values for technical picloram containing these three levels of guanidine were 32.9, 17.7, and 19.4 ppm. Picloram with a concentration of guanidine at 0.22% to 0.25% with "slightly toxic" (246) to bluegills. These data suggest that the toxicity of picloram to fish may be affected if guanidine is present at levels of 0.22 percent and higher. Guanidine is not present in picloram at these levels.

Williams and Gantz (84) found that the sodium and potassium salts of 4-amino-3,5,6-trichloro-picolinic acid were nontoxic to goldfish at a concentration of 80 ppm. Duddles (85) determined the triisopropanol amine salt of picloram had a 96-hour TL_m value of 375 ppm to rainbow trout. Fogels and Sprague (59) using rainbow trout, zebra fish, and flagfish found the 96-hour LC_{50} values to picloram were 26.0, 35.5, and 26.1 ppm, respectively. The Fish Division of the Wyoming Game and Fish Commission (88) determined the 48-hour TL_m for rainbow trout was 29.3 ppm for the potassium salt of picloram as TORDON 22K.

Elder et al. (87) using a technical grade of picloram of 99% purity found both samples exhibited low toxicity to 18 different species of fresh water and marine algae at rates approaching their maximum solubility in water (430 ppm).

E. E. Kenega (82) wrote an excellent review on the toxicity of picloram to fish and birds. Nine formulations were used on fifteen different species of fish and four species of birds. Different forms of picloram vary in their toxicity to fish as shown in the following table. If one omits the isooctyl ester which is not currently commercially available, picloram would be considered only "slightly toxic" (243) to rainbow trout, one of the fish species most sensitive to picloram.

Table 5. Comparative Toxicity to Rainbow Trout (82).

Compound Tested	96-Hour LC50 in ppm
4-Amino-3,5,6-trichloropicolinic Acid	26
Potassium Salt	13
Triisopropanol Amine Salt	209
Triethylamine Salt	29
Isooctyl ester	3

Kenaga pointed out that application of one pound of picloram applied directly to a 3-acre-inch layer of water and completely dissolved would give a concentration of 1.47 ppm. Thus, this table shows the hazard to fish from the use of picloram is extremely low since picloram is not applied to water and the likelihood of contamination from runoff in a concentration high enough to harm fish would be unlikely.

The technical grade of the potassium salt of picloram was tested for aquatic toxicity using standard procedures (50). The 48-hour LD_{50} for daphnia was 212 ppm. The 96-hour LC_{50} values for rainbow trout were 40 ppm for bluegill 137 ppm and for fathead minnow was 201 ppm. Such values indicate that the technical potassium salt of picloram is "practically nontoxic" to daphnia, bluegill, and the fathead minnow and is only "slightly toxic" to rainbow trout.

The toxicity of a technical grade trisopropanol amine salt was measured on representative fresh water organisms (51). The 48-hour LC_{50} value for daphnia was 125 ppm and the 96-hour LC_{50} values for rainbow trout, bluegill, and fathead minnow were 51, 109, and 150 ppm respectively. These data indicate that the triisopropanol amine salt of picloram is "practically nontoxic" to daphnia, bluegill and fathead minnow and is "slightly toxic" to rainbow trout.

In a recent study (66) using the latest aquatic testing techniques the 48-hour LC_{50} values for picloram were found to be 50.7 ppm for daphnia, 19.3 ppm for rainbow trout, 31.2 ppm for bluegills, and 55.3 ppm for the fathead minnows.

The most recent review of the aquatic toxicity of picloram by Mayes and Dill (240) summarize their earlier work (50, 51, 66) and other papers on aquatic toxicity of picloram. They concluded: "Examination of environmental fate data indicates that under normal use conditions it is unlikely that the concentrations of picloram in the aquatic environment would reach levels that are acutely toxic to fresh water organisms." To support this statement they cite Davis and Ingebo (125) where 9.25 lb of potassium salt of picloram was applied per acre and the maximum concentration of picloram found in a stream draining the test site was 370 ppb following 2.5 inches of rain the fifth and sixth days after treatment. They concluded "Because of its relatively low toxicity and low potential for substantial amounts in the aquatic environment, picloram presents a low acute hazard to aquatic life."

Picloram was tested against 19 species of algae (54) and exhibited low toxicity to all fresh and marine algae species tested even at rates approaching the maximum solubility of the herbicide in water. Picloram, at a concentration of 240 ppm did not adversely affect the growth of the algae species tested.

To help put the aquatic toxicity data reviewed here in perspective, it should be noted that EPA requires a label statement saying "This product is toxic to fish" when the formulation kills fish at 1 ppm. Since the LC_{50} value for picloram is so much higher than one ppm as seen in these studies just reviewed, this fish kill statement is not required on picloram labels by EPA. The data from many experiments on many species, although variable as would be expected, clearly show that picloram formulations have a low degree of toxicity to fish and other aquatic organisms.

Bioconcentration. In a bioconcentration study (108) bluegill sunfish were exposed to radioactive picloram with ^{14}C labeled in the ring for up to 28 days at 0.1 and 1 ppm. Analysis of the fish and water indicated that picloram does not bioconcentrate in bluegill sunfish.

Channel catfish were also exposed up to 28 days to picloram labeled in the ring with ^{14}C at 0.1 and 1 ppm (109). Analyses showed that picloram did not bioconcentrate in catfish. Also, at the end of 28 days, no degradation products were found, giving further evidence that when picloram degrades it goes rapidly to CO_2 and H_2O. These reports clearly show that picloram did not bioconcentrate in aquatic organisms.

Youngson and Meikle (238) conducted a similar study with mosquito fish, Gambusia sp., grown in water containing 1 ppm and 5 ppb carboxyl ^{14}C-labeled picloram. The fish grown in the 1 ppm solution of picloram at the end of an 18-day exposure period had 0.021 ppm picloram in the fish tissue. At the end of 567 days the picloram content in fish living in water containing 5 ppb contained 1.12 ppb picloram.

Bird Toxicity. In one of the first tests to measure the toxicity to birds, mallard ducks were given picloram in their diet at levels of 500, 1000, 2000, 3000, 5000, 7000 and 10,000 ppm (97). There was no mortality caused by the picloram at any dietary level. There was also little or no decrease in body weight or food consumption.

Fink (55, 58) determined that TORDON 101 Mixture in an eight-day dietary feeding experiment for bobwhite quail and mallard ducks was "practically nontoxic." At 10,000 ppm which was the highest concentration tested there was no mortality or any other signs of toxicity. The 8-day LC_{50} of TORDON 101 Mixture for mallard ducks and bobwhite quail was, therefore, estimated to be greater than 10,000 ppm.

In an eight-day dietary test on Bobwhite quail and the Mallard duck the potassium salt of picloram caused no mortality at 10,000 ppm which resulted in a LC_{50} of greater than 10,000 ppm (56, 57). In both tests, TORDON 22K was "practically nontoxic" to these bird species. Fink (89) also determined that the acute LC_{50} of TORDON 10K Pellets for both bobwhite quail and mallard ducks (90) was greater than 10,000 ppm. The test procedures used were in accordance with those described by EPA in the 1978 Federal Register.

Using these current testing procedures Beavers (83) measured the toxicity of technical picloram of 93.8% purity on mallard ducks. The acute oral LD_{50} was found to be greater than 2510 mg/kg which was the highest dosage tested.

In a wildlife test in England (98) the potassium salt of picloram at 3/4 oz. per acre was applied to spring cereal fields largely surrounded by tall, thick, uncut hedges. A relatively good cross-section of birds, approximately 20 different species, lived in the area. No adverse effect was noted on the numbers of birds or the health of the nestlings at the time. In view of the low toxicity of picloram to birds these results are not surprising.

Bird Egg Toxicity. Fertile chicken eggs were sprayed with a commercial mixture containing 2,4-D and picloram in a 4:1 mixture (TORDON 101) at a rate which would be 0.625 lb picloram/acre plus 1.875 lb 2,4-D. There were no adverse effects on hatching success, number of deformed embryos, or subsequent chick mortality compared to the controls (91). In a companion study the same TORDON 101 rate was applied to ring-neck pheasant eggs (92). No treatments caused adverse effects on hatching, number of deformed embryos, subsequent chick mortality or growth compared to the controls. These results are in conformity with their earlier study on chicken eggs.

This same team (93) repeated the first experiment with fertile chicken eggs but with the 2,4-D used separately at greatly exaggerated doses up to 20 times the normal application rate. The highest picloram application (6.5 lb/acre + 2,4-D) was 10 times the normal application rate. The results obtained were similar to and confirmed the other experiments. Again these investigators (94) used the potassium salt of picloram on chicken eggs at the high rate of 10 lb per acre. Results were similar to

their earlier data. There was no affect on embryonic development or subsequent growth of the hatched chicks. They also investigated reproductive behavior from chickens that had hatched from similarly treated eggs (95). This investigation measured egg production, hatchability, deformed offspring, sperm count, testes weight, shell porosity, egg weight, and mortality. Picloram sprayed on chicken eggs at 10 lb/acre (a dose 10 times the usual rate of application) had no effect on the resulting chickens when these eggs were hatched or the egg production and reproductive success of these chickens.

Bird Reproduction. In a three-generation reproductive study on Japanese quail fed picloram at dietary levels of 100, 500, and 1000 ppm (96) there were no significant differences between the groups with picloram in their diet and the controls as measured by egg production, fertility, hatchability, survival and gains in body weight. Food consumption data also showed all levels of picloram in the diet were acceptable to the birds.

Kenaga (82) summarized the toxicity of picloram to birds as low because: it has a low acute oral LC_{50} to chickens of 6000 mg/kg; and the eight-day dietary LC_{50} for mallard ducks and bobwhite quail is between 10,000 and 385,260 ppm. A 1000 ppm dietary level of picloram in a three-generation reproduction study on Japanese quail caused no adverse effects on food consumption, egg production, hatchability, survival, fertility and body weight. Kenaga concluded that TORDON herbicides are "no hazard whatsoever to birds."

Honey Bee Toxicity. Picloram applied in acetone, as the triisopropanol amine salt and the potassium salt to honey bees showed that picloram is practically nontoxic to honey bees. For example, the insecticide malathion used in these tests as a treated check at 50 ppm killed 100% of the bees, whereas, 4000 ppm of picloram killed only 4% of the bees.

The potassium salt of picloram sprayed on honey bees in a water solution at a rate of 4 lb a.i. per acre did not result in mortality above that of the controls sprayed only with water (99). The same authors (101) sprayed bees with both the potassium salt of picloram and a mixture of the triisopropylamine salt of picloram and 2,4-D (TORDON 212) in water. The dosage for the potassium salt of picloram was at an approximate rate of 4 lb a.i./acre. The dosage used for TORDON 212 might have been 4 lb of picloram a.i. or perhaps 1 lb of picloram and 2 lb of 2,4-D a.i. Both formulations were nontoxic to bees. In a third study (102) they found that 1000 ppm of the potassium salt of picloram in a 60% sugar solution had no adverse effects on egg production, hatching and development of young bees. In fact, there was a noticeable, although nonsignificant increase, in the brood produced in colonies receiving this herbicide compared to the controls.

Environmental Fate of Picloram

Photodegradation in Water. Picloram is degraded by ultraviolet light (138) suggesting that dechlorination plays the major role in photochemical degradation and that it is the first step in the process followed by decarboxydation, loss of aromaticity and deamination. Ultraviolet light degraded 100 ppm picloram to 0.5 ppm picloram in 30 minutes.

In a laboratory experiment (154) approximately 20% of a 4,830 ppm solution of picloram degraded for every 48-hr period when exposed to ultraviolet light until the end of the experiment at 192 hrs. Decomposition also occurred after exposure to sunlight but it occurred at a lower rate with approximately 15% degrading every 72 hr. At the end of 200 hr 40% of the picloram had decomposed.

Hamaker (158) found that a 5 ppm solution degraded to approximately 1.7 ppm in 16 min. Photodecomposition was slower in natural waters (pond, canal, etc.) being approximately 20 to 40% the rate in distilled water at a three-foot depth.

The sodium salt of picloram decomposed 61% after 34 hr exposure to ultraviolet light (300-380 nm) and degraded 99% after 172 hr exposure (192). Decarboxylation was not a major degradation pathway. No degradation products could be identified and a particular effort to find 4-amino-2,3,5 -trichloropyridine and 4-amino-3,5-dichloro-6-hydroxypicolinic acid was unsuccessful.

Hedlund and Youngson (165) measured the effect of sunlight quantity on the photochemical degradation of picloram. Degradation measurements were made at nine different locations ranging from Davis, California, to Winter Park, Florida, and Wayside, Mississippi, to Lincoln, Nebraska. Concentrations from 0.25 to 2500 ppm were used and measurements at one site at Davis, CA were made using radioactive picloram (carboxyl ^{14}C). With abundant sunshine, picloram decomposed in clear distilled water at a rapid rate. The half-life was 6-8 days. In areas with abundant sunshine, 90% of the picloram was decomposed after a 30 day exposure except from the most concentrated samples. Lower losses occurred in areas with little or hazy sunshine.

The speed of photodecomposition of picloram in water is proportional to the light intensity and depth of solution but is independent of the initial concentration (166). The range in half-lives observed varied from 2.2 to 41 days. Under conditions of bright summer sunlight in one experiment, the half-life was less than 10 days versus 41 days for the hazy, less intense sunlight of fall. In one experiment at depths of 1, 6, and 12 feet the half-lives were 3.3, 6.4 and 9.6 days, respectively.

Fifty-seven percent of a one ppm solution of picloram, as the sodium salt in a six-inch layer of pond water was found to decompose in 22 days when exposed to sunlight whereas no measurable decomposition occurred in a similar sample inside a greenhouse (234). At the end of 65 days, 87% of the picloram had decomposed and after 146 days 100% had degraded in sunlight, whereas none had degraded in a greenhouse. It should be remembered that standard greenhouse glass filters out ultraviolet light. In a 12-foot deep tank filled with a solution of 1 ppm of picloram as the sodium salt without obvious circulation 78% decomposed after 94 days and 89% after 154 days. In a similar test with circulation no picloram was found after 94 days. Four-ounce jars were filled with a 1 ppm solution of picloram as the potassium salt and exposed to sunlight for 1, 2, and 3 months in twelve states. Under these conditions the half-life of picloram varied from 7.4 to 23.5 days with an average half-life of 15.6 days.

Hamaker (155) studied the decomposition of picloram in water and found that 56% of a 9 ppm solution of picloram decomposed after exposure to direct sunlight for 9.2 days and 85% was decomposed in 30 days.

Baur et al. (106) studied the effect of heat and ultraviolet light on the degradation of picloram. They found that at 140°F there was a

significant loss of picloram and that ultraviolet light also caused significant degradation of picloram.

A California investigation using a bioassay analytical technique showed that 0.05 to 50 ppm of picloram in clear water are rapidly (7-22 days) degraded by sunlight (224). After seven day's exposure to August sunshine at Walnut Creek, CA, in a 1" layer of distilled water, there was 100% decomposition of the sodium salt of picloram at 0.05 ppm; 97% from 0.5 ppm; 91% for 5 ppm and 79% for 50 ppm. Using canal water with 5 ppm picloram there was 84% decomposition after seven days. There was 100% decomposition in all samples after 22 days. At a depth of 12" and with a concentration of 5 ppm of the sodium salt of picloram 95% had decomposed after 16 days.

In rate of photodecomposition studies picloram underwent photolysis easily and certain materials, sensitizers, such as benzophenone accelerated the process (244). 38% of a 265 ppm solution of picloram degraded in 0.5 hour using light with a wave length of 254 and 313 mm from a low pressure mercury lamp.

Redemann's studies (206) also showed that picloram readily undergoes photolysis. Picloram at the rate of 1.5 lb/A was contained in a thin layer of water. Twenty percent was degraded in six hours in direct sunlight and the daily rate of degradation was approximately 0.4 lb picloram/acre/day. Comparing the photodegradation of picloram under different light sources; it was most rapid under a murcury vapor arc, next direct sunlight and slowest inside a greenhouse. In laboratory studies pH's of 4, 6, and 10 did not affect the rate of degradation of picloram. In shallow layers of clear water at 1.2, 2.4 and 4.8 mm depths the rate of photodecomposition of picloram was the same at all depths. Picloram at 2.9 lb/A degraded by photolysis 100 times faster in a clear aqueous water solution compared to a dry film.

Photodegradation in Soil. Merkle et al. (188) studied the photodegradation of the potassium salt of picloram in soil. One milligram of picloram was spread over the bottom of three inch petri dishes. Thin layers of the soil containing 1 mg of picloram were also spread over the bottom of three petri dishes and both sets were exposed to sunlight, ultraviolet light and darkness. Results after 48 hour's exposure showed that 60% of the picloram from the glass surface alone was degraded by the ultraviolet light and 35% was degraded by sunlight. After one week's exposure, 90% of the picloram had been degraded by the ultraviolet light and 65% by sunlight. Picloram degradation from the soil surface was slower and only 15% had degraded after one week's exposure to sunlight.

In a similar study (245) comparing the photolysis degradation of the isooctyl ester and the potassium salt of picloram an average of 43% photolytic degradation of picloram as the ester from wet and dry sandy loam soil occurred after 72 hour's exposure to ultraviolet light. Under the same conditions there was 9% photolytic degradation of the potassium salt. There was 96% photolytic degradation in 72 hours from the glass surface of the petri dishes.

Again, picloram was incorporated in three different types of soil in four-ounce jars at concentrations of 0.023 to 24 ppm (234). These jars were then exposed to sunlight, shade and darkness for 30 days. No differences were found in the picloram content in any of the treatments. In another experiment, picloram was mixed in soil and exposed in ¼ inch layer in full sun and shade for nine days and then analyzed for picloram. No apparent decomposition was found.

The results of these three reports show that picloram readily undergoes photolytic decomposition from a non-adsorptive surface such as glass and some can photodegrade from the soil surface. When picloram is incorporated into the soil, however, it does not undergo photolysis.

Aerobic Soil Metabolism. A laboratory study (227) showed no difference in the behavior of picloram degradation after three different methods of sterilization: autoclaving, chemical (ethylene oxide) and irradiation. All three methods of soil sterilization stopped the degradation of picloram. Comparison of radioactive CO_2 evolution from sterilized and unsterilized soils showed that microorganisms play the major role in the degradation of picloram in soil.

A companion study (226) showed that as the soil depth increased, picloram decomposition decreased, although decomposition did not cease at the 42"-45" level, the lowest level tested. The microbiological activity of the soil as measured by the evolution of carbon dioxide also decreased as the soil depth increased thus strongly suggesting that microbial activity plays an important role in the decomposition of picloram.

A laboratory study (161) measuring the disappearance of technical grade picloram under aerobic conditions at 70°F in 13 different California and Texas soils showed the amount of picloram remaining after six months varied from an average of 75% at 3 ppm to an average of 24% at 0.047 ppm. Even though the amount degraded at 3 ppm was unchanged in some soils, in other soils considerable degradation occurred. For instance, in one case only 78% of picloram had degraded and in another 87%. The average half-life for picloram applied to these 13 soils at dosages from 0.047 to 3 ppm was six months. This data also shows that soil degradation of picloram under aerobic conditions takes place at a faster rate at lower concentrations than at higher concentrations.

Hance (162) reported that decomposition of picloram in soil would not take place by purely chemical means. The author said "it seems reasonable to conclude that non-biological chemical processes do not play an important part in the loss of these chemicals from the soil." The author (163) subsequently concluded that at lower concentrations of herbicides in soil, non-biological chemical degradation could possibly be a significant pathway by which herbicides are lost from soil and that there would be great variability in soils for this type of action.

In a study of the degradation of the potassium salt of picloram in two English soils at rates of 0.67, 1.25, 4.0, and 20 ppm, the average half-life of picloram in these soils was approximately three months (164). Forty percent of the picloram remained in the silt loam soil and 55% remained in the calcareous silt loam soil after three months.

In a laboratory study, Youngson (232) analyzed the soil for picloram from field plots in twenty-four locations in North and South Dakota, Saskatchewan, Michigan, Montana, and Minnesota. A bioassay method of analysis utilizing the safflower plant was developed to make these analyses sensitive to 0.001 ppm. Various formulations of picloram were applied at rates up to 4 oz/A to grain or grass plots in these states. With one exception, no picloram was found in plots receiving 0.5 oz/A or less. This data indicates the time required for dissipation of picloram below 0.001 ppm when used at less than 0.5 oz/A was between 3 and 30 months. The recommended use rate of picloram for weed control in small grains is 0.25 to 0.375 oz/A.

Picloram in soil incubated under an atmosphere of nitrogen gas decomposed more slowly than under air (237). The authors noted that under both nitrogen gas or water-logged soil complete cessation of picloram degradation did not occur. They were not sure, however, that a true anaerobic condition had been achieved.

Different soils varied very significantly in their ability to decompose picloram (236). In a 423 day period using a picloram concentration of 0.4 ppm, some soils had 52 to 82.5% of the picloram decomposed and others had only 5.2 and 7.6% decomposed. If the soil was sterilized there was practically no decomposition. The data also suggest that there are great differences in the capacity of micro-organisms to decompose picloram. The organisms that thrive on easily available energy materials are probably least efficient and the scavengers are most efficient. Certain soils that did not decompose picloram rapidly were treated with radioactive labeled picloram. After 423 days incubation, these soils were extracted and 90.6 to 97.5% of the herbicide was recovered. Correlation coefficients between the decomposition of picloram and the following factors were calculated: pH, percent clay, percent organic matter, temperature, percent water-holding capacity, and rate of carbon dioxide production. The most significant factors affecting decomposition were percent organic matter, and percent water holding capacity and temperature. The rate of decomposition of picloram increased as its concentration in the soil decreased.

Guenzi and Beard (151) using radioactive ^{14}C in the carboxyl group showed that the degradation of picloram is predominantly a microbial process and is temperature dependent. There was little degradation in sterile soils. The extractable picloram from the soil plus the $^{14}CO_2$ generally accounted for more than 90% of the applied chemical. No volatilization of picloram was detected at any temperature up to 122°F.

Redemann et al. (207) applied 0.1 and 0.91 lb/A of totally labeled picloram to soil subsequently planted with spring wheat. No major degradation metabolites were found in either the soil or the plants. Eighty-three percent of the original radioactivity was still found as picloram in wheat extracts 84 days after application. The major radioactivity (54%) found in soil extracts was picloram. Neither 4-amino-3,5-dichloro-6-hydroxypicolinic acid or 4-amino-2,3,5-trichloropyridine are major metabolites in either plant or soil metabolism or picloram. The major compound found in the metabolism of picloram is picloram itself and when it breaks down it goes to simpler compounds normally found in living systems.

Banks and Meikle (104) applied carboxyl labeled ^{14}C picloram to soil to determine its degradation pathway and metabolic degradation products. Only radioactive picloram itself and some simpler compounds normal to a living system were found. No labeled ^{14}C metabolites of picloram were found.

In a study of the degradation pathway of picloram in soil, the major metabolite or breakdown product of picloram in soil was carbon dioxide (185). Decarboxylation was not the initial reaction in the microbial decomposition of picloram. Other possible decomposition products were very simple short-lived compounds in quantities too small to be identified which did not accumulate in the soil.

Meikle et al. (186) further demonstrated that there were no major intermediate soil metabolites in the decomposition of picloram. The ring structure breaks open after which the molecule is rapidly degraded to

carbon dioxide. Several compounds in minor amounts have been observed such as 4-amino-3,5-dichloro-6-hydroxypicolinic acid and 4-amino-2,3,5-trichlroropyridine. These, however, have been proven not to be on the main metabolic pathway for the breakdown in soil and they do not accumulate in the soil.

In a laboratory study of the soil behavior of carboxyl labeled ^{14}C picloram premoistening the soil before incubation only slightly increased the rate of degradation (23). These results suggest the indigenous or native soil microorganisms that can survive on less readily available soil organic matter are chiefly responsible for the degradation of picloram in the soil.

A detailed laboratory study showed little or no degradation of picloram in 300 days under anaerobic conditions (186). Under aerobic conditions in seven different soils at a concentration of 1 ppm, the half-life of picloram varied from 167 to 513 days. It should be noted that acetone was used as the solvent for picloram which probably slowed the degradation of picloram. The major and practically speaking, the only metabolic product was carbon dioxide. Several minor compounds were detected using high performance liquid chromatographical methods of analysis, but the total amount never exceeded four percent of the picloram applied. Individually there was not sufficient material for identification. One experiment was started under aerobic conditions and then was switched to anaerobic. This study showed that degradation essentially stopped under anaerobic conditions.

Hydrolysis. Hamaker (157) found the rate of hydrolysis of carboxy ^{14}C labeled picloram to be extremely slow. After 70 days at 113°F, 93.3% was still present as picloram. The half-life of picloram at this temperature was calculated to be 1.8 years.

Aquatic Metabolism. In a greenhouse experiment (221) more than 95% of the picloram degraded in 13 months in static water containing sediment at the bottom. The concentrations of picloram used were 0.2 and 2 ppm. The light intensity varied from 1000 foot candles on a cloudy day to 4000 foot candles on a sunny day. The water temperature varied from 70-90°F.

Hamaker (156) used ^{14}C ring labeled picloram to determine whether picloram in a pond will accumulate in bottom sediments. This was accomplished by putting the picloram into tubes containing water with a four inch layer of sediment at the bottom. At the end of 27 days, less than 20% of the labeled picloram was in the sediment which increased to near 30% after 85 days. Moreover, 90% of this 30% in the soil sediment was in the top 2 to 3½ inches. Thus, the conclusion was picloram would not accumulate in the bottom sediment of ponds by either adsorption or penetration processes.

Leaching. Helling (167, 168, 169) developed a laboratory testing technique and classification system for measuring the potential for movement of chemicals in soils. Under this classification system, picloram falls in class IV having the potential for moderate mobility. It is less mobile than dicamba, has about the same mobility as 2,4-D and is more mobile than propachlor. The importance of organic matter content in soil and its effect on mobility was demonstrated by the increased mobility of picloram when the organic matter is removed. Helling's technique provides a convenient laboratory test to determine the potential a chemical has for mobility in the soil. It should be noted, however, that climate, soil

structure, quantity of water percolating through the soil, degradation rate and organic matter content of the soil are all important factors determining the actual mobility of a chemical in the field. This is particularly illustrated by picloram where many field experiments have shown that while it has the theoretical potential for being mobile under field conditions, picloram does not move extensively and remains primarily in the top layers of the soil.

Bovey et al. (245) conducted a leaching study on picloram using 1000 mg as the potassium salt, the free acid, and the isooctyl ester. The soil was a sandy loam in column 60 cm high. With the soil having a moisture content at field capacity, the addition of 12.5 cm of water to the soil columns in one application resulted in 91% of the potassium salt and 74% of the acid being leached to the 17-30 cm soil layer. With the ester 60% hydrolyzed to the acid and was distributed through the first 45 cm of soil while 40% of the ester remained as such and was confined in the top 5 cm of soil. Application of the ester to air dry soil resulting in 97% of the picloram being in the top 7.5 cm of soil.

Youngson (230) in a laboratory experiment applied picloram at the rate of 2 lb/A to sandy, clay and muck soils in 12 foot columns. Water was applied weekly in ¼, ½, 1, 2, and 4 inch increments for 37 weeks after which the picloram was measured at different levels using a bioassay technique. As the amount of water applied was increased, the depth to which picloram was leached also increased, particularly in the sandy and clay soils. After 18.5 inches of water, picloram was leached to the fourth and fifth foot level in the sandy soil at concentrations of 0.285 and 0.084 ppm, respectively, and none was found above or below these levels. In the clay soil picloram was confined to the first four foot soil levels at concentrations of 0.0015, 0.0006, 0.174, and 0.087 ppm. No picloram was found below the four foot level. For the loam soil with 25% organic matter, the corresponding values were 0.34 and 0.03 ppm in the first and second foot levels and none was found below the two foot level. Picloram was most easily leached in the sandy soil and most resistant to leaching in the muck soil. At the end of 37 weeks, picloram was leached to a depth of 12 feet in sandy soil by 62 inches of water; to a depth of 8-10 feet in the clay soil by 74 inches of water; and to a depth of 2-4 feet in the muck soil by 148 inches of water.

Goring and Youngson in a laboratory study (143) with leaching columns on four different soils showed that leaching of picloram varied with the soil type. It moved readily through a California sandy soil but moved with difficulty through a red soil high in hydrated iron, aluminum oxides and gibbsite (an aluminum hydroxide). They also showed picloram is adsorbed on organic matter and moves slowly through soils with a high organic matter content.

MacDonald et al. (182) conducted field and laboratory studies on three Canadian prairie soils (sandy loam, silty clay loam and a silty clay) to measure the leaching of picloram. The potassium salt of picloram was applied at one and two lb/A to a brome-alfalfa pasture on a light sandy loam soil chosen to maximize movement of picloram in the soil. In the plots with 5.8 inches of rainfall nearly all the picloram was found in the top 18 inches of soil. A light irrigation of 0.8 inches of water on other plots had no effect on leaching. A heavy irrigation of 4 inches moved the picloram down to 41 inches. In the laboratory soil column studies the

leaching was greatest with the sandy loam followed by the silty clay loam and then the silty clay. Statistical analysis showed that the organic matter content of the soils accounted for 92% of the retardation of picloram movement in the soil. The clay content of the soils had little effect on the leaching of picloram.

Merkle et al. (188) studied a clay, a sandy loam and a commercial grade of sand in a laboratory leaching study. One mg of picloram as the potassium salt was applied in a water spray per column. The soil columns were 60 cm high and one inch of water was applied. The majority of the picloram was found in the top 15 cm. The columns with soil at field capacity had greatest movement of picloram. In the column containing pure sand, picloram moved as far down as the 30-60 cm sand level after one inch of simulated rain.

Adsorption - Desorption. Biggar et al. (110) deals with theoretical concepts of soil adsorption. The author's data showed that at normal ranges of soil pH, adsorption of picloram takes place primarily on the soil organic matter while at pH's of less than four, adsorption is primarily on the clay fraction of soil.

Cheung et al. (77) in a theoretical paper on the absorption/desorption of picloram calculated an equilibrium constant and their data show that desorption is slower as the organic matter in the soil increases.

Davidson and Change (124) stated that the adsorption of picloram was highly dependent on the bulk density and particle size of the soil as shown by the soil structure and the velocity of the water moving through the pores. The adsorption of picloram was greater when the soil particles were smaller than 0.42 mm in diameter and less when they were larger than 2.0 mm.

This paper supports the idea of a two-stage process for the leaching of picloram. In structured soils most water percolates through the larger cracks and pores. Immediately after application only the picloram in the vicinity of these large cracks and pores is subject to migration in the water. This is why picloram may be most subject to leaching immediately after application if a heavy rain falls. As time passes, picloram migrates into the smaller cracks and pores of the soil aggregates and away from the larger channels. Thus, the tendency to leach diminishes with time. This phenomena is a mechanism for explaining field observations and data that show picloram generally remains in the top 12 inches of soil.

Farmer and Aochi (133) measured sorption/desorption for picloram on six western soils. They found increased adsorption of picloram with increasing content of organic matter in the soil and that variation in soil adsorption of picloram was not correlated with soil type. Increased adsorption also resulted with decreasing pH of any individual soil although there was no correlation between soils in the pH range of 5.6 to 7.4.

Duseja (130) also studied the adsorption and desorption of picloram. He found adsorption was highly correlated with organic matter ($r=0.99$) in the soil. An increase in the temperature from 63.5°F to 77 also increased adsorption. Adsorption was found to be inversely correlated with a pH change from 3.6 to 9.2 The presence of inorganic salt slowed movement of picloram in soil presumably by increasing picloram adsorption.

Grover (146) studied the adsorption of picloram in Canadian prairie soils. He too found that its adsorption was correlated with the soil organic matter but not with the clay content.

In further work on the movement of picloram, Grover (148) using ^{14}C carboxyl labeled picloram studied the leaching behavior of picloram, dicamba, and 2,4-D in five Canadian soils. His results show that picloram is slightly less mobile than dicamba and slightly more mobile than 2,4-D. The data also show that soil adsorption of picloram was significantly related to soil organic matter content, to a lesser extent with pH and was not correlated with the clay content of the soil.

Grover (149) continued his experimental work with picloram movement in a laboratory study on eight Canadian prairie soils. In this study he showed that picloram had the greatest movement in soils with a low organic matter content, such as the Asquith sandy loam with a soil organic matter content of 1.8%. The least movement occurred in soils that were high in organic matter, such as the Lacombe loam with an organic matter content of 12.4%. Picloram moves with water in the soil both upward and downward.

Hamaker et al. (159) stated that the sorption of picloram is greatest in soils containing a high percentage of organic matter and in red and acidic soils. Their data suggest that sorption of picloram is primarily caused by organic matter and hydrated metal oxides with clays probably playing a secondary role. Sorption of both the non-ionized picloram and its anion took place.

Work by McCall (183) shows that as time increases more picloram is adsorbed to the soil. The adsorption of picloram in the soil appears to take place both at surface of soil particles and at interior sites. Adsorption at surface sites is rapid (a matter of hours) and the amount adsorbed is nearly constant. The adsorption to interior sites is slow (a matter of days) and the amount adsorbed increases with time. This laboratory study also provides a theoretical basis for many field dissipation studies that have shown the mobility of picloram decreases with time. It also shows why picloram stays in the top layer of soil in the field even though classic column leaching studies have shown that picloram has the potential for mobility.

Field Dissipation Terrestrial. Merkle et al. (187) studied the behavior of picloram in 11 different soils. They concluded that the rate of decomposition of picloram in soil is most affected by temperature and soil moisture. Increases in temperature and soil moisture increase the speed of degradation. The data also suggested that the decomposition is biological rather than chemical. Picloram in these soils at 0.4 ppm had an average half-life of approximately one year. Organic matter content, sand, clay, silt, and pH did not significantly affect the rate of degradation. The data show that at higher temperatures, higher soil moisture, and at lower concentrations, picloram degrades faster.

Merkle et al. (188) in an early laboratory study mixed the potassium salt of picloram with a clay, a sandy loam Texas soil and a commercial grade of sand to give concentrations of 0.25 and 1 ppm. The soils had water added to bring them to field capacity and 0.1 of field capacity. Samples were stored in temperature controlled chambers at 39.2, 68, and 100.4°F. Picloram was more persistent at the lowest temperature than at the higher temperatures and in clay or sandy loam than in sand. The average amount of picloram that degraded at the end of one year was 85% at the 1 ppm rate and 75% at the 0.25 ppm rate. If one averages their results for all soils at all temperatures and all levels of moisture you obtain a half-life of approximately three months.

Gibson and Hammer (140) summarized several field studies where picloram was applied on 13 sites at rates from 0.25 to 2. lb/A using the triisopropanol amine, the triethylamine salts, the isooctyl ester and the potassium salt of picloram both in pelleted and liquid formulations.

Twenty-eight soil samples were analyzed and in 21 cases no picloram was found. In the seven cases where picloram was found, four were collected from a very dry section of western Texas. The maximum amount of picloram found was 20-58 ppb in the 1-6 inch soil layer six months after application. The analytical limit of detection was 5 ppb. The sampling time after application varied from 4 to 41 months.

Fryer et al. (135) applied 0.044, 0.25, and 1.5 lb/A of picloram as the potassium salt on a well-drained sandy loam soil with a pH of 7 and containing 2% organic matter. These dosages were applied in June, 1967 and again in August of 1969 and 1970. There were only small amounts of residue 1 year after application of the lowest and medium rates. At the highest rate, five to six percent of the original amount was recovered at the end of the first year. Following the final application at the highest rate of 4.5 lb the residue declined to 0.5% of the total amount applied four years after application. In stratified soil samples, picloram was found at a maximum depth of 36 inches one year after the initial application, but 69 weeks after the final spraying no residue of picloram was found below a depth of 12 inches. The authors concluded there was no accumulation of picloram in the soil after repeated applications and that after an initial fast disappearance of much of the herbicide, the balance disappeared slowly over several years. They also grew a variety of crops successfully on all plots the fourth year after the final treatment. These crops included beans and potatoes which are very sensitive to picloram. They did note a few very minor leaf abnormalities in beans and potatoes, but they stated "Morphological differences in crops grown in soil containing picloram residue do not necessarily indicate yield loss."

Goring et al. (144, 145) conducted field studies that showed the dissipation of picloram from thirteen locations in the four western states of Kansas, South Dakota, Minnesota and California. Application rates varied from 1.68 to 4.2 lb/A. A bioassay analytical technique showed picloram losses of 58-96% one year after treatment and 78-100% two years after treatment. For all locations with one exception, the highest amounts of picloram were found in the top 12 inches of soil. There was an indication that there was a greater percentage loss of picloram at the lower than at the higher rates of application. The estimated half-lives varied from 1 to 13 months.

Hamaker et al. (160) developed a model to predict disappearance of picloram in the field based on data taken from locations in 18 states and provinces of Canada. A total of 207 picloram treatments were used in this study. Rainfall varied from 7 to 40 inches per year. Taking the average values observed and using the mathematical model developed from actual field data, the half-life for picloram ranged from a minimum of 3 months to a maximum of 19.5 months after application of 1 lb/A. For ½ lb/A application these half-lives ranged from 2.1 months to 13.8 months. Apart from developing this valuable model for predicting picloram degradation, they found the average loss of picloram was 80% and only 12 plots out of the 207 had picloram below the top two-foot soil layer.

Herr et al. (170) showed the relative tolerance of five crops to picloram. Picloram was applied at rates of 2, 4, 8, 32, and 64 oz/A to two Ohio soils, one a heavy silty clay and the other a medium textured silt loam. Both soils had approximately 4% soil organic matter. The heavy clay plots had 16 inches of rain and the silt loam had 26 inches of rain during the nine months after treatment but before the crops were planted. The crops tested were barley, alfalfa, corn, oats, and soybeans.

Two ounces of picloram applied nine months before planting had no observed effect on any of these crops. The 32 oz/A rate had no effect on corn or oats but reduced the barley stand approximately 50% and the alfalfa and soybean stands 100%. In another experiment picloram was applied at 32 oz/A 20 months before planting soybeans. There were some minor leaf symptoms (a slight puckering between the veins) seen but there was no effect on the soybean stand or crop yield. The tolerance of these crops to picloram was corn>oats>barley>alfalfa and soybeans.

Hunter and Stobbe (174) applied picloram at rates from 0.031 lb/A to 0.624 lb/A at the first location on a dark colored fine textured clay soil. The half-life varied from 12.3 months at 0.03 lb/A to 14.6 months for the 0.624 lb/A. Approximately one year later a repeat application was made and this time the half-life varied from 2.3 months at 0.03 lb/A to 4.5 months for the 0.624 lb/A rate. The first year was abnormally dry (4 inches of rainfall), approximately half that of a normal year. The second year had high rainfall, approximately twice that of a normal year.

At the second site on the same soil, with more normal rainfall only 18% picloram remained in the top three inches of soil after 4.4 months and none was found below 3 inches. Temperature was considered to be a factor in the more rapid dissipation. This occurred when the temperature was over 80.6°F. After two applications at 0.3 lb/A, 32% of the picloram remained in the soil after 25.2 months. Annual repeat applications of 0.062 lb/A resulted in no detectable residues of picloram in the soil.

Moffat (191) applied the potassium salt of picloram at 1, 2, 4, 8 and 16 oz/A on bare ground, cereal crops, and pasture covered plots in New Zealand. At rates up to 2 oz/A there was no significant hazard to clovers seeded after the treated crop was harvested or in the autumn following a spring application. For higher application rates, one year would probably be required before the treated area could be planted safely to pasture legumes.

Norris (195) determined the picloram residues from applying the isopropanol amine salt of picloram to certain powerline rights-of-way in Washington and Oregon. The picloram was applied at the rates of 0.4 to 1.5 lb/A. The lower limit of sensitivity of the analytical method was 0.01 ppm in soil and 0.002 ppm in water. All the picloram found was in the top 12 inches of soil and forest floor litter, most of which was in the top six inch soil layer. These samples were taken five to six months after spraying. The maximum amount of picloram found was 0.11 ppm in one litter sample and the maximum in any soil sample with 0.05 ppm. Picloram was not found in most soil samples. Some sites that had been sprayed earlier were also analyzed and quoting Norris, "Virtually no detectable residues of either 2,4-D or picloram were found at sites 1, 2, and 3 in western Oregon." Norris also made particular mention of site 4 that received three applications of herbicide between 1965 and 1970. At this site, picloram residues found seven months after the most recent application were no higher than residues found on the other sites sprayed for the first time in 1970. Therefore, repeated spraying did not cause a picloram residue to

build up. The report states that one site with water samples from a stagnant pool showed a threefold drop in the concentration of picloram in seven weeks but the figures were not given.

Norris (197) in further field studies on picloram residues from herbicidal spraying on powerline rights-of-way obtained essentially the same results already reported.

In a Kansas field study Phillips and Feltner (203) applied the potassium salt of picloram both as pellets and in solution at rates of 2 and 3 lb/A to silty clay loam soils. This was a six-year study with repeated applications. The majority of the picloram was found to remain in the top eight inch layer of soil. In one location, there was extensive cracking of the soil and testing showed greater herbicidal activity in these areas and at lower depths. At the second location with no cracking all the picloram found was in the top 8 inch layer of soil. At one location 2 lb of picloram per acre had been applied in 1963, 1964, and 1965. Soybeans grew as well on these plots in 1968 as the controls. The same treatments at 3 lb/A caused injury to soybeans.

Rao et al. (205) conducted a Hawaiian field study on picloram behavior in a silty clay soil. Immediately after an 18 lb/A application it was irrigated with 9.4 inches of water and two subsequent irrigations of 4.7 inches of water one and two weeks later. After the first irrigation, the majority of the picloram remained in the first sixteen inch layer of soil with little change in the concentration of picloram at lower depths. After the two subsequent irrigations the majority of the picloram was in the top six inch soil layer. The application rates and irrigation were very excessive compared to normal field conditions. Nonetheless it showed much less leaching of picloram in the field, even under extreme conditions of a very high application rate and a high amount of water, compared to what laboratory leaching data would suggest. The authors suggested different rates of absorption between a macropore and a micropore system would account for the lessened amount of picloram leaching in the field. This point was discussed in more detail in the review of the Davidson and Chang article (124) and Rao's paper adds further data to support that idea.

Scifres et al. (210) in a Guthrie, Texas field study applied 0.25 lb picloram as the potassium salt by aircraft. Approximately 85% disappeared from the top 0-1 inch layer of a sandy loam soil ten days after application. At the same time there was only a trace, 12 ppb, in the 1-6" layer and none in the 6-24" layer of soil. Picloram was usually restricted to the top 12 inches of soil for the first 60 days. Five ppb or less picloram was detected below 12 inches at 120-180 days after application but the picloram usually dissipated from the soil profile within one year. The approximated half-life for picloram under these conditions was 4.3 days.

In a Canadian study, Sirons et al. (212) determined residues in soil and vegetation after picloram had been applied at the rate of 0.31 lb/A over a seven-year period. The applications were repeated on alternate years. Soils in the treated areas included clays, clay loams, sandy loams and sands. Average picloram residues in the top six inch layer of soil were: 0.124 ppm after 0.2 months, 0.555 ppm after 1.6 months, 0.0045 ppm after 12.5 months and no picloram was detected after 36 months. Grass samples were also taken and the average levels of picloram in them were: 15.7 ppm 0.2 months after application, 12.6 ppm after 0.6 months, 0.9 ppm after 2.1 months and no picloram was detected after 36 months. The maximum amount of picloram that leached to the 12-18 inch soil layer was 0.0014 ppm (1.4 ppb) in 11.6 months. The authors stated that as much as 50% of the

applied herbicide was retained by the vegetation, that lateral movement was limited, and that 0.31 lb/A application of picloram every three years would not result in an accumulation of picloram in the top 20 inches of soil.

Burnside et al. (121) conducted a field study in Nebraska at three different locations. Three years after application, picloram at 2 lb/A very adversely affected the yield of sensitive crops, such as field beans or soybeans, which demonstrated the activity of picloram to these plant species. This is a very excessive rate for controlling weeds in a field crop.

Dowler et al. (128) conducted a field study in Puerto Rico where picloram was applied as pellets at 3, 9, and 27 lb ai/A. One year after application at the high rate of 27 lb/A, the picloram concentration in the soil ranged from 0.1 to 0.005 ppm at the location with 30 inches of rainfall per year; less than 0.1 ppm at the site with 90 inches of rainfall per year; and less than 0.05 ppm at the area with rainfall of over 100 inches per year. The authors reported, "Although a high degree of woody plant defoliation was obtained from several treatments, total vegetation control was short lived. Secondary succession occurred within 18 months on all defoliated plots at all test sites."

Bovey et al. (119) conducted a field study on two Texas and three Puerto Rican soils. Picloram was applied at rates varying from 1-9 lb/A on both sandy and clay soils. There was a rapid loss of picloram applied to dry soil in Texas during the first six weeks following application which the authors attributed to photodecomposition. At the application rate of 1 lb picloram per acre, the picloram disappeared in 12 to 18 months from all sites in both Texas and Puerto Rico. At the 9 lb/A rate the highest amount of picloram found in Texas soils was 0.61 ppm in the 0-6 inch layer in the clay soil but it was zero in the sandy soil. In Puerto Rico it was 0.52 in one soil but in the other two it was 1 and 0 ppm.

Merkle et al. (189) studied the behavior of the potassium salt of picloram applied at rates of 2 and 8 lb/A to a Texas gravelly sandy loam and a fine sandy loam soil. In the fine sandy loam soil at the 2 lb rate, no picloram was found at any depth six weeks after treatment or thereafter. At the 8 lb/A rate, six weeks after treatment, the highest residue of picloram found was 0.33 ppm which was in the top 5 inch soil layer. This was 16% of the amount found immediately after application. At the 8 lb/A rate, traces of picloram were found at the lower limit of the analytical method (0.05 ppm) 26 weeks after treatment.

In the gravelly sandy loam, no picloram was found at the 2 lb/A application rate at the 12 week sampling and thereafter. At the 8 lb/A rate 0.24 ppm picloram was found in the top one inch of soil six weeks after application. This was 17 percent of the amount found immediately after application. At the end of the 26-week sampling, the maximum amount of picloram found was 0.11 ppm which was 8% of the amount found immediately after application. At the end of one year no picloram was found at any rate for either soil. Approximately 31 inches of rain fell during this time.

Bjerke et al. (115) analyzing Texas soils collected 4.7 months after the application of 1/4 and 1/2 lb/A of picloram found the highest average residue of picloram was 35 ppb in the top six inch soil layer. Six inches of rain fell between treatment and sample collection. Under these conditions, more than 85% of the picloram had disappeared.

At six locations, treatment rates varied from 1/2 to 2 lb/A. Soil samples were taken as soon as five months after application and after ten

inches of rain to as long as 30 months and after 120 inches of rain. These soil samples were taken usually in six inch layers to a depth of 30 inches and in one case to a depth of 60 inches. Picloram was not detected in 96% of these samples (92 cases out of 96) and the highest amount found was 12 ppb in the 12-16 inch soil layer. This indicates that 90% of the maximum amount of picloram that could be present had degraded.

At two locations there had been multiple applications of picloram. In one case the rate was 1 lb/A the first year followed by 1/2 lb/A the second year. At the other location 1/3 lb of picloram per acre was applied for three years. In all these cases with repeated annual applications of picloram, no picloram was found after the last treatment.

Hiltbold et al. (171) reported the movement of picloram through two Alabama soils: a loamy sand and a fine sandy loam. Picloram applied as the potassium salt at the rate of 10 lb/A moved downward in the soil at the rate of about 1 inch per inch of rainfall. The authors also pointed out that picloram movement was similar to that of nitrate except for the tendency of picloram to be retained in the surface foot of soil.

Herr et al. (172) reported the results of applying picloram at 2, 4, 8, 32, and 64 oz/A to three Ohio soils. One soil was a heavy clay, one was a medium textured silt loam and one was a light textured soil. The highest concentration of picloram in the heavy and medium textured soil was near the surface when sampled nine and 15 months after application. On the light textured soil picloram had moved fairly completely through the two-foot sampling area. In all cases practically no picloram was found after 439 days at the 8 oz/A rate and less.

Johnson and Warsknow (176) in an Arizona study applied 2 lb/A of picloram aerially to chaparral. Five weeks after treatment the chaparral was burned and the concentration of picloram in the soil went from 2.14 lb/A to 0.13 lb/A, a 94% reduction. On unburned chaparral the picloram content went from 1.81 to 1.69 lb, only a 9% reduction. It is noteworthy that the picloram content in the soil under the chaparral canopy was approximately 10% of that found between canopies (0.17 lb/A vs. 1.96 lb/A) showing that most of the applied picloram was on the vegetation. The authors also pointed out the decomposition temperature for picloram is 419°F and the soil temperature in intense fires such as those consuming large brush clumps may exceed 1192°F. Thus, the destruction of picloram by the heat in the burned-over area would explain these results.

Altom and Stritzke (103) using the potassium salt of picloram at a concentration of 4.79 ppm on three Oklahoma soils found that 23 to 37% of the picloram disappeared in 100 days. This experiment was discontinued at that time.

Baur et al. (105) conducted soil residue studies on a sand and clay loam Texas soil following application of 1 lb/A of picloram applied as the potassium salt. This application resulted in a residue of 164 ppb picloram in the top six inch layer of soil five days after application; 93 ppb 30 days after application; 7.3 ppb 180 days after application and 1.8 ppb 365 days after application. The analytical sensitivity of the test methods was 6 ppb. The majority of the picloram (in this case anything over 9 ppb) was always found in the top 12 inch soil layer. Practically speaking, on two different Texas soils 1 lb/A of picloram applied as the potassium salt nearly completely disappeared after 180 days. In this experiment the half-life of picloram was approximately 40 days.

Keys and Friesen (179) in a Canadian field study applied picloram to clay and loam soils at rates from 0.5 to 48 oz/A. After 24 months, picloram declined to about 10% of the original dosage and after 35 months it was 6% or less even for the highest rates. Picloram in all cases was concentrated in the top surface six inch layer of soil indicating limited downward movement in both soils.

In western Canada, Kirkland and Keys (180) investigated the effects of repeated applications of picloram to control weeds such as wild buckwheat in wheat. Picloram was applied every year for an eight-year period at rates from 0.3 oz to 1 oz/A to a loam soil in Saskatchewan. At these dosages, approximately 55% of the picloram degraded 12 months after application and 90% degraded 24 months after the last application. The third year after the last treatment picloram sensitive species showed no signs of picloram phytotoxicity. The residues from the 0.3, 0.5 and 1.0 oz/A rates taken either in the spring or fall were 7, 14, and 28 ppb, respectively. Wheat tolerated these repeated annual dosages as high as 0.5 oz without adverse effects on yield. There were some minor symptoms of toxicity such as stem twisting and delayed maturity, however, at harvest time visual differences in maturity had gone and there was no apparent effect on yield. Even at the one oz/A dosage of picloram, the average reduction in wheat yield over the two-year period was only four percent. Control of the weed wild buckwheat was excellent.

Grover (150) studied the rate of disappearance of picloram in a heavy Canadian clay soil at concentrations of 0.25, 0.5 and 1 ppm. There was a lag period before degradation started to occur which increased as the picloram concentration increased. The half-life at these three concentrations was approximately 55, 90 and 180 days, respectively. The average half-life of picloram in Regina heavy clay soil at 77°F and with plenty of moisture was 68 days if the lag time at the beginning is disregarded. This data clearly shows that degradation of picloram occurs faster at a lower than a higher concentration.

Moden (190) made the following points about picloram's behavior in soils. Picloram has, practically speaking, no volatility under field conditions and would not volatilize from the air drying of samples before analysis. Picloram is more strongly adsorbed in soil after it undergoes a wetting and drying cycle. Picloram can move upward with soil water. In two Nebraska soils, picloram degraded during the months when the soil temperatures were warm (between May and October) and did not degrade over the cold winter months.

Ragab (204) incorporated 4 lb/A of the potassium salt of picloram into the top six inch layer of a Canadian soil. This dosage would result in a concentration of 2 ppm using the customary accepted figure that a three inch layer of soil over an acre weighs one million pounds. Using a gas chromatographic method of analysis and a bean bioassay test, the amounts of picloram found after application are given in Table 6.

One year after application before the planting of crops the soil contained 0.70 ppm picloram. The growth of sweet corn and oats planted in this soil was reduced by about 20% and beans, parsnips, and swiss chard did not grow.

Beans, a crop very sensitive to picloram, showed injury in soil *containing 2.5 ppb picloram approximately 3 years after this treatment.* The author concluded it would take 4-5 years before crops sensitive to *picloram such as* beans, beets, potatoes, and swiss chard could be grown following this treatment of 4 lb picloram per acre.

TABLE 6 Residues after Incorporation of 4 lb/A of Picloram in the Top Six Inch Layer of Soil (2 ppm)

Days After Application	Inches of Precipitation Between Sampling Dates	Picloram Residues in PPM
18	4.76	1.86
63	0.27	1.78
145	13.50	1.32
337	28.97	0.70
504	10.43	0.28
690	16.14	0.12
843	18.42	0.02

This is a very theoretical experiment because picloram is not used at such high dosages on croplands nor is it incorporated into soil to control weeds. This type of application would not be made by a farmer.

Perez (202) reported on a field study in North Dakota and Texas. The high rate of three lbs of picloram per acre was applied to grass plots in North Dakota and Texas. The application was by ground equipment in North Dakota and by fixed wing aircraft in Texas. Residues of picloram in the 0-6 inch soil layer in North Dakota increased to a maximum of 1040 ppb 18 weeks after application which then went to 159 ppb 57 weeks after application. Although picloram was distributed through the soil profile to a depth of 24 inches, 90 percent remained in the top 12 inches of soil in North Dakota and 99 percent in Texas. The highest amount found below 12 inches was 72 ppb and usually it was much less. The accumulated rainfall over this time period was 13.2 inches. In Texas, the maximum amount of picloram found in the top six inches was 1150 ppb four weeks after application which went down to 11 ppb 61 weeks after application. Little (less that 10 ppb) or non-detectable levels of picloram were found in soils below a depth of 12 inches. The accumulative rainfall at the Texas site was 38.4 inches. At both locations, most of the picloram degraded.

In a Kansas experiment, Youngson (228) used picloram to control field bindweed. Picloram was applied to a silty clay loam soil at rates of 1.4 and 2.88 lb/A. Soil samples taken from 1.44 lb/A plots 24 months after treatment contained no detectable picloram residues. In the plots treated at the 2.88 lb/A rate, there was 85% loss of picloram 21 months after treatment. No picloram was found in these plots below the top 0-6 inch layer of soil, which still had 15% of the original amount of picloram.

Young (223) conducted field studies in Florida where six lb/A of picloram had been applied between 1966 and 1970. In 1969, he found 2.8 ppm picloram in the 6-12 inch soil layer. Assuming all the picloram was applied before sampling (which the article implied) a total theoretical concentration of approximately 3 ppm would occur if it were all to be concentrated in that layer. In 1971, the picloram found using the author's words "concentrations were significantly less (ppb)." The actual figures found were not given.

Youngson (231) reported on a field experiment where picloram was applied annually in three states over a two- and three-year period. A

bioassay analytical method was used to determine the residues. In a sandy loam Michigan soil, picloram was applied at rates of 0.25 to 2 lb/A in 1962 and again in 1963. In 1965, this soil contained less than 0.5% of the applied picloram and it was in the 0-6" layer and none occurred lower than a depth of 42 inches. There had been a total of 80 inches of rain plus irrigation water applied over this period. In the Texas sandy clay loam soil, picloram was applied at rates as high as 2.88 lb/A in 1963 and 4 lb/A in 1964. In 1965 no picloram was found. In a California loam soil, picloram was applied over a three-year period at rates that totaled between 0.72 and 10.88 lb/A. Picloram residues found were between 9.9 and 22% of the amounts applied.

Youngson (233) analyzed soils for picloram residues from field plots treated to control various weeds in twelve different states and Canada. Various formulations of picloram were applied to 53 test sites in California, Colorado, Idaho, Michigan, Montana, Nebraska, Nevada, New Mexico, Oregon, South Dakota, Texas, Washington and the Province of Alberta, Canada. The test sites contained problem weeds in small grains, pasture, rangeland, rights-of-way, and Christmas tree plantations. The bioassay technique using the safflower plant sensitive to 0.001 ppm was used for the analyses. On the wheat and bare ground sites treated with 0.06 to 5 lb/A, the amount of picloram remaining 10-46 months after application in the upper two feet of soil ranged from 0 to 90.8 percent. On the range plots treated with 0.72 to 8 lb/A the amount of picloram remaining in the top two feet of soil 17-26 months after application was 0 to 1.4%. For the pasture plots treated at 0.5 to 3 lb/A the amount of picloram remaining in the top 2 feet of soil 13-15 months after treatment was 1.5 to 10.5%. In the Christmas tree plots treated with 1 to 2 lb/A, the amount of picloram remaining in the top two feet of soil 11 to 12 months after treatment was 0.4 to 33%. As the interval between treatment and sampling lengthened the percent of picloram remaining in the soil decreased. At the lower rates, picloram was rarely found at the two foot depth. At the high rates, some picloram was found throughout the entire two foot soil profile sampled, although primarily it was in the top six inch soil layer.

VandenBorn (218) in Alberta, Canada applied picloram as the potassium salt at 1.44 and 2.88 lb/A as a spot treatment to patches of perennial weeds. The author concluded that the results suggest fall application of picloram to perennial weeds like Canadian thistle will permit production of near-normal yields of grain, especially oats, the second year following treatment. During the third year normal grain growth can be expected and during the fifth year picloram sensitive crops such as alfalfa and sunflower can be grown. Application rates of this magnitude are not label recommendations for broadcast treatment of cropland. Even for spot treatments, such rates are suggested only if the treatment areas can be left fallow until phytotoxic levels of picloram residues degrade.

Bjerke and Ervick (112) studied picloram residues in Michigan soil. Four formulations of picloram (ester, potassium salt, and two amine salts) were applied at 1 lb/A on a sandy loam soil. The first year after application the maximum residue found was 35 ppb from the ester formulation which was distributed through the top 24 inches of soil. When the amine salts formulations were used the picloram was in the top 12 inches of soil. With the potassium salt application it was in the 12-24" layer of soil. These differences between the formulations are so small they are considered to be insignificant. Two years after application the

maximum residue found was one sample that contained 5.8 ppb in the top 0-6" layer. This amount was barely above the detection level of the analytical method. Three years after application, picloram was not found in any of the samples. The lowest quantitative limit for the analytical method used was 5 ppb.

The same researchers conducted a similar study (113) with a California sandy soil. The isopropanolamine salt of picloram was applied at the rate of 2.16 lb/A and sampled at intervals up to one year following the application. The highest amount found was 470 ppb in the 0-6" soil layer and it degraded to a maximum of 89 ppb one year after application. At this time, the picloram was essentially distributed evenly throughout the top three six inch layers of soil and none was detected below 18 inches.

Bjerke and Ervick (114) did further research on picloram behavior in soils from Minnesota, Washington, Colorado, Louisiana, Ohio and Texas. The highest rate of picloram applied as the potassium salt was 6 lb/A in Louisiana. At the end of 11.5 months there was 36 ppb picloram in the top 6 inch layer of soil. A rate of 1.5 lb/A applied in Washington resulted in a residue of 374 ppb in the top 12 inches of soil 35 months after application. The results from these experiments varied but it can be said that degradation of picloram took place significantly faster in Louisiana, Ohio, and Texas compared to Minnesota, Washington and Colorado. This shows the importance of temperature and moisture in affecting degradation rate of picloram.

Runoff and Aquatic Dissipation. A Texas field study by Trichell et al. (216) studied the loss of the potassium salt of picloram applied at 1 or 1 lb/A to sod and fallow plots. The plots were sprinkled with enough water to equal 0.5 inch of rain 24 hours after treatment. Picloram losses were greater from sod plots than fallow plots and the percent of picloram in the runoff water was decreased when it passed over untreated sod. The highest loss was 5.21 ppm amounting to 3.7% twenty hours after application and after 1/2" of simulated rainfall. Four months after treatment the plots were again subjected to 1/2" of simulated rainfall and at that time the concentrations of picloram in the runoff water were 0.027 ppm and amounted to 0.02%. Eight and one half inches of rain had fallen after treatment in addition to the simulated rainfalls.

Bovey et al. (118) studied runoff from a native grass pasture watershed that was sprayed five times at six month intervals with a mixture of 2,4,5-T and picloram at the rate of 1 lb of picloram and 1 lb of 2,4,5-T per acre. Plant "washoff" was the main source of the picloram detected in runoff water. The concentration in runoff immediately following application ranged from 349-830 ppb and averaged 590 ppb. Ten days after treatment the runoff had 15 ppb picloram which increased to 180 ppb two days after a severe rain (1") but decreased to a trace (1-2 ppb or less) 30 days after treatment and thereafter. They continually degraded and disappeared, even after repeat applications. Cotton and sorghum were planted 30 feet downslope from the treated grass area. At the time of spraying the sorghum was 3-4 inches tall and the cotton was about 2 inches tall with only the cotyledons showing (seed leaves). No herbicide damage was shown by either the cotton or the sorghum from spray drift or from runoff water. A dense stand of bermudagrass developed on the treated plots as a result of controlling the weeds.

Bovey et al. (117) measured the chemical residues in grass foliage, soil, water seepage and well water after five applications of picloram

plus 2,4,5-T over a three-year period. The picloram residue in the grass varied from 17 to 70 ppm immediately after spraying but degraded rapidly after each treatment. For instance, a 17 ppm concentration of picloram in grass foliage degraded to 0.48 ppm in three days. The amount of picloram in the seepage and well water was extremely low, being less than 1 ppb during the three-year study period. The authors said "Essentially no 2,4,5-T or picloram was found in seep (subsurface) water from an area treated five times with 2,4,5-T and picloram over a three-year period."

Zero to small amounts (1-2 ppb) of picloram were found in the water drainage from a lysimeter after an application of 1 lb of picloram/A. Supplemental irrigation increased this to 3-4 ppb. 122 samples were analyzed from this lysimeter. The study was designed to maximize herbicide leaching and movement. A total of 34" of rain fell during this period. The concentration of picloram in the soil (a black clay) varied from a high of 162 ppb picloram immediately after treating, to 0 ppb 188 days after treatment. In one case the soil residue was 130 ppb three days after retreatment and went to 31 ppb 38 days after the retreatment. The authors said "The herbicide did not accumulate in plants or soil; it degraded and disappeared even after several repeated applications."

Bovey et al. (120) in a Texas field study applied 2 lb of picloram/A both as pellets and as a spray to rangeland plots. A heavy rain (3.3") two days after application resulted in 2.3-3.3 ppm picloram in the runoff, however, 10 days later it averaged 0.38 ppm and 2.5 months after treatment it was less than 5 ppb. There was a shallow well in the center of the watershed and picloram was not detected one month after treatment nor one year later in water samples taken from this well.

Byrd et al. (122) conducted a field study on railroad and highway rights-of-way in the North-Central States. The purpose was to determine the potential for movement of picloram from such sites after treatment. The results showed that movement of picloram from the treated area was in very samll quantities and decreased with time, suggesting that such movement is associated with surface runoff caused by rainfall immediately following application. Movement of picloram off the treated site was slight and not significantly affected by increased application rates. The authors estimated as much as 50% of the picloram had been intercepted by the sprayed vegetation. The maximum amount of picloram in the soil ranged from 0.575 ppm to 3.6 ppm approximately one month after spraying during which time it had rained. Not quite a year later the residue ranged from 0-0.120 ppm. There was no evidence of accumulation of picloram in catch basins off the sprayed right-of-way in Michigan and Ohio. It was concluded from these trials that 2.16 lb/A of picloram would not result in undue hazard to desireable adjacent vegetation from runoff water.

Davis and Ingebo (125) applied 9.3 lb/A of picloram as the potassium salt in pellets to a 2.1 acre portion of a watershed covered with chaparral in Arizona with an average slope of 51%. The soil was a well-drained shallow gravelly loam sand over granite bed rock. The maximum concentration of picloram measured in water from a dam of the stream at the bottom of the watershed was 350-370 ppb three months after application. The application was made February 1 and the first sample taken February 8 had 370 ppb of picloram. During the next 18 days it declined to 31 ppb and on March 11 was 14 ppb. On April 14 after a 3.92" rain picloram in the stream rose to 350 ppb. 14 months later during which 40" of rain fell, picloram was no longer detected in the stream water.

The authors estimate 4.5% of the picloram was lost in the stream water and that its use when picloram levels were 46 to 370 ppb could have damaged sensitive crops such as cotton.

In a southwestern study Johnson (175) applied 2.5 lb/A of picloram as the triisopropanolamine salt (plus 5 lb 2,4-D/A) to a 46 acre semiarid watershed in north-central Arizona. This application rate was five times more than the label recommended rate for an overall rangeland treatment. Picloram at a concentration of 1 ppb was detected in the runoff water for 35.5 months after treatment. The highest concentration detected was 320 ppb in the first runoff water after application. A total of only 1.17% of the applied picloram left the treated area in runoff water. No picloram was found beyond 3.5 miles downstream. Nine months after application 66% of the picloram found in the soil was in the 36-48" layer. The authors concluded the movement was due to the soil churning and development of cracks as large as two inches wide and 40 inches deep after every wetting and drying cycle. This is not a typical leaching situation as such soils occupy only 1% of the soil area in the United States. Under such atypical circumstances, any chemical could leach much more than normal and subsequent degradation at deeper soil depths would be slower.

Lutz (et al. (181) found in this field study that approximately 65% of the potassium salt of picloram applied at 2 lb/A disappeared within 15 days when applied to a watershed in North Carolina covered with orchard grass. The slope varied from 23-30%. There were three soil types: a fine sandy loam a clay loam and a loam soil. 87% of the picloram remaining from this treatment was in the top three inch soil layer. The authors reported "Practially no herbicide was found more than 0.3 m (1 ft) and none beyond 1.2 m (4 ft) downslope." Some application rates were as high as 4 lb/A.

Dennis et al. (126) conducted a West Virginia field study on picloram residues in water following an application of picloram to control multiflora rose using a rate of 4 lb/A. The maximum distance picloram was found downstream from the test locations where picloram had been planted was 3.4 miles. Picloram was found in pond sediments but not in stream sediments. Residues were highest within 1-3 weeks following applications. The highest residue found in pond sediments was 657 ppb. The picloram residues in pond waters varied with the highest being 437 ppb one week after treatment - mostly it was much less. There was a lot of variation in the picloram content in the water samples from streams. Out of eight streams in the three counties sampled, two streams had no picloram detected at any time. Three streams had one sample out of ten with approximately 0.3 ppb picloram. The other three streams had picloram present. The highest concentration was 11 ppb approximately three weeks after treatment. No picloram was found in six of these streams six months after treatment and was 0.5, and 0.25 ppb in the other two streams. In the fourth county in three streams, the highest concentration of picloram found was 1.82 ppb and no picloram was found in any of these streams six months after treatment.

In an EPA sponsored study, Evans and Duseja (132) found after application of 1 lb/A picloram as the potassium salt that the highest amount of picloram found in runoff water was 28 ppb after 1/4" of rain about 10 days after application and 32.8 feet from the treated site. 326 feet was the maximum distance from the treated site that picloram was found and it was present there at a concentration of 21 ppb. The slope was 3-10% and the water was sampled for 16 months. In another experiment

one and two pounds of picloram per acre were applied. Picloram found in the runoff water varied from 1851 ppb at 32.8 feet from the tested site to 51 ppb at 328 feet from the site to 17 ppb at 3280 feet. The authors conclude: "Under field conditions picloram does not present a serious threat to water quality a short distance downstream from the site of application. It is evident that precautions given on the herbicide label are adequate to allow the material to be used safely."

In Texas the potassium salt formulated as pellets and as a liquid concentrate; the triethylamine and the triisopropanol amine salts, and the isooctyl ester of picloram were used on soils ranging from sandy and rocky to clay in texture (139). Application rates were from 0.25 to 5 lb/A. Runoff tests were conducted using simulated rainfall and some larger treated areas drained into ponds. Picloram was applied at 1 and 2 lb/A as the potassium salt in solution and 24 hours after application 0.5" of simulated rain was applied within an hour. Runoff samples were obtained frequently at the edge of the treated areas and small amounts of picloram (maximum amount was 5.21 ppm from the 2 lb/A application) were found. The total amount of picloram in the runoff water from the 2 lb/A rate was between 0.063 to 0.075 lb/A. When the runoff from the the 2 lb/A application ran over untreated sod, this was reduced from a maximum of 5.21 ppm to a maximum of 2.11 ppm. The total amount of picloram in the runoff water was 0.18 to 0.032 lb/A which was over 50% less than the picloram content in runoff water obtained from the edge of the treated site. Thus, data indicate that 60-70% of the residue in the runoff water was removed during the passage over five feet of untreated sod. In large field runoff studies over 400 acres of land were treated. In 13 tests measuring picloram runoff into livestock ponds, only two ponds had detectable levels of picloram. The picloram concentrations in these ponds were 1 and 5 ppb five months after application and nine months after application none could be detected. Six wells were located in test sites which covered more than 500 acres and picloram was not detected in any of these wells. At one well the water level dropped from a depth of 76 feet to 5 feet during the time the experiment was run and still no picloram was found in it.

Glass and Edwards (141) investigated the movement of picloram in surface runoff in Ohio where the soil was a silt loam. The potassium salt of picloram was applied at the rate of 2 lb/A. Approximately one month later after 1.88" of rainfall there was 14.5 ppb in the runoff. Approximately four months later the concentration of picloram had dropped to 2.9 ppb and seven months later it was 0.7 ppb. This amounted to a total runoff of picloram during the entire seven months of 0.13 mg of picloram out of a total applied of 1548 mg or a loss of 0.008% after a total of 8.89 inches of rain. In the percolation water studies from the lysimeter, picloram was first found in a concentration of 1 ppb at a depth of 7.87 feet. After two years, only approximately 0.2% of the applied picloram leached through the lysimeter. The authors concluded leaching of picloram did not appear to be a major route of dissipation under these conditions.

A field experiment in Texas showed that if picloram got in a relatively static aquifer that the aquifer could be purged and cleaned up by pumping (209). The aquifer was in fine sand and 2500 grams of the potassium salt of picloram was pumped into the well giving it an initial concentration of 0.125 ppm. Picloram was found in nearby observation wells 30 and 60 feet away from the dual purpose well where the injection took place. Ten days after injection approximately 93% of the picloram

was recovered by pumping. The authors conclude that picloram accidentally injected into a well in a relatively static aquifer can be recovered by pumping. Scifres et al. (210) applied 0.25 lb of picloram as the potassium salt by aircraft in a Texas field study. The amount of picloram in the runoff water from these large plots (8-20 acres) when irrigated by sprinklers 10 days after treatment had 17 ppb picloram. Runoff water when irrigated 20, 30, or 45 days after treatment had less than 1 ppb picloram. Water samples from a livestock pond in the treated watershed contained no detectable picloram until a year after treatment when the pond was nearing dryness and at that time it was 1 ppb. At another location a livestock pond in the treated watershed had 2 ppb at early sampling and one year later less than 1 ppb. This experiment shows little picloram being present in runoff water after an application of 0.25 lb/A; that it remains in a shallow layer of top soil; and that it rapidly degrades under warm conditions.

Scifres et al. (211) treated three watersheds in Texas with 1 lb of picloram plus 1 lb 2,4,5-T/A using ground equipment. One watershed was treated two consecutive years at this dosage. The use of Mylar cards placed on the open surface of the ground indicated that 92% of the application dosage hit the vegetation or ground. Picloram dissipated to trace levels, ≤ 10 ppb, 56 to 112 days after application. It was not detected deeper than 2 feet and was usually restricted to within the top six inch layer of soil. Surface runoff water contained traces of picloram for about 30 days after treatment. There was no evidence of residue carry over into the second year in water, soil or vegetation. Monitoring the cumulative residues in water, soil and vegetation showed that approximately 75% of the picloram was dissipated from the ecosystem within 28 days after application and over 90% after 112 days. During this 112 day period, there was 14.17 inches of rainfall.

Warren (219) reported on the amount of picloram in runoff water following application to ditch banks and measuring the residues with a bioassay analytical method. Picloram as the potassium salt was applied to experimental plots by ground equipment. The application rates were 0.25, 0.50, and 2.0 lb/A of picloram. These plots included the banks and whole cross sections of the irrigation ditch and were 1/2 to 3 miles long. Applications were made in late November and early December when the ditches were dry. The soil was loam to sandy loam. Soil samples were analyzed from four depths in irrigation ditches taken in March before water was allowed to run through them. The highest concentration of picloram found was 0.65 ppm in the 0 to 1/2 inch soil layer for the 2 lb/A application. There was 0.019 ppm in the 12-24" level. For the 1/2 lb/A and the 1/4 lb/A application the highest levels of picloram found were 0.072 and 0.0225 ppm, respectively. These concentrations were found in the 0-1/2 inch soil layer. At the other levels (1/2-2", 2-12", and 12-24") the concentrations were 0.0035 ppm or less.

The first flush of water through these plots had 0.051 ppm for the 2 lb/A application and less than 0.004 ppm from picloram applications at 0.25 and 0.5 lb/A. Water samples taken three days after water flow started showed no detectable picloram present.

Picloram was also applied at the rate of 1/4 lb/A to several roadside plots in California during January and February 1967. Runoff water from these plots was analyzed for picloram. The maximum found was 0.39 ppm approximately five weeks after application which dropped to 0.018 ppm approximately eight weeks after treatment.

On June 2, 1967, several small watersheds on rangeland in California (3-10 acres each) were treated by helicopter with picloram at the rates of 1/2 to 4 lb/A. The highest amount of picloram found in the soil samples was from the 4 lb/A treatment which was 0.157 ppm in the top six inch soil layer 10.5 months after treatment. This dropped to 0.019 ppm 20.5 months after treatment. The maximum level of picloram in the 12-18" soil layer at the 4 lb/A rate was 0.09 ppm after 10.5 months which went to 0.0003 ppm after 22.5 months.

On May 3-4, 1967, the potassium salt of picloram pellets was applied at the rate of 5.3 lb of picloram/A to 20 acres in a clear cut forest area of 80 acres. Picloram levels in a stream at the base of this treated area using a bioassay analytical method reached a peak of 0.0437 ppm the last of July and decreased below the lower limits of detection at 0.004 ppm in the latter part of August and early September of that year.

Norris (196) measured the picloram residues in soil and water samples taken from and near powerline rights-of-way that had been sprayed for brush control. On the long term sites, no picloram was found below the top six" soil layer and these samples were taken 16-18 months postspray. The maximum amount found was 0.05 ppm. Some picloram was found in forest litter samples. Considering that forest litter is pure organic matter with a great power of adsorption, this is not surprising. Norris states these results indicate long-term persistence of picloram is not a problem in these lands there is little likelihood of significant movement of picloram to the aquatic environment.

At one site detectable amounts of picloram were associated with the first runoff. This probably represented the simple mobilization of surface residues in dry stream channels which had been sprayed. A number of water samples taken at another site after 0.75 and 1.3 inches of rain resulted in no picloram residue being found. Norris concluded this is good evidence that picloram is not leaving the spray site by leaching through the soil profile or in overland flow into stream channels.

Wicks and Fenster (220) in a Nebraska field study applied picloram as the triisopropanolamine salt in two locations at the rate of 0.5, 1.0 and 2.0 lb/A. A total of 1078 water samples were analyzed. Picloram was not detectable in most of the water samples which were taken from depths of 3.5 to 13.5 feet during a 38-month period. The analytical method had a validated sensitivity of 0.5 ppb. Traces of picloram ranging from 0.5 to 28 ppb were found in less than 5% of the 1078 samples analyzed. The greatest number of samples containing positive readings occurred in the first nine months. No picloram was detected in water from a 37 foot cased well used to irrigate the treated plots when sampled 38 months after treatment. At a second location, there was a 50-foot cased well that was frequently sampled during the experiment and no picloram was detected at any time. The authors state there was some question as to the validity of the data at this location due to lack of water at all sampling times and some false positives in the watershed control. One case of lateral movement 40 feet from a heavily irrigated plot was noted. A lake 300 feet downslope from the treated area had no picloram detected in it.

An Arizona watershed field experiment (235) had the potassium salt of picloram applied at the rate of 0.75, 1.0, 1.5 and 3.5 lb/A to large plots (total area treated was 31.1 acres) containing chaparral vegetation. Water samples collected from near the base of the treated plots contained picloram immediately after treatment ranging from 0.190 to 0.680 ppm. These picloram concentrations quickly decreased to 0.004 ppm and remained

at this level for four months. Then after five months, a period of heavier rainfall occurred and the concentration of picloram in the water rose to a high of 0.094 ppm after which the concentration decreased to 0.004 ppm for the remainder of the 18 month study. It was concluded that under these conditions most of the residual and easily removed picloram was lost in the first 12 months after application.

In a Texas field study 0.25 lb and 0.5 lb of picloram plus corresponding amounts of 2,4,5-T was applied in July for three successive years (173). After 3 year's treatment at the rate of 0.5 lb picloram/A, the amount of picloram in and/or on grass foliage was 24.49 ppm one day after the last treatment, 3.88 ppm after 30 days and 0.26 ppm after 95 days. This loss, the authors said, was due to degradation rather than dilution since there was little rain for most of that period and the loss after a 3-1/2 inch rain storm was only 2 ppm. While the rainfall between 1969 and 1970 varied from 17.08 to 12.85 inches no detectable residue of picloram was found either year roughly 200 days after the last application. Surface runoff water samples collected for two years after about 13 inches of rain showed less than 1 ppb 120 days after application. The lower sensitivity limit of the analytical method for the detection of picloram was 1 ppb. The data also show the largest amount of picloram was removed in surface runoff water during the first rain. A composite water sample collected from a pond 1/4 mile from the treated area never showed any signs of picloram. The area treated was 35 acres and the total watershed was 50 acres. Soil samples showed no picloram present at depths from 0 to 4 feet following yearly applications of picloram at the rate of 0.5 lb/A.

In a Southwestern study picloram was injected into a small stream in central Arizona at a rate of 6.26 ppm (177). The maximum concentration found the day of injection was 2.362 ppm one-quarter of a mile below the injection site. Four miles was the maximum distance picloram was found from the injection site and the maximum concentration found there was 0.001 ppm. The concentrations found at different locations are given in Table 7.

Table 7. Concentration of Picloram in a Small Arizona Stream.

Distance Downstream from Injection Site	Concentration of Picloram in ppm	
	Maximum	Average
0 mile (injection site)	6.260	6.260
1/4 mile	2.362	1.630[a]
1/2 mile	0.943	0.497
1 mile	0.316	0.282[b]
2 miles	0.014	0.010
4 miles	0.001	0.001

[a]This is 26% of the original amount of 6.26 ppm
[b]This is 4.5% of the original amount of 6.26 ppm

It took about 1-1/2 hours for the main body of contaminated water to pass each sampling point. Soil samples and water collected one and two days after injection of picloram into the water are given in Table 8.

Table 8. Picloram Concentration in Soil and Water Samples 24 and 48 Hours After Treatment.

Distance Downstream From Treatment Site	Concentration of Picloram in ppm	
	Soil Samples	Water Samples
1/4 mile	0.500	0.011
1 mile	0.150	0.006
2 miles	0.005	0.001

This article did not distinguish between the samples taken 24 hours and those taken 48 hours after treatment.

Stream water containing 1.28 ppm picloram was exposed to direct sunlight. After 8.8 hours exposure it contained 0.544 ppm of picloram which is 43% of the original amount present. The authors noted there was no significant damage to the vegetation along the stream banks either following treatment or later in the season. They also stated "Casual observation did not indicate any marked changes in the activity or apparent numbers of insects and small fish observed in the stream during or after the injection, which is in agreement with the observations of others."

In another Arizona field study picloram was applied by aircraft at the rate of 1.7 lb/A to a 37-acre site and 1.5 lb/A on a 233-acre site (178). A bioassay method of analysis was used. Small amounts (less than 0.1 ppm) of picloram was found in runoff water from the smaller site only during the first year after treatment. Spring water near this site the first year after heavy rains also had detectable amounts of picloram which the authors attributed to runoff water rather than groundwater contamination. Symptoms of picloram damage appeared on vegetation on the stream banks below the smaller treated area the first spring following treatment but then these symptoms disappeared rapidly. Grasses collected from an area treated with 3.3 lb of picloram/A had 20 to 26 ppm picloram in or on the foliage at the end of the first growing season. At the larger area, picloram was detected in the water only immediately after the application.

In a Texas rangeland study (107) picloram was applied at the rate of 1 lb/A as the potassium salt. Two days after treatment and following two rains totaling 1.57 inches the maximum amount of picloram found was 89.7 ppb. Water samples were taken at the edges of the treated plots. The concentration declined to less than 1 ppb ten to twelve weeks after treatment. The maximum amount of picloram found in streams draining the area was 13.4 ppb one week after application and three days later it went to 1 ppb or less. This site was retreated the following year and the maximum amount found was 14.4 ppb immediately off the site approximately one month after application. Water samples from the streams that year were all zero or less than 1 ppb. This experiment would indicate that there is little movement of picloram off the treated plots as well as no residue of picloram carried over from one year to the next.

Haas et al. (152) measured the amount of picloram in runoff water from various forms of picloram. The potassium salt, the triethylamine and the triisopropyl amine salts and the ethyl hexyl ester of picloram, were applied and their movement was considered to be equivalent. Two weeks after application of 1 lb/A of picloram to a south Texas grassland the

concentration of picloram in runoff water varied from 0.055 to 0.184 ppm. Six weeks after application the concentration was 0.002 and 0.029 ppm and after 13 weeks the picloram concentration was 0.001 to 0.002 ppm. After application of 1 lb/A picloram to approximately 80 acres, picloram was not detected in a flowing stream 1/2 mile away from the treated site. Picloram was not detected in domestic water wells at any time up to two years following treatment of adjacent areas at 1 lb/A of picloram. In one case, the well was in the center of a 12-acre plot. After application of 1 lb/A picloram directly to a pond surface there was 14-18% loss of picloram per day initially. This decreased to 1% per day 100 days after treatment and at this time the concentration appeared to vary with dilution due to rainfall or concentration from runoff from adjacent treated areas.

In a Canadian field study conducted on a power line right-of-way near Sudbury, Ontario, 1/2 lb of picloram and two pounds of 2,4-D was applied/A to a Great Lakes forest clear cut area on a podsoil (213). A layer of organic matter 0-4 inches thick made up the top layer of soil. The same day of application following 1.1 inches of rain 0.0414 g or 0.0000912 lb of picloram was lost the first year after application during seven runoff events was 0.0816 g (0.000179 lb) or 0.22% of the amount applied.

Yoshida and Castro (222) showed that at 1 ppm picloram degraded under both upland (dry) and flooded conditions in two Philippine soils. In one clay soil the half-life under flooded conditions was less than three months. In another clay soil, it was approximately six months.

Bjerke and Dishburger (111) conducted a study to determine the residue of picloram in soil following pellet application at a rate of 4 lb ai/A to control the multiflora rose in West Virginia. Soil samples were taken 1, 5, 25, and 50 feet downslope and in six inch layers usually to a depth of three feet. The analytical method had a lower sensitivity limit of 5 ppb. Picloram was not detected in 267 of the 281 soil samples analyzed. In the 14 positive samples the highest amount of picloram found was 21 ppb and seven occurred within one foot of the treated plots. Two occurred within five feet of the treated area. Of the remaining five samples two occurred at 50 feet and three at 25 feet from the treated plots. These results indicate that no significant amount of picloram moved from the treated sites.

Field Dissipation - Forestry. Neary et al. (193) applied the potassium salt of picloram as pellets to a 10-acre watershed in North Carolina. The application rate was 4.46 lb/A of picloram as a forest site preparation treatment for planting eastern white pine. It was an intermittently dry summer and during the first two months after application the maximum amount of picloram in the soil solution at the 12 inch level was less than 10 ppb. Following approximately 11.5 inches of rain in August the soil solution at the 12 inch level reached a maximum of 174 ppb of picloram. Two months later the soil solution at the 24 inch level peaked at 179 ppb. Picloram was found only twice in the stream in late June and early July and the maximum amount found was 8 ppb. After the heavy rains in August no picloram was found in the stream. The authors concluded such low-level, short duration peaks of picloram would not affect stream biota or constitute a hazard from a nonpoint source of pollution. The authors also concluded that based on this data, well controlled application of picloram pellets to ridge and upper slopes of the southern Appalachians would not produce any significant pollution of streams draining these deep soil systems.

Norris (199) in a laboratory investigation showed that the degradation rate of picloram is unaffected by the presence of other herbicides or insecticides used in silviculture. The report specifically stated that 2,4-D did not influence the rate of degradation of 2,4,5-T or picloram. The data also showed that picloram did not affect the degradation rate of 2,4-D.

Another study (194) showed that after 0.51 lb of picloram/A was applied to red alder forest floor matierial, 35% degraded in 180 days. When 0.5 lb of picloram and 2 lb of 2,4-D were applied to red alder forest floor material, 41% of the picloram degraded in 180 days.

Norris (198) reported on three experiments where picloram was applied to utility rights-of-way going through a forest area. In the first experiment initiated in July 1967, 11% of a 3.3 acre forest watershed was treated in Washington at the rate of 0.5 lb picloram plus 1.0 lb 2,4-D/A. In August 1967 67% of this watershed was treated at the rate of 1 lb picloram plus 4 lb 2,4-D/A. Runoff water was collected from a pond at the base of the slope. Water samples from this pond had a maximum concentration of picloram of 78 ppb following a one-inch rainfall on September 11, 1967. Picloram levels decreased rapidly with time going to 15 ppb on October 13 to 2 ppb on October 25 and 1 ppb on October 27, 1967. The concentration of 2,4-D went from a high of 825 ppm to 3 ppm on October 13 to 1 ppm on October 27, 1967. The rainfall over this period had been a total of 11.24 inches with several individual storms depositing approximately two or more inches of water.

The second experiment was located in Oregon where the lower 2% of a 200 acre watershed was treated in August 1967 at the rate of 1 lb of picloram plus 4 lb of 2,4-D/A. Water samples taken from a stream of running water at the bottom of the watershed sampled from October 2, 1967, to December 5, 1967 contained no picloram even after storms containing as much as five or more inches of rain.

The third experiment was conducted in Oregon when four 14-acre plots in the lower portion of a 112-acre watershed adjacent to a stream was treated with 0.5 lb/A of picloram and 2,4,5-T amine salts. Six months after treatment several stream samples were taken after the first substantial storm of the season (4.45 inches of rain between December 2 and December 7, 1967). Picloram was found at 1 ppb in three of these samples. There had been light rains in October and November that probably favored infiltration of picloram.

In a field study on forest and hill-pasture land in southwest Oregon (200), picloram was applied to a heavy clay soil at the rate of 2 lb of picloram/A (plus 4 lb 2,4-D). Average rate of deposition at the top of the brush was 85.2%. The picloram level in the top 6 inch layer of soil was calculated to be 348 to 609 ppb immediately after application. Picloram levels in this top 6 inch layer decreased to 64 ppb at 10 months, 22 ppb at 18 months and 1 ppb at 29 months. Picloram was found at 1 ppb in the 12-18 inch soil layer at 10 months but was not detected below 6 inches afterwards. At another site, the same product was applied at a rate of 1.5 lb of picloram/A (plus 3 lb of 2,4-D) to a forest site in Oregon in June, 1969. Water samples were taken from a spring fed and intermittent stream at the bottom of the slope. The maximum amount of picloram found was 110 ppb following the first significant rainfall that occurred approximately 3 months after application. At seven months, the picloram concentration was 1 ppb. After seven months, no picloram was found. The authors calculated that the amount of picloram found in the stream at this site was about 0.3%

of that applied and concluded most of it came from material applied directly to the stream beds and banks. The authors concluded there was no significant leaching of picloram under these conditions.

An extensive review by Norris and Morre' (201) concluded that most forest chemicals offer minimum potential for pollution of the aquatic environment. Direct application to surface waters is the major source of aerially applied forest chemicals in the aquatic environment. These authors further concluded "a strong background of research experience permits us to predict with confidence that concentrations of 2,4-D, picloram, 2,4,5-T and amitrole exceeding 0.1 ppm will seldom be encountered in streams adjacent to carefully controlled forest spray operations. Concentrations exceeding 1 ppm have never been observed and are not expected to occur. The chronic entry of these herbicides to streams for long periods after applications does not occur."

Suggit and Winter (214) demonstrated that it is possible to have a sharply delineated application by air with little spray drift. In this experiment, a helicopter laid down a 50 foot swath flying at 100 feet above the ground in 6 mph cross winds. A sharp swath edge resulted with tailing off of only four to five feet. Water sensitive marking tapes extending over and beyond the sprayed swath were used to demonstrate this point. This application was made with a thickened spray containing a water swellable polyacrylamide polymer as a thickening agent.

Contamination Reports. Gaufin (137) wrote a preliminary one-year survey of the Flathead Indian Reservation with later work concentrated on Osprey survival and nesting on Flathead Lake, Montana. Four reports were included:

1. Initial Report of Effect of Pesticide Practices on the Flathead Indian Reservation.
2. Report of Pesticide Analysis of the Mission Valley by Phillip Tourangeau.
3. Flathead Lake Osprey Study: Progress Report #1 by James R. Koplin and Arden R. Gaufin.
4. Ospreys of Flathead Lake by Donald L. McCarter

These reports will be reviewed sequentially. The first report discusses some wildlife problems (decline in game population), fish kills, and analysis of water samples in which pesticides including picloram were stated to be found. Actual data and figures were not given. The report stated pesticides were responsible and implied that picloram was responsible for the previously cited problems. This was unsupported with any data, however, and rested solely on speculation by the author.

The second report showed that out of approximately 50 water samples from various sources not specifically identified, 21 had picloram in concentrations ranging from a trace to a high of 0.5 ppm in one instance although the average was 0.1 ppm. It was also stated that there was a sharp decline in the picloram concentration from the Kicking Horse Reservoir from 0.09 ppm in late August to 0.017 ppm in the early part of October and that in an aresian well it went from 0.031 to a trace. The data are sketchy and lacking in necessary detail and thus it is not possible to judge the accuracy and reliability of the analytical method. The reader has no way of validating whether picloram was or was not present in the water.

Of ten species of wildlife analyzed, only the insecticide DDT and its metabolite TDE were found. It was pointed out that DDT and its metabolite can cause thinning of egg shells and has been responsible for the decline of many predatory bird populations. There is no data fo picloram being

present to implicate picloram at all as causing the decline of the predatory bird populations.

The third report was a survey of the declining osprey population of Flathead Lake. The cause was not ascertained but DDT was found in some of the eggs analyzed. Picloram was not found in any eggs which suggests that it was not responsible for the decline.

The fourth report, also on the osprey population of Flathead Lake, found that infertility of the osprey eggs was the major cause of nesting failure. There was no data or evidence that picloram was implicated any way in causing this infertility and its cause was unknown.

At Kimball, Nebraska (127, 131, 136) some plants were being adversely affected by herbicides. A greenhouse grower could not grow tomatoes and there was also crop injury to several fields growing field beans. A sewage lagoon had been treated with picloram at a rate of 16 lb/A plus 40 lb/A of 2,4-D to control Canadian thistle. There were four seismographic holes approximately four inches in diameter and reportedly about 12 inches in diameter at the top in this lagoon. The city engineer said these holes were 80-90 feet in depth and ended 30 feet above the water bearing strata. A report of known seismographic drillings in the area states the average depth of holes drilled in that area is 180 feet. When crops were watered from irrigation walls about 88 feet deep crop damage resulted. Water samples analyzed for picloram both by a bioassay as well as by chemical analysis indicated one to four ppb picloram in the water. There was an uncontaminated well 1.5 miles "upstream" from the treated lagoon. Sudsing of these waters had also occurred. Water analyses showed that the contaminated wells were also noticeably higher in chlorides and nitrates which are considered to be indicators of disposal contamination. It was concluded the source of the picloram contamination in the Kimball area irrigation well was likely due to contaminated water reaching the water table through seismographic holes in the Kimball sewage lagoon.

Frank et al. (134) reviewed the results of ten year's sampling of water from Canadian wells because of complaints that they had been contaminated with herbicides. Water from 237 wells was analyzed. Herbicides were found in 159 wells or in 68% of the complaints. In these contaminated wells 98 had one herbicide, 45 had two, 12 had three, 1 had four, and 1 had five herbicides. Of these 159 cases only 6 involved picloram, 2.5% of all wells examined and 3.7% of the contaminated wells. Looking at these incidents of contamination, three cases in this ten-year period were involved in accidental drift into the well, one was the result of storm runoff and two were suspected of being caused by cotaminated groundwater. One of these cases involved the dumping of excess chemical over an aquifer near the soil surface and the well was shallow being about 13 feet deep. Although these incidents with picloram are few in number, they would not have occurred if label recommendations and use precautions had been followed.

In West Virginia, pellets of the potassium salt of picloram have been used under a federal label to control multiflora rose since 1975. This has been a very effective method to control this noxious weed. Between January and August 1983, water samples were taken from a number of streams and rivers in the north central and north eastern area of West Virginia that ran through extensive areas where multiflora rose had been treated. Some of these samples contained small amounts (0.05-0.4 ppb) of picloram. After an investigation, the West Virginia Department of Agriculture concluded that this situation was a result of misuse and misapplication. For

instance, aerial photographs have shown that sizeable amounts of multiflora rose growing along the stream banks were treated. Apparently, the product had been used disregarding label instructions and the product was applied too close to and sometimes directly into water. Minute amounts of picloram can be injurious to sensitive plants and crops. It must, therefore, be kept out of water that may be used for irrigation. Likewise, it should not be allowed to contaminate drinking water even though minute quantities would not be harmful to human health.

Consequently, two public hearings were held by the West Virginia Commissioner of Agriculture to take remedial and preventive action. The Commissioner then issued additional regulations for the sale and use of pelleted forms of picloram in the state. New regulations, such as a reemphasis and stricter training for certified applicators in the use of TORDON 10K pellets, are now in effect. In addition, the size of the buffer zones between the application sites and water was widened. An ongoing water monitoring program will measure progress in reducing picloram contamination in waters of West Virginia.

Critical Opinions on Picloram

Vietnam War. During the Vietnam war, George R. Harvey and Jay D. Mann published an article in the September 1968 issue of Science and Citizen with the title of "Picloram in Vietnam." The article pointed out the effectiveness of picloram as a herbicide and seems to suggest this is a fault. The main thrust of the article appeared to be concerns that the use of picloram and 2,4-D would permanently damage the ecology of Vietnam and its agriculture. Our knowledge then and certainly our knowledge and historical experience now has shown these fears to be invalid. After the war, one forester who had gone to Vietnam and investigated the efforts of the defoliation program has told me that bombs caused far more ecological damage to the Vietnam forests than the defoliation program. The article was also wrong when it discussed the toxicology of picloram. Harvey and Mann said, quoting Jackson's paper (39) as a source, that 36 mg/kg of picloram combined with 134 mg/kg of 2,4-D killed sheep. This was an incorrect quotation. Jackson said a single oral dose of 720 mg/kg of picloram had no effect on sheep whereas a single oral dose of 535 mg/kg of 2,4-D killed sheep. Jackson does point out that five consecutive daily doses of 36 mg/kg of picloram plus 134 mg/kg of 2,4-D kills sheep. This would amount to 670 mg/kg of 2,4-D and, therefore, for sheep to die from such a dosage administered within a five-day period is not surprising. This is due, however, to the toxicity of 2,4-D not to a synergistic response of the two herbicides as the Harvey/Mann article stated.

The Cherokee County Story. A story about an alleged cancer edpidemic in Cherokee County, North Carolina, has received widespread distribution via major newspapers in the United States and Canada.

This inaccurate story was published originally in the March 15, 1982 issue of Inquiry magazine under the title of "Agent White: It Kills Weeds, Bushes, Trees and Maybe People" and authored by Keith Schneider. It is an accepted fact that cancer is primarily an old-age disease. The figures in this story were not corrected for old age or for the increase in population in the county. When these important adjustments are made the greatest increase of cancer mortality in any one year was 9%. In fact, the number of cancer deaths reported for 1981 shows a decrease of 21% below the national average or a total decline of 30% from the 1980 figures which were

9% above the national average. In any case, a one-year increase of 9% is not evidence of a cancer epidemic. Other factors such as more sophisticated county health care, improved death certificates coding and reporting could also account for the higher statistics in the isolated years. In fact, it is interesting to note that the annual Cherokee County death rate has been steadily declining since 1972 when compared to the national average.

This story aroused the interest of Mr. Lane Palmer, the well-known and highly respected editor of a widely circulated farm magazine, The Farm Journal. Mr. Palmer had been invited to give a talk "The Scientific Method - A Writer's Best Friend" before the Readers Digest's Writers Workshop which was held at the University of North Carolina at Chapel Hill in 1982. After Mr. Palmer investigated this Agent White story, he chose to use it as an example of very unscientific reporting and made the criticism of this article a major part of his speech. Part of Palmer's criticism was that the factual content of this article was very biased and inaccurate leading to a slanted story with erroneous conclusions. Palmer also pointed out that it would have been easy to correct these factual deficiencies and illustrated how he had done so with a few telephone calls. This refutation had not been solicited by Dow although after they learned about it, part of this talk was printed in an issue of Industrial Vegetation Management (250) which is a Dow trade magazine.

From the technical medical point of view, this Agent White story has also been found wanting. Dr. Seymour Grufferman, Director of the Cancer Prevention and Control Program at Duke University has also examined the Cherokee County cancer epidemic question and published a letter on the subject in the local newspaper the Cherokee Scout. A copy of this letter (247) was reprinted in the Fall 1982 issue of the Dow publication "The Bottom Line." One of his concluding sentences was, "Considering all these factors there is no cause for alarm, despite the Inquiry article."

Carlo et al. (248) published on this subject in the official journal of the North Carolina Medical Society which undergoes peer review. The following conclusions were drawn.

1. "There is currently no indication of excess cancer mortality in Cherokee County with respect to either the state of North Carolina or the other western counties;
2. The historical decline in all causes mortality in Cherokee County has paralleled the decline in the other western counties and has been greater than the decline in the state;
3. The historical pattern of the proportion of all deaths due to cancer in Cherokee County has been similar to the patterns in both the other western counties and the states;
4. A historical decline in cancer mortality has occurred in Cherokee County while an increase in cancer mortality has occurred in both the other western counties and the state."

The most recent paper on this subject is a North Carolina Health Department study released June 19, 1984. This comprehensive North Carolina Health Department study conducted over a two-year period corroborated the results found by Carlo et al. and concluded that:

there is not a cancer epidemic occurring;

factors likely to have contributed to any cancer rate fluctuations include the in-migration of retirees and better detection of malignancies as a result of improved medical procedures, and;

the most likely cause of cancer among this population is factors associated with their lifestyle.

In summary the small numbers responsible for the cancer mortality in Cherokee and Macon Counties do not support suggestions that "a cancer mortality epidemic" recently occurred or is reoccuring in these counties.

It is noteworthy that when scientific specialists in this field examined the figures upon which Schnieder's article was based, they were found to be incomplete and erroneously interpreted. Thus, there is no cancer epidemic in Cherokee County, North Carolina and the allegations that one was caused by picloram is not true.

The Reuber Opinion. Dr. Melvin Reuber (249) formerly a toxicologist with the Frederick Cancer Research Center believes picloram is carcinogenic. There is controversy about Dr. Reuber's opinion of picloram. A cancer research study, "A Bioassay of Picloram for Possible Carcinogenicity," was conducted for the National Cancer Institute (NCI) by the Gulf South Research Institute, New Iberia, Louisiana. These study data were reviewed by 20 NCI scientists who concluded that picloram was not carcinogenic.

Dr. Reuber, however, who was not part of that study review group, later rendered his own personal opinions of the NCI study which contradicted the original conclusions. Subsequently, Dr. Reuber's superior at the Frederick Cancer Research Center severely criticized him for the way in which he had taken issue with the original NCI conclusions. Dr. Reuber's superior also maintained that NCI's original conclusion that picloram was not carcinogenic was correct.

Dr. Grufferman (242) also discussed Dr. Reuber's opinion in his letter and stated "You should be aware that Reuber's findings are highly controversial and have been challenged by other researchers in this field. Both methodology and interpretations are in question."

Of course, Dr. Reuber has a right to interpret the data as he sees fit and to his own opinion. However, it must be remembered that it is his personal opinion and it differs drastically both from the scientists who write the NCI report as well as the NCI scientists who reviewed it. Following Reuber's comments and review of the NCI study data, EPA has advised The Dow Chemical Company that the Agency concurs with the NCI conclusion, and not with Dr. Reuber's interpretation.

Afterthoughts

Today many herbicides have been scrutinized by the public, and questions have been raised about their possible harmful effects on public health. The fear of cancer or some other dreaded disease whose cause is not well understood serves as an emotional and rallying basis for opposition of herbicidal usage. It is ironical that more is known about pesticide effects before they are marketed than new drugs. However, the uninformed public disregards the elaborate and intensive testing that is required to obtain EPA registration before any pesticide can be marketed.

Certainly the public has the right to question the use of herbicides, and intelligent criticism which often has beneficial results should be welcome. This process becomes detrimental, however, when the public accepts alleged and emotional charges instead of the factually based authoritative opinion of weed scientists and toxicologists who have made the study of such products their life work. Unfortunately, a negative can

never be completely proven so it will always be impossible to prove that the use of a product is without any risk. Historically speaking, the record is excellent and the present system does an excellent job of ensuring that a herbicide on the market will not have an unreasonable effect on the environment and is safe to man, wildlife, and livestock when properly used.

The record on picloram contains typical illustrations of the type of claims made by people opposing the use of herbicides. After having read some of the scientific information available on picloram, the reader may draw his own conclusions as to the validity of these critical claims. In my opinion, however, they are not supported by the evidence and are invalid. The scientific data available as well as over 20 years of global usage, indeed, show that picloram herbicides may be used with great benefits to man and the environment without harming either.

Nonetheless, the public's perceptions and concerns must be addressed if they are ever to feel reassured about the safety of herbicides and the effectiveness of EPA's registration process. An enlightened public will only come to be if those knowledgeable throughout all phases of agribusiness, whether in industry, academia, or government, take advantage of all opportunities, in fact make opportunities, to communicate the excellent story of pesticide benefits and safety to the public. In the final analysis, ignorance is not bliss and public perception is reality.

EPA Fact Sheet

EPA issued a fact sheet on picloram dated May 12, 1982. In view of the controversy on this subject and to avoid any question about possible bias in reporting its contents, this EPA fact sheet is quoted below in its entirety.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

May 12, 1982
Office of Pesticides
& Substances

Picloram

Current Issue

A number of recent press articles have raised public concern about the safety of the herbicide picloram. These stories suggest that the use of picloram in certain areas is linked to a variety of points suggesting cause for concern:

-picloram is one of a small number of pesticides restricted for use by certified applicators;

-some of the data supporting its EPA registration have been found invalid;

-one study of rats fed picloram has been interpreted by several scientists as evidence of cancer risk;

-EPA believes the record should be set straight on these points.

Background

Picloram has been used since 1963 to control broad-leaf weeds and woody plants in forests, principally 2,4-D. It is marketed under the brand names Tordon and Amdon.

Picloram has low toxicity for mammals and birds and moderate toxicity for fish. It is more persistent in the environment than most herbicides, lasting from several months to several years depending on conditions. However, picloram has low potential for accumulating in animal tissues; if ingested, it is rapidly excreted.

Picloram is restricted for use by certified applicators because of its potential for damaging non-target plants by runoff or leaching. Certified applicators are trained in methods of avoiding drift or runoff to vulnerable crops and non-target assigned to this chemical because of known or suspected health risks.

EPA Position

Under current law, pesticides marketed in this country must be registered with EPA. To register a product an applicant must submit data to the Agency adequate to demonstrate that the proposed use will not pose risks of unreasonable adverse effects on human health or the environment when used according to its approved labeling.

Data on picloram concerning various short term effects support the current registration. However, it has been found that some studies on long term (chronic) effects performed by Industrial Bio-Test (IBT) laboratories were invalid due to improper laboratory practices. Finding a study invalid does not mean the chemical is posing risks, but only that the Agency cannot use the study to draw valid conclusions.

Two long term studies sponsored by the National Cancer Institute (NCI) were not involved in the IBT problem. One of these studies in mice is considered negative for cancer effects. The second study, in rats, is considered of questionable value due to laboratory procedures. The reults suggest that picloram may induce benign liver tumors. Some scientists interpret this effect as evidence of cancer risk, but NCI, EPA and an independent research firm have reviewed this study and do not regard it as providing an answer to the cancer risk question. In addition, EPA has estimated that even if this study were accepted as positive evidence of potential for inducing tumors, given the high doses needed to produce the effect, and the very low potential for human exposure from current uses of picloram, existing uses of the product would not pose a significant risk of increased cancer in the population.

In sum, the data on short term effects, environmental effects and genetic mutation, as well one NCI cancer study, support the current registration of picloram. The registrant is conducting a new rat feeding study to clarify the ambiguous results of the second NCI study. The pesticide law places the burden for testing chemicals on their manufacturer, and it is the usual practice for industry to undertake the development of the basic data needed by EPA to make regulatory decisions. We have no current evidence that picloram is posing risks of unreasonable adverse effects to human health or the environment, although more data is needed on long term effects to support this conclusion.

Ongoing Actions

EPA is required by law to re-register previously registered pesticides to ensure that the data supporting registration meet current scientific standards. This is done through a program called Registration Standards. A standard is developed for a particular

chemical by examining the current data base, identifying areas of inadequate or missing information, and describing the kind of information registrants will have to submit in order to maintain registration of products containing that active ingredient. Under an experimental program the registrant is now developing the Registration Standard for picloram, subject to EPA review and approval. This action was decided upon in mid-1981 and was not the reuslt of the current allegations of human health effects. The standard is scheduled for completion by early 1983.

As the replacement study and the development of the Registration Standard proceed, our knowledge about picloram will have an improved base of scientific evidence. If, at any time, evidence arises showing that picloram does pose an, as yet unidentified risk to human health or the environment, the Agency will take steps to evaluate the evidence and initiate appropriate risk reduction measures. (End of quoted text.)

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THE BIOLOGICAL CONTROL OF MUSK THISTLE (*Carduus thoermeri* L.) BY *Rhinocyllus conicus* IN FREMONT COUNTY, WYOMING

John L. Baker, Karen Almas and Mary Jo Williams[1]

Abstract: Fremont County, Wyoming, has about 5,000 acres infested with musk thistle (*Carduus thoermeri* L.) much of which is located on rangeland where limited access and low population density makes economical and effective herbicide treatment difficult. When *Rhinocyllus conicus* became available through Dr. Norm Rees at the USDA Rangeland Research Lab at Bozeman, MT in 1979, Fremont County Weed and Pest Control District began to collect there each spring and release insects at numerous sites throughout the County. A photographic record was kept of this activity and a selection of these photos has been used on several occasions since to publicize Fremont county Weed and Pest Control District activities, promote weed control in general, and biological control of weeds specifically. The photos and text explain the life cycle of *Rhinocullas conicus* on musk thistle and graphically show the reductions in plant populations that resulted.

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[1]Fremont County Weed & Pest Control District, Lander, WY.

LO-DRIFT, A DRIFT CONTROL ADDITIVE FOR HERBICIDE SPRAY PROGRAMS

J.E. Gallagher[1]

Pesticide drift, the movement of fine spray particles to non-target sites, remains a critical aspect of pesticide spray applications. Drift control is the utilization of practical spray application technology.

The two most critical aspects of drift control are equipment spray pressure and wind speed and direction. Spray additives and proper equipment pressure can reduce the problems of pesticide drift.

Union Carbide Agricultural Products Company, Inc. has been testing an anionic polyacrylamide formulation as a drift control additive. Laboratory and field studies have shown it to be compatible with most herbicides used in industrial weed control programs.

Cooperative tests with pesticide applicators using air and ground spray equipment reported few problems. Aquatic, industrial, highway, home lawn and agricultural herbicide applications effectively reduced drift when the drift control agent was used in the proper ratio to spray volume.

[1]Union Carbide Agricultural Products Co., Inc., Research Triangle Park, NC.

SIMULATED HERBICIDE DRIFT INJURY IN POTATOES

P.W. Leino and L.C. Haderlie[1]

Results from drift and subsequent seed vigor experiments performed at the University of Idaho Research & Extension Center at Aberdeen, Idaho during 1982 and 1983 are discussed here.

Simulated herbicide drift was studied a second year on Russet Burbank potatoes at Aberdeen, Idaho under furrow irrigation in a Declo silt loam with 8.01 and 1% organic matter. Treatments were applied 11 July 1983 when the maximum tuber size was about two inches and potatoes were 15% flowering. A tractor-mounted, compressed air sprayer was used with a side-mounted 12 ft boom which delivered 17.5 gpa at 28 psi with TJ 8002 nozzles spaced at 18 inches on a 12 ft boom. Individual plot size was 18 x 50 ft with the center 12 x 40 ft receiving the treatment. Tubers were harvested 26 and 28 September 1983 from a 6 x 30 ft area. The experiment was designed in a randomized complete block with four replications. The 1982 study was laid out in a similar manner.

During both years, dicamba (3,6-dichloro-2-methoxybenzoic acid), dicamba + 2,4-D [(2,4-dichlorophenoxy)acetic acid], 2,4-D, glyphosate (N-(phosphonomethyl)glycine), bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), bromoxynil + MCPA [(4-chloro-2-methylphenoxy)acetic acid] were included as treatments at various rates (Tables 1 and 3). These herbicides are commonly used for weed control in grain or fallow fields which are often adjacent to potato fields.

[1]Research Assoc. & Assoc. Res. Prof., Weed Science, Univ. of Idaho Research & Extension Center, Aberdeen, ID.

Treatments are grouped into three foliar symptom expression categories for discussion purposes: 1) dicamba, dicamba + 2,4-D and 2,4-D as phloem-mobile herbicides with epinasty and leaf cupping symptoms, 2) glyphosate as a phloem-mobile herbicide with chlorosis and some leaf cupping symptoms, and 3) bromoxynil and bromoxynil + MCPA "contact" type herbicides with leaf chlorosis and necrosis symptoms.

Group 1 foliar symptoms were not as obvious in 1983 as they were in 1982. The pronounced leaf cupping and "fiddle necking" which were typical of the higher rates of dicamba in 1982, were nearly absent. The only exception occurred in off-type 'giant hill' potatoes were distributed uniformly throughout the field and showed symptoms typical of last year's treatments. All rates of dicamba over 0.05 lb/A caused increased fruit set which was similar to 1982 responses.

Dicamba significantly reduced total yield by up to 18% when applied at 0.05 lb/A (Table 1). The lowest and highest rates did not affect yield. These results are consistent with the 1982 data (Table 3) and suggest that the 0.05 lb/A dicamba rate is a particularly sensitive rate physiologically in potatoes at this stage of growth. Tuber bud-end creasing at the 0.05 lb/A rate was greater than in the check and the high (0.1 lb/A) rate in both years (Tables 2 and 4). Bud-end creasing in the 0.1 lb/A rate was also greater than in the check. Dicamba caused 99-100% tuber skin ulcer appearance at 0.05 and 0.1 lb/A rates. The ulceration consisted of ulcerous pits covered with thickened, flaking "elephant hide" skin over the bud-end of the potato. Potato tubers treated with these higher rates of dicamba had generally a rounder tuber shape than untreated tubers and more were in the <4 oz grade category. Dicamba + 2,4-D combinations also had tuber ulcerations but only the high combination rate (0.05 + 0.01 lb/A) reduced yield and produced bud-end creasing. Specific gravity was not affected (Table 1).

No tuber ulceration, bud-end creasing, or yield reduction was noted with treatments of 2,4-D alone. These observations are also in agreement with the 1982 data (Table 4). Tuber grade out and specific gravity were not different than for the untreated.

Glyphosate (Group 2) foliar symptoms included chlorosis of the newes leaves at even the lowest rate (0.01 lb/A). Chlorosis and leaf margin cupping increased as the rates increased. Glyphosate caused a tuber skin ulcer appearance at the 0.1 and 0.2 lb/A rates which appeared as a worm-like hollow at the apical end lined with heavily russetted skin (Table 2). There was little or no bud-end creasing this year as there was in 1982 for glyphosate treatments (Table 4). Yields at 0.1 and 0.2 lb/A rates were significantly lower than the check. In 1982 the 0.2 lb/A rate reduced yield by 50% and in 1983 the same rate reduced yield by 30%.

Group 3 (bromoxynil and the bromoxynil + MCPA treatments) caused a slight chlorosis which started at the margins of leaves even at the low rate (0.01 lb/A) of bromoxynil. Chlorosis covered more of the leaf area and necrosis followed sometimes destroying whole leaves at 0.05 to 0.2 lb/A rates. The combination of bromoxynil + MCPA generally exhibited the same symptoms, which became more severe as the rates increased. Tuber yield reductions were similar with both bromoxynil and bromoxynil + MCPA at the highest rates with only two thirds of the normal yield (Table 1) and these tubers graded into smaller szie categories. There was greater yield reduction in 1983 than in 1982 (Tables 1 and 3). Tubers had no bud-end creases or ulcers.

Experiment 8306

Table 1. Yield and percentages (of total) and specific gravity in each grade from simulated herbicide drift to potatoes at Aberdeen, ID in 1983. Data are means of four replications. (P.W. Leino and L.C. Haderlie).

Chemical	Formulation	Rate lb ai/A	Total Yield cwt/A	Total Yield T/ha	Percent <4 oz	Percent 4-10 oz	Percent >10 oz	Percent Malformed	Sp. Grav.
1. Untreated			308	34.5	27	59	10	4	1.087
2. Dicamba	4	0.01	293	32.9	25	61	8	6	1.091
3. Dicamba		0.05	253	28.5	39	39	3	19	1.084
4. Dicamba		0.10	281	31.6	39	48	1	13	1.088
5. Dicamba+2,4-D	4.0 Amine-2,4-D	0.025+0.1	299	33.6	28	61	3	7	1.091
6. Dicamba+2,4-D		0.05+0.1	247	27.8	34	47	3	16	1.088
7. 2,4-D		0.01	316	35.4	22	59	11	8	1.088
8. 2,4-D		0.05	295	33.2	29	58	6	7	1.085
9. 2,4-D		0.1	311	34.9	23	64	7	6	1.088
10. 2,4-D		0.2	274	30.8	31	59	6	4	1.080
11. Glyphosate	3.0 acid eq.	0.01	298	33.5	24	58	10	8	1.087
12. Glyphosate		0.05	286	32.1	28	53	8	10	1.088
13. Glyphosate		0.1	249	28.0	35	50	3	13	1.087
14. Glyphosate		0.2	213	24.0	42	34	1	23	1.091
15. Bromoxynil	4E	0.01	256	28.7	31	57	6	6	1.089
16. Bromoxynil		0.05	268	30.1	32	51	7	9	1.087
17. Bromoxynil		0.1	212	23.8	51	39	3	6	1.082
18. Bromoxynil		0.2	189	21.2	57	31	2	10	1.084
19. Bromoxynil+MCPA	3+3E	0.01+0.01	268	30.1	31	53	7	8	1.076
20. Bromoxynil+MCPA		0.05+0.05	202	22.7	44	43	4	9	1.082
21. Bromoxynil+MCPA		0.1+0.1	204	22.9	51	35	3	11	1.079
		LSD 5%	41	4.6	11	9	5	9	n.s.
		C.V.	11	11	22	12	71	63	

Experiment 8306

Table 2. Extent of tuber malformations after simulated herbicide drift to potatoes at Aberdeen, ID in 1983. Data are means of four replications (P.W. Leino and L.C. Haderlie).

	Chemical	Formulation	Rate lb ai/A	Percent Bud-end crease	Percent Ulcer
1.	Untreated			0	0
2.	Dicamba	4	0.01	1	5
3.	Dicamba		0.05	31	99
4.	Dicamba		0.10	14	100
5.	Dicamba+2,4-D	4.0 Amine-2,4-D	0.025+0.1	4	99
6.	Dicamba+2,4-D		0.05+0.1	31	99
7.	2,4-D		0.01	0	0
8.	2,4-D		0.05	2	0
9.	2,4-D		0.1	1	0
10.	2,4-D		0.2	8	0
11.	Glyphosate	3.0 acid eq.	0.01	1	0
12.	Glyphosate		0.05	4	3
13.	Glyphosate		0.1	1	44
14.	Glyphosate		0.2	4	93
15.	Bromoxynil	4E	0.01	1	0
16.	Bromoxynil		0.05	0	0
17.	Bromoxynil		0.1	0	0
18.	Bromoxynil		0.2	0	0
19.	Bromoxynil+MCPA	3+3E	0.01+0.01	0	0
20.	Bromoxynil+MCPA		0.05+0.05	0	0
21.	Bromoxynil+MCPA		0.1+0.1	1	0
			LSD 5%	12	13
			C.V.	167	37

Experiment 8209

Table 3. Yield and percentages (of total in each grade) from carryover or drift to potatoes at Aberdeen, ID in 1982. Data are means of four replications. (L.C. Haderlie, S.W. Gawronski, P.W. Leino).

Herbicide	Post lb ai/A	Post kg/ha	Pre-Plant lb/A	Pre-Plant kg/ha	Total Yield cwt/A	Total Yield t/ha	U.S. #1's cwt/A	U.S. #1's %	Percent <4 oz	Percent 10 oz	Percent >4-10 oz	Percent Mal-frmd
1. Untreated					334	37.4	155	46	20	28	18	34
2. Dicamba (Banvel)			0.05	0.06	267	29.9	130	47	25	35	11	28
3. Dicamba			0.10	0.11	248	27.8	102	41	28	30	11	31
4. Dicamba			0.50	0.60	121	13.5	45	38	38	31	7	25
5. Dicamba	0.01	0.01			342	38.3	171	50	24	39	11	26
6. Dicamba	0.05	0.06			249	27.8	24	9	33	9	1	58
7. Dicamba	0.10	0.11			284	31.7	52	19	40	18	1	41
8. Dicamba+2,4-D	0.025+0.1	0.03+0.11			281	31.5	76	27	24	24	4	50
9. Dicamba+2,4-D	0.05+0.1	0.06+0.11			262	29.4	39	15	43	15	0	42
10. 2,4-D	0.01	0.1			310	34.7	166	53	22	35	18	25
11. 2,4-D	0.05	0.06			286	32.0	133	47	25	37	10	28
12. 2,4-D	0.10	0.11			312	34.9	129	41	28	34	8	30
13. 2,4-D	0.20	0.22			280	31.3	73	27	31	21	6	42
14. Glyphosate (Roundup)	0.01	0.01			324	36.3	137	42	19	28	14	39
15. Glyphosate	0.05	0.06			244	27.3	89	38	28	28	10	34
16. Glyphosate	0.10	0.11			289	32.3	72	25	29	20	5	46
17. Glyphosate	0.20	0.22			167	18.7	10	5	40	5	0	54
18. Bromoxynil (Brominal or	0.01	0.01			298	33.4	144	48	21	30	18	31
19. Bromoxynil Buctril)	0.05	0.06			293	32.8	131	45	22	31	14	33
20. Bromoxynil	0.10	0.11			250	28.0	118	48	24	30	18	28
21. Bromoxynil	0.20	0.22			249	27.9	93	37	22	28	9	41
22. Bromoxynil+MCPA (Brom	0.01+0.01	0.01+0.1			324	36.2	157	49	22	35	14	29
23. Bromoxynil+MCPA plus or	0.05+0.05	0.06+0.06			329	36.8	129	38	26	31	8	35
24. Bromoxynil+MCPA Bronate)	0.1+0.1	0.11+0.11			239	26.8	63	27	27	23	4	47
		LSD 5%			57	6.4	42	12	10	10	6	14
		C.V.			15	14.9	29	24	25	28	45	28

Experiment 8209

Table 4. Various tuber characteristics after 5 months storage following post-emergence herbicide carryover and drift treatments which were made to potatoes in 1982. Stem-end discoloration was evaluated by cutting several tubers. Malformations of creasing at bud-end and elephant-hide skin appearance were a visual estimate of the number of tubers with such malformations. Data are means of four replications. (L.C. Haderlie & P.W. Leino).

Herbicide	Type of Application (kg/ha)		5 Tubers of total in sample		
	Post	Pre-Plant	SED[1] in 0-1 rating categ.	Bud-end crease	Elephant Hide (ulcers).
1. Untreated			94	0	0
2. Dicamba			93	0	0
3. Dicamba		0.11	89	1	0
4. Dicamba		0.60	97	4	0
5. Dicamba	0.01		98	0	0
6. Dicamba	0.06		90	69	33
7. Dicamba	0.11		97	41	68
8. Dicamba+2,4-D	0.03+0.11		96	15	18
9. Dicamba+2,4-D	0.06+0.11		93	26	53
10. 2,4-D	0.01		97	0	0
11. 2,4-D	0.06		97	0	0
12. 2,4-D	0.11		100	0	0
13. 2,4-D	0.22		100	0	0
14. Glyphosate	0.01		99	1	0
15. Glyphosate	0.06		95	0	0
16. Glyphosate	0.11		97	16	0
17. Glyphosate	0.22		92	69	18
18. Bromoxynil	0.01		89	0	0
19. Bromoxynil	0.06		96	3	8
20. Bromoxynil	0.11		84	0	1
21. Bromoxynil	0.22		95	0	0
22. Bromoxynil+MCPA	0.01+0.01		99	1	0
23. Bromoxynil+MCPA	0.06+0.06		99	0	0
24. Bromoxynil+MCPA	0.11+0.11		100	0	0
	LSD 5%		n.s.	12	12
	C.V.		7	86	104

1/ Internal (stem-end) discoloration, 0 = no discoloration; 4 = severe discoloration.

Tubers produced during the 1982 drift and carryover experiment were planted in a seedpiece vigor experiment during 1983. Seedpiece vigor as measured by rate of emergence is reduced from dicamba (Banvel), dicamba + 2,4-D and glyphosate (Roundup).

Generally, the lowest rates of each of these herbicides when applied in July were not greatly detrimental to the yield or quality of Russet Burbank potatoes. However, the higher rates of dicamba and glyphosate produced severe tuber malformations and yield reductions. Bromoxynil and bromoxynil + MCPA reduced yield at the higher drift rates but did not affect tuber quality. The growth stage at the time of application was important to foliar symptom expression as indicated by the 'giant hill' potatoes. However, this foliar symptom expression was not always linked to yield.

THE CONTROL OF ANNUAL AND PERENNIAL GRASSES IN ORNAMENTALS WITH FLUAZIFOP-BUTYL.

G.D. Johnson and H. Buckwalter[1]

Abstract: Fluazifop-butyl ((±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy] phenoxy]propanoic acid) is a selective post emergent herbicide used to control annual and perennial grasses in cotton and soybeans. Because of its unique herbicidal activity it has proven useful in landscape maintenance weed control programs. In the desert southwest, bermudagrass (Cynodon dactylon L. Pers.) appears to be the predominant weed species inhabiting commercial landscapes. Bermudagrass as well as other perennial and annual grasses rob ornamentals of moisture, nutrients and sunlight necessary for normal productive growth. Previous control alternatives include costly and ineffective handhoeing or hand weeding or the use of non-selective herbicides. Fluazifop-butyl, being a true graminicide, has proven to be extremely safe to most broadleaf ornamentals while delivering excellent control of virtually all grass problems. For controlling grasses in large areas a rate of 0.56 kg/ha applied as a broadcast treatment is recommended. Another useful method of applying fluazifop-butyl is to prepare a 0.39% v/v solution as a spot treatment. The grasses should be sprayed to obtain thorough coverage. A nonionic surfactant at the rate of 0.25% v/v should be utilized. Crop oil concentrates should not be used on ornamentals due to potential phytotoxicity. Just as in row crops, fluazifop-butyl should be applied to immature grasses that are actively growing. A second application at the same rate may be necessary to provide season long control. Phytotoxicity screening trials indicate that fluazifop-butyl is safe to most ground covers, trees, vines, shrubs and desert vegetation.

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[1]ICI Americas, Tempe, AZ.

A TIME FOR SPRAYER PERFORMANCE

Harry S. Howard III[1]

Abstract. There are common causes for most misapplications of pesticides. Nozzle performance is a major factor and many applicators do not fully understand how nozzles function (in relation to equipment design) or how they are actually spraying at a selected target height. Proper spray distribution (spray pattern) is a critical link to pesticide performance.

We have a versatile new model of spray collector available...The Spray Chek Demonstrator. This is a completely portable, selfcontained spray table that incorporates a removable Spray Chek collector, reservoir, an adjustable three nozzle boom, quick release nozzles, pressure gauge, electric pump and pressure relief valve. The unit is rugged for instant shipping anywhere and is ideal for indoor demonstrations of nozzle performance. Now regional growers can bring in their nozzles for checking during the winter months. The spray collector (unfolded dimension 60 x 26") used on this model is detachable enabling the user to test actual field sprayers as well. (To be used with flat fan or flood jet nozzles.)

[1]AccuTech Associates, Inc., Bozeman, MT.

INTEGRATED WEED MANAGEMENT IN CALIFORNIA RICE

J.E. Hill, M.L. LeStrange, D.E. Bayer and J.F. Williams[1]

Abstract. Weeds are the major pest problem in California rice (*Oryza sativa*). A wide array of broadleafs, grasses, and filamentous algae infest rice in its aquatic habitat. The most troublesome weeds are a complex of land and water adapted barnyardgrass species including *Echinochloa crusgali* #ECHCG, *Echinochloa oryzoides* #ECHOR, and *Echinochloa phyllopogon* #ECHOR. The rapid introduction of short stature varieties in California rice production in 1979 appeared to increase the difficulty of barnyardgrass control. Changes in management practices with the introduction of these varieties included higher nitrogen fertility and lower water depth. In 1981 studies were initiated to determine the effects of these various management practices in controlling barnyardgrass.

Experiments on the effect of barnyardgrass density in rice showed average losses over all fertility levels and varieties tested were 50% at a barnyardgrass density of 86 plants/m^2 (Fig. 1). Tall (S-6) and short (S-201) stature rice cultivars were compared to determine differences in their competitive abilities with barnyardgrass. Rice height did not greatly effect the response to barnyardgrass density indicating that stature was not the most important factor (Fig. 2) in competition. Small differences in early growth and development between the tall and short varieties during stand establishment may account for the small differences

[1]Univ. of California, Coop. Extension and Agricultural Experiment Station.

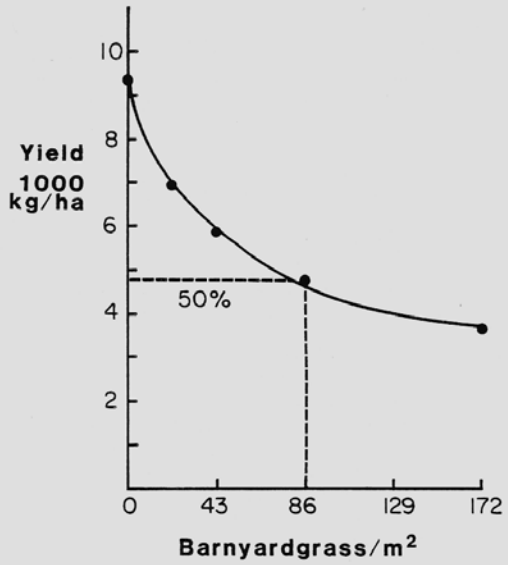

Figure 1. Barnyardgrass competition to rice.

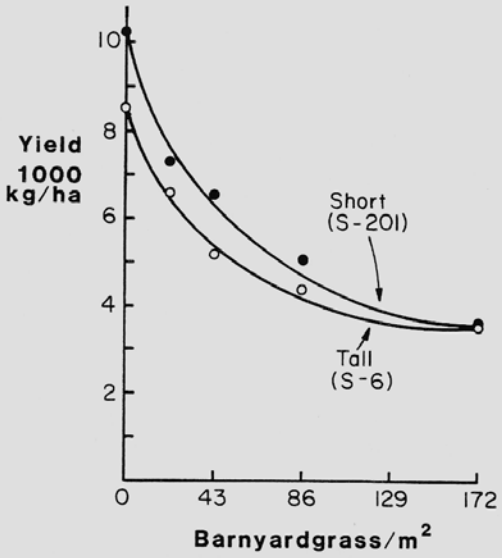

Figure 2. The effect of rice stature on barnyardgrass competition.

in competitive ability. The level of applied nitrogen, however, had a very strong influence on the competitive relationship of barnyardgrass to rice (Fig. 3). In the absence of barnyardgrass rice responded to nitrogen with increasing yields. In contrast, at the highest density of barnyardgrass, yields decreased with each incremental increase in nitrogen.

California rice is grown under continuous flood. Short stature rice varieties require lower water depths for emergence and stand establishment than the taller varieties. The introduction of precision land leveling with lasers has allowed growers to achieve uniformly shallow water depths to facilitate rice emergence. The effect of water depth at 0, 10 and 20 cm on the severity and control of barnyardgrass was investigated. Acceptable weed control was not achieved under field-drained conditions and reached only 75% of the best treatment with the application of an herbicide (Table 1). Water depths of either 10 or 20 cm without herbicide also provided approximately 75% control. The addition of an herbicide at water depths of 10-20 cm provided acceptable control demonstrating the importance of water in suppressing barnyardgrass growth.

Surveys have estimated that the average infestation of barnyardgrass on 90% of California's rice is 36 plants/m^2. Experiments were conducted to determine cost-benefit analysis of the rice herbicides in controlling barnyardgrass. Results of these studies indicated that when barnyardgrass infestation was low (10.5 plant/m^2) a $325 per hectare benefit was gained by one application of herbicide (Table 2). The benefit from herbicide

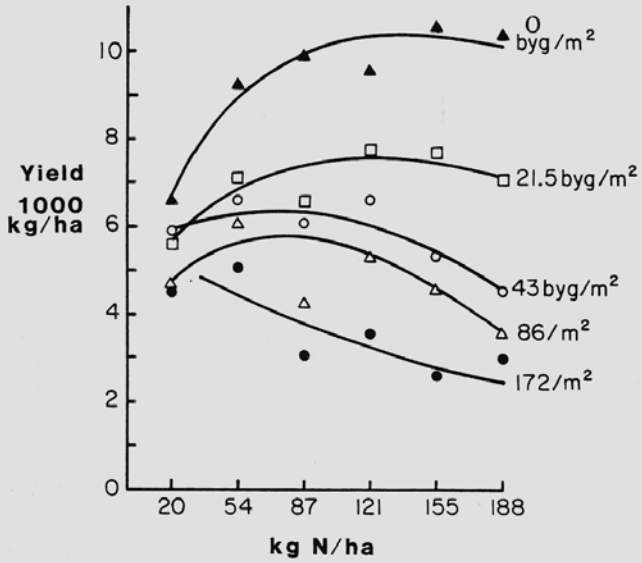

Figure 3. The effect of nitrogen on barnyardgrass competition to rice.

Table 1. The influence of water depth on barnyardgrass control.

Water Depth CM	Yield Untreated kg/ha	Yield Treated kg/ha
0	2,180	8,500
10	8,500	11,990
20	8,720	11,445

Table 2. Barnyardgrass competition and herbicide benefit.

Barnyardgrass Density (plants/m^2)	Yield Untreated (kg/ha)	Yield Treated (kg/ha)	Herbicide Benefit ($/hectare)[1/]
0	11,118	12,208	---
10.5	8,066	11,990	325
21	6,758	11,772	425
43	4,360	11,554	525
86	2,398	11,336	785

LSD (.05) = 1490 lbs/acre
C.V. % = 10.9

1/ Benefit calculated for all significant differences at $.90/kg and $35 per herbicide application.

increased substantially to $525 and $785 per hectare acre, when investigation densities reached 43 and 86 barnyardgrass/m^2, respectively.

WILD OAT (AVENA FATUA) INTERFERENCE IN SPRING BARLEY (HORDEUM VULGARE)

Don W. Morishita, Donald C. Thill and Robert H. Callihan[1]

Abstract. Field experiments were conducted in 1983 and 1984 to measure the interference of wild oat (Avena fatua L.), removed at various growth stages of development (2-3 leaf, 2-3 tiller, 2 node, heading, not removed, wild oat free, and wild oat alone), on the growth and yield of spring barley (Hordeum vulgare L.). The experiments were arranged as randomized complete block designs with four replications. The barley was seeded at 73 kg ha^{-1} and the wild oats were seeded to obtain a density of approximately 172 plants m^{-2}. Interference was determined by detailed plant growth measurements, plant-water relationships, and yield components.

No differences in barley height, tillers m^{-2}, plant biomass, and several yield components were observed among the different wild oat removal stages in 1983. Barley yield and 1000 kernal weight were reduced 33 and 19%, respectively, when compared to wild oat free barley, only when the wild oats were not removed from the crop. No differences in barley water potential, i.e. total, osmotic, and turgor potential, due to wild oat interference were observed. Treatment comparisons of wild oat free barley and wild oat alone showed that barley had a lower total water potential and turgor potential than did wild oat at the 4-5 tiller stage of both species. Barley also had a lower osmotic potential than wild oat at heading, but this was reversed when measured approximately 10 days after anthesis. Soil moisture content was not limiting throughout the 1983 growing season. Barley growth and yield measurements in 1984 did result in differences due to wild oat interference. Barley height was 8-10% greater from late boot to anthesis in those treatments where wild oats were not removed. After anthesis, barley height for all treatments was the same except in the 2-3 tiller wild oat removal treatment which was 9% shorter. The number of barley tillers m^{-2} after heading was an average 39% less compared to the wild oat free treatment in the 2 node, heading, and not removed wild oat removal treatments. Similar results were observed in barley biomass. As in 1983, no difference in water potential was observed in the barley among the different wild oat removal times at either the late boot or milk stage of barley growth. Barley yield and components of yield were affected in 1984 by wild oat interference to a greater extent than in 1983. Barley yields in the 2 node, heading, and not removed wild oat removal treatments were all less (35-47%) than the wild oat free barley. Analysis of yield components showed that kernal number m^{-2} was most affected (41-52%) by the wild oat competition. The earlier onset of wild oat interference on barley growth and yield in 1984 was attributed to the initial soil moisture content and subsequent water availability in 1984 compared to 1983.

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[1]Dept. of Plant, soil and Entomological Sciences, Univ. of Idaho, Moscow, ID.

THE CHARACTERISTICS OF SECONDARY DORMANT WILD OAT (*Avena fatua* L.) SEED

G.M. Fellows, P.K. Fay, and M.E. Foley[1]

Introduction

Seed dormancy is regarded as the main survival mechanism of wild oats. For this reason Dr. Mike Foley and his lab group at Montana State University have been researching the mechanism of wild oat dormancy. The ultimate goal is to develop a treatment that will force all of the dormant seeds in the soil to germinate at once. This could reduce wild oats from a severe problem to just a nuisance.

Wild oats like many other seeds have three types of dormancy; primary, secondary and enforced dormancy. Primary dormancy is an innate type of dormancy being present in the seed as it dehisces from the mother plant. Secondary dormancy occurs when a nondormant seed is induced into a dormant state due to environmental conditions. In wild oat the conditions that are believed to induce secondary dormancy are low oxygen and high moisture. Enforced dormancy occurs when the nondormant seed is placed under conditions that are unfavorable for germination. Enforced differs from secondary dormancy in that secondary dormant seed will not germinate when placed in favorable conditions.

Wild oat dormancy has been the subject of research since the first important paper was published by Atwood in 1914. Almost all of the research that has been conducted has dealth with the primary dormant seed. Since wild oats will also enter a secondary dormant state, we have begun research into the mechanism of secondary dormancy with the goal of identifying the characteristics of secondary dormancy in wild oats. This knowledge is essential if a treatment is to be developed that will force all the dormant seeds in the field to germinate.

Induction of Secondary Dormancy

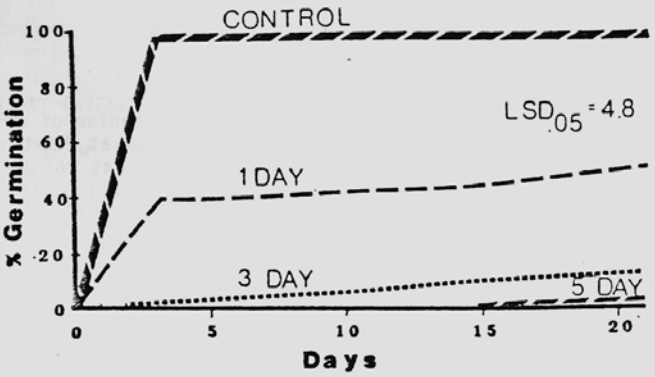
The first objective was to develop a method by which we can induce a nondormant population of seed into a secondary dormant state. Hay (1959) reported a method by which secondary dormancy can be induced. His method involved the use of vacuum infiltration to replace the air in the seed with water. In testing this method we found that a large percentage of the seed was killed during the vacuum infiltration.

We found that secondary dormancy can be induced by placing seeds in a flask and stored at 20°C in the dark. An experiment was then peformed to determine the optimum duration for the seeds to be left in the water (Fig. 1).

The germination of the control seed was almost 100% after 4 days. Seeds that were left in the water for only one day displayed germination of about 50%. When the seeds were left in water for three days the germination was reduced further to 10%. Seeds soaked in water five days exhibited 2% germination after three weeks. At three weeks a tetrazolium test was conducted on the nongerminated seed to determine the total percent of viable secondary dormant seed. Based on the results of these tests we concluded that a four day soaking treatment provided the best balance

[1]Plant & Soil Science Dept., Montana State Univ., Bozeman, MT.

Figure 1. Percent germination of wild oat seed left in water for various lengths of time.



between viability and dormancy. A four day treatment will induce 80% of the nongerminating seeds into secondary dormancy.

Gibberellic Acid and Sodium Azide Effects on Secondary Dormant Seed

Primary dormant wild oat seeds have been stimulated to germinate using several chemical treatments. Among those used are gibberellic acid (GA), sodium azide, nitrate, nitrite, ethanol, fusicoccin, and hydrogen peroxide. To date the promotive action of these chemicals have not been tested on intact secondary dormant wild oat seed. Gibberellic acid and sodium azide actively break primary dormancy. Our goal was to evaluate their promotive effect on secondary dormant wild oat seed.

Germination studies were conducted on secondary seed of the wild oat line CS40. This inbred line was utilized to reduce variability caused by varying degrees of dormancy and nondormancy in the seed. Nine cm petri plates lined with two filter papers and wetted with 5 mls of water or treatment solution were dark incubated in high humidity at 20°C. Germination was recorded at regular intervals.

Gibberellic acid at a level of 0.5 mM stimulated 95% of the seeds to germinate after three days. Sodium azide stimulated 95% of the seeds to germinate by the end of the third week. The response of secondary dormant seeds to gibberellic acid and sodium azide is similar to that shown by primary dormant seed suggesting that there might be a similarity in the two types of dormancy.

Protein Differences in nondormant and Secondary Dormant Seed

The third goal of this project was to compare the protein isolated from the embryos of both nondormant and secondary dormant wild oat seed. This study was conducted to determine if secondary dormancy was brought about by a change in the protein composition during dormancy induction. Only the seed embryos were used because several reports in the literature proposed that the locus of the primary dormancy is in the embryo.

The embryos were isolated from the seed using a small surgical knife and washed with a buffer solution to remove adhering endosperm. The embryos were then homogenized in a Tris-HCl buffer solution containing 1% sodium dodecyl sulphate (SDS). The homogenate was then centrifuged at 10,000 g for 10 minutes and the supernatent analyzed for total protein. The supernatent was brought to 5% 2-mercaptoethanol, 10% glycerol, and 1% bromephenol blue. The mixture was heated for 10 minutes at 100°C. The proteins were then electrophoretically separated on a SDS-polyacrylamide gel (SDS-PAGE). The proteins separated on the basis of their molecular weight.

Differences were observed between the resulting protein patterns. Comparative differences were located in the region around 20-24 kdal. These results are preliminary. A higher degree of resolution and detection is needed for verification.

Conclusion

Secondary dormancy can be induced in a nondormant population of wild oats. A four day soaking treatment will induce 80% of the seeds into a secondary dormant state. Longer treatment periods increase the loss in seed viability.

Gibberellic acid rapidly stimulates 95% of the secondary dormant seed to germinate. Sodium azide stimulates 100% of the dormant seed to germinate after three weeks. These results suggest a similarity between primary and secondary seed dormancy.

Using electrophoretic separation, differences in the protein composition of nondormant and secondary dormant embryos were located. This suggests that the induction of secondary induces protein changes in the embyro of the seed. These results are preliminary with more comprehensive research needed to adequately confirm this finding.

THE EFFECT OF DICLOFOP TREATMENT ON THE PHOTOSYNTHETIC RATES, WATER POTENTIALS, AND CHLOROPHYLL CONTENTS OF FOUR WILD OAT ACCESSIONS

K. George Beck, Donald C. Thill, and Robert H. Callihan[1]

Abstract. Experiments were conducted in 1984 to assess the effects of diclofop (2-[-4-(2,4-dichlorophenoxy)phenoxy]methyl-propanoate) on several physiological parameters among wild oat (Avena fatua L.) accessions. Four accessions were randomly allotted to two replications of two experiments, each arranged in a randomized complete block design. Wild oat were chosen on the basis of 1983 field experiments from which the two most tolerant and the two most susceptible accessions to diclofop were selected. Treated plants were broadcast sprayed with 0.84 kg ai/ha of the methyl ester formulation of diclofop when the majority of plants had developed two to five leaves and one to three tillers. Plants were harvested 2, 6, and 10 days after spraying and treated plants were compared to non-sprayed check plants. Each experiment was conducted twice. No differences due to herbicide treatment were observed among wild oat accessions for total water

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[1]Dept. of Plant, Soil and Entomological Sciences, Univ. of Idaho, Moscow, ID.

potential, osmotic potential, turgor pressure, or photosynthetic rate. Differences were observed between experiments and among harvest days for osmotic potential and turgor pressure. Differences due to herbicide treatment were observed among accessions and harvest days and between experiments for chlorophyll a and chlorophyll b content, as well as chlorophyll a+b content. Additionally, a significant accession by harvest day interaction was observed for chlorophyll a, chlorophyll b, and chlorophyll a+b. All physiological experiments are presently being repeated. In addition, the results from absorption and translocation studies currently being conducted using 14C-diclofop, will be reported.

PREVENTING SEED PRODUCTION IN DOWNY BROME WITH APPLICATIONS OF DPX-Y6202 AND FLUAZIFOP-BUTYL

J.M. Richardson, D.R. Gealy and L.A. Morrow[1]

DPX-Y6202 (2-[4-[(6-chloro-2-quinoxalinyl)oxy]-phenoxy]-propionic acid, ethyl ester) and fluazifop-butyl (butyl (RS)-2[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate) were each applied at rates of 0.28 and 0.07 kg/ha to downy brome (Bromus tectorum L.) at tiller elongation, anthesis, or seed fill. Fluazifop-butyl prevented seed formation at both rates applied during tiller elongation and at the higher rate when applied at anthesis. DPX-Y6202, applied at the higher rate during tiller elongation, prevented seed production. In all other treatments, plants produced viable seeds. In a study using radiolabeled herbicides, absorption and translocation of fluazifop-butyl was substantially greater than DPX-Y6202. Over 20% of applied fluazifop-butyl was translocated to developing spikelets, while less than 1% of applied DPX-Y6202 was translcoated to the same tissue. To determine possible mechanisms involved in preventing seed formation, the cut ^{14} ends of excised spikelets were allowed to absorb ^{14}C-DPX-Y6202 or ^{14}C-Fluaziflo-butyl. The spikelets were subsequently fixed in glutaraldehyde fixative, dehydrated in a graded ethanolic series, infiltrated and embedded in Spurr's resin, and sectioned on an ultramicrotome (2 um thick). Preliminary microautoradiographs indicate that much of the radiolabel is associated with the pollen grains.

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

EFFECT OF DIFFERENT TEMPERATURES ON THE ABSORPTION, TRANSLOCATION AND METABOLISM OF METRIBUZIN BY DOWNY BROME AND WINTER WHEAT

D.L. Devlin, D.R. Gealy and L.A. Morrow[1]

Root absorption, translocation, and metabolism of ^{14}C-metribuzin [4-amino-6-tert-butyl-3-methylthio)-as-triazin-5(4H-one)] by downy brome (Bromus tectorum L.) and winter wheat (Triticum aestivum L.) grown at either 15 or 25 C in nutrient solution were investigated. On a dry weight basis, downy brome absorbed significantly greater amounts of metribuzin than did winter wheat at both 15 and 25 C. Both species absorbed greater amounts of metribuzin at 25 C than at 15 C. Downy brome translocated less metribuzin to the shoots than did winter wheat at both 15 and 25 C. Studies examining metribuzin metabolism found winter wheat to metabolize metribuzin more rapidly than did downy brome.

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

PATTERN MOVEMENT STUDIES OF TEBUTHIURON IN SOIL

T.W. Schultz and R.E. Whitesides

Greenhouse studies were conducted to observe the movement of tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea) applied in bands. Plywood boxes (9 cm x 114 cm x 61 cm) were filled with a silt loam soil and broght to field capacity. A 2.5 cm band of tebuthiuron at 4.5 kg ai/ha was applied across the 9 cm width of the boxes. After applying 24 cm simulated rainfall, the boxes were laid flat, one side removed, and barley planted in a 2.5 cm grid across the exposed soil surface. Visual observations and dry weights were compared to growth response curves to approximate tebuthiuron movement in the soil. The pattern was rectangular, approximately 30 cm in depth and 7 cm wide.

[1]Dept. of Agronomy & Soils, Washington State Univ., Pullman, WA.

THE INFLUENCE OF ETHEPHON ON THE MALTING QUALITY OF TEN VARIETIES OF SPRING BARLEY

D.R. Gaiser and D.C. Thill[1]

Abstract. The ethylene-releasing plant growth regulator ethephon (2-chloroethyl phosphonic acid) was applied as an antilodging agent to 15 varieties of spring-planted barley (Hordeum vulgare L.). The experiment was designed

[1]Dept. of Plant, Soil & Entomol. Sci., Univ. of Idaho, Moscow, ID.

as a split-plot factorial with varieties as main plots and ethephon rates (0 and 0.42 kg/ha) as subplots. The ethephon was applied between growth stages 9 and 10.1 (Feekes-Large scale). The treatments were replicated four times at two locations: Kimberly and Moscow, Idaho.

Ten of the 15 varieties evaluated in the field experiment were selected for an analysis of ethephon's effect on certain malting quality factors. Subsamples of grain obtained from the field experiment were sized on a 2.4 x 19 mm sieve and malted using a micromalting procedure. The malt samples were analyzed for seven malting quality factors: percentage malt recovery, total protein, soluble protein, percentage malt extract, malt viscosity, alpha-amylase activity, and diastatic power.

The effect of ethephon treatment at Kimberly decreased malt viscosity (Table 1) by 4%, and there were no variety treatment interactions for any of the variables measured.

Table 1. The effect of ethephon treatment on the mean malt viscosity of ten barley varieties at Kimberly, ID.

Treatment	Malt viscosity
	(centipoise)
Control	1.75
Treated	1.68
LSD (0.05)	0.04

At Moscow, the ethephon treatment increased percentage malt recovery (Table 2) by 0.6%, and a variety by treatment interaction was observed for percentage malt extract (Table 3).

Table 2. The effect of ethephon on the mean malt recovery of ten barley varieties at Moscow, ID.

Treatment	Malt recovery
	(%)
Control	88.00
Treated	88.49
LSD (0.05)	0.34

Table 3. The effect of ethephon on the malt extract of two barley varieties at Moscow, ID.

Treatment	Malt extract	
	Moravian III	Piroline
	(%)	
Control	77.90	81.17
Treated	79.70	78.87
LSD I (0.05)	1.65	
LSD II (0.05)	2.00	

LSD I--for comparison of treatments within variety
LSD II--for comparison of varieties within treatment

The results of this experiment indicate that ethephon, applied as an antilodging agent to spring barley, has little effect on malting quality factors in the varieties studied.

EFFECT OF CHLORSULFURON RESIDUES ON ROTATIONAL CROPS IN MONTANA

D.C. Burkhart and P.K. Fay[1]

Introduction

Chlorsulfuron (2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)-amino]carbonyl]benzenesulfonamide) is an important herbicide in Montana. It has several properties that make it more attractive to use than other herbicides such as 2,4-D ((2,4-dichlorophenoxy)acetic acid). Some of the properties that are important in Montana include: flexibility of application timing, a broad spectrum of weeds controlled and crop safety on wheat.

Chlorsulfuron has an extended soil residue which damages rotational crops in Montana. It is important to determine the length of this residual period so that sensitive rotational crops will not be damaged.

Chlorsulfuron is degraded in soil by acid hydrolysis and microbial activity. The rate of acid hydrolysis increases at low soil pH, while the rate of microbial degradation is dependent upon several soil factors including soil moisture and soil temperature. In Montana precipitation and temperature are generally low and soil pH is high. These conditions slow the degradation of chlorsulfuron. Other areas have more rainfall and lower soil pH which increases the rate of degradation. It is important to determine how the rates of degradation differ under various climatic and soil conditions so that a simple method can be developed to predict degradation rates. Parameters in this method must be easy to measure for adoption by agricultural producers.

The objectives of this study are to determine when rotational crops in Montana can be safely grown and to develop a simple method to predict chlorsulfuron dissipation.

Materials and Methods

Chlorsulfuron was applied to spring wheat at rates of 0, 4.5, 9, 18, 35 and 70 gm/ha at five locations in Montana in the spring of 1983. The location of each study area, soil factors and climatic conditions are shown in Table 1. In the spring of 1984 barley, lentils, alfalfa, sugar beets, flax, potatoes, safflower, garbanzo beans, faba beans, pinto beans, sunflower and corn were planted into the chlorsulfuron soil residues. The plots were harvested by taking ten plants per plot from each of the 12 crops and analyzed as a percent of the control.

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[1]Plant & Soil Science Dept., Montana State Univ., Bozeman, MT.

Table 1. Selected soil and environmental properteis of chlorsulfuron plantback locations.

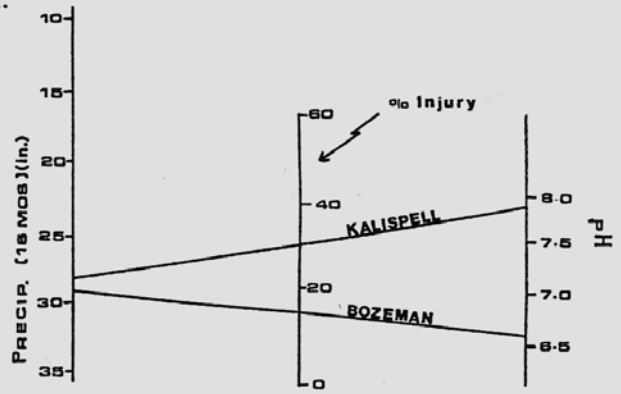
Location	% O.M.	% Clay	pH	CEC	Precip. (16 mos)	Temp. °C (April-Sept.)
					(in)	
Bozeman	1.8	30	6.6	16.2	29.1	15.0
Kalispell	4.4	17	7.8	32.2	28.7	15.3
Huntley	2.4	40	7.4	29.1	17.7	16.6
Havre	1.2	25	6.6	12.6	12.2	16.1
Glasgow	2.2	55	7.3	31.9	15.5	17.7

Results and Discussion

Results of this study showed each of the 12 crops varied in their responses to chlorsulfuron soil residues. The average dry weight of plants grown in chlorsulfuron residues for all locations combined indicated that the order of crop tolerance from least to most sensitive is: barley > safflower > faba beans > pinto beans > potatoes > flax > sunflower > garbanzo beans > sugar beets > alfalfa > corn > lentils.

The amount of chlorsulfuron injury varied by location. Correlations between percent injury versus several environmental and soil properties showed that no single factor is significant in accounting for this variation. However, multiple regression analysis indicates there is a high correlation between percent injury versus soil pH and total precipitation from application time until harvest. As precipitation decreases and soil pH increases the percent injury by location increases (Table 2).

Table 2. Relationship between soil pH, precipitation and percent injury at five chlorsulfuron plantback locations. Y = % injury, X 1 = precipitation (Total inches from chlorsulfuron application to harvest, 16 months.), X 2 = pH.



$y = -16.14 - 1.429 X_1 + 11.04 X_2$

$R^2 = 0.9578$

These results suggest that rotation options in areas with high moisture and low soil pH will be less restrictive than in areas where the opposite conditions prevail.

Conclusion

Rotational options in Montana depend upon soil pH, precipitation and crop. The rate of chlorsulfuron dissipation can be determined if soil pH and precipitation amounts are known. The results of this study will be used to ensure the continued safe and successful use of chlorsulfuron in Montana.

EFFECT OF SOIL PH ON THE DISSIPATION OF CHLORSULFURON

Duane G. Flom, Donald C. Thill and Robert H. Callihan[1]

Abstract. Chlorsulfuron (2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide) applied at 10-20 g ai/ha, generally provides good season-long control of most broadleaf weeds in cereal grains. Reduced rates of dissipation result in a longer half-life for chlorsulfuron in soils with above neutral pH. A field study was conducted to determine the rate of loss of biologically active concentrations of chlorsulfuron in soils differing primarily in pH.

Chlorsulfuron was surface applied at 0, 35, and 70 g/ha to two similar soils in March, 1983 near Lewiston, Idaho. Treated soils were similar in particle composition and organic matter content but had pH values of 5.9 and 8.7. Soil samples were collected periodically at 0 to 7.5 cm, 7.5 to 15 cm, and 15 to 30 cm depths from each site for 600 days. Herbicide residues were extracted from each sample by mixing air-dry soil and distilled water (1:1 w/w) on a reciprocal shaker for 30 min and centrifuging at 10,000 rpm for 10 min. Thirty ml of supernatant were decanted into growth pouches containing five pregerminated corn (Zea mays L.) caryopses. Corn root length was used to calculate biologically active, water extractable chlorsulfuron concentrations using standard curves.

The calculated half-life of chlorsulfuron in the 5.9 pH soil was approximately 4 weeks. Chlorsulfuron was not found in samples from depths greater than 7.5 cm and none was found at any depth 200 days after application. The calculated half-life of the herbicide in the 8.7 pH soil was approximately 21 weeks. Chlorsulfuron was found in samples from depths below 7.5 cm 300 to 400 days after application and none was found in samples from any sampled depth 500 days after application.

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[1]Plant, Soil & Entomol. Sci. Dept., Univ. of Idaho, Moscow, ID.

PATTERN MOVEMENT STUDIES OF TEBUTHIURON IN SOIL

T.W. Schultz and R.E. Whitesides[1]

Tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl[-N,N'-dimethylurea) is considered to be stable in soil with little or no lateral movement. However, in a banding application subjected to high amounts of surface runoff or rainfall it does show some movement in the soil. Greenhouse studies were conducted to simulate the movement pattern of tebuthiuron applied in bands and to observe that movement pattern using a bioassay plant.

Plywood boxes (10 cm x 122 cm x 61 cm) were filled with a silt loam soil, compacted, and brought to field capacity. A 2.5 cm band of tebuthiuron at 4.5 kg ai/ha was applied across the 10 cm width of eight boxes. Four boxes received 13 cm simulated rainfall while four other boxes received 25 cm of simulated rainfall. Two more boxes were watered with the simulated rainfall system and were used as untreated checks. After the desired amount of water had been applied the boxes were allowed to drain and then laid flat, one side removed, and barley planted in a 2.5 cm grid acorss the exposed soil surface. Visual observations and dry weights were taken at 2 weeks after planting. Dry weights from the treated boxes were compared to the check boxes. The treated boxes showed a definite tebuthiuron movement pattern below the area of application.

Tebuthiuron had leached approximately 15 cm down into the soil in the boxes receiving 13 cm rainfall, and had leached approximately 30 cm in the boxes receiving 25 cm rainfall. Both rainfall treatments showed a lateral movement of about 8 cm. The tebuthiuron moved in a rectangular pattern downward into the soil with some lateral movement, but that movement maintaining a specific width.

In conclusion, the amount of leaching was proportional to the amount of precipitation and regardless of precipitation volume lateral movement was consistant. Barley was a good bioassay plant for the study of tebuthiuron movement.

[1]Dept. of Agronomy and Soils, Washington State Univ., Pullman, WA.

EFFECTS OF CHLORSULFURON ON MEIOSIS AND SEED VIABILITY IN RYE (Secale cereale L.)

R.K. Zollinger and J.O. Evans[1]

Abstract. Chlorsulfuron (2-chloro-N-((4-methoxy-6-methyl-1,3,5-triazin-2-yl)-aminocarbonyl)benzenesulfonamide) is the active ingredient in the commercial herbicide "Glean" Weed Killer, and has been developed for broadleaf weed control in cereals such as wheat, barley, oats, and rye. It has been determined that an effect of this herbicide on susceptible plants is inhibition of mitotic cell division. This study was designed to

[1]Plant Science Dept., Utah State Univ., Logan, UT.

investigate the effects of chlorsulfuron on meiotic cell division in Secale cereale and to test seed viability and germination abnormalities in the same species.

Approximately 24,000 pollen mother cells (PMC's) in various stages of meiosis were examined. Aberrations were rare, but consisted primarily of unpaired univalents at diakinesis-metaphase I, bridges, lagging chromosomes and fragments at telophase I and II, and micronuclei at the tetrad stage. Plants treated with varying rates of chlorsulfuron were allowed to reach maturity. Caryopsis were harvested and 400 seeds from each treatment were planted and percent germination was calculated. Differences in germination did not vary significantly from the control.

Introduction

It has been determined that the mode of action of chlorsulfuron is inhibition of mitotic cell division. Since chlorsulfuron greatly reduces the mitotic index in susceptible plants it may also have an effect on meiotic divisions. This is important in the usage and long term registration of this herbicide. Chlorsulfuron is recommended for the selected control of weeds in wheat and barley, fallow followed by wheat, and on land that is rotated to wheat, barley, oats, or rye. In these grain crops a portion of the grain harvested may be used as seed grain for the following growing season. If chlorsulfuron does affect meiotic processes this could have an adverse affect on the development, viability, and germination of grain used as seed in subsequent generations.

This study was designed to investigate the effects of chlorsulfuron on meiotic cell division in Secale cereale and to test for seed viability and germination abnormalities in the same species.

Materials and Methods

Four sets of test plots were established on a field of undisturbed volunteer rye. Plots consisted of two fall and two spring applications and were arranged in a randomized block design with two replications per treatment. Individual plots measured 2.4 x 6.1 meters with 1.5 meters between plots as a border. Herbicide applications were made with a bicycle sprayer which was calibrated to deliver at a rate of 187 l/ha. The experiment included six treatments plus an untreated control. The treatments were: 35, 70, 140, 280, 560, and 1120 g/ha.

Seedlings were permitted to reach anthesis each spring. Plants in the control and the 140 g/ha treatment were selected for meiotic analysis. Young spikes in the early boot stage were dissected from the boot and placed in mixture of absolute alchohol and glacial acetic acid (3:1). Meiotic analysis consisted of examining pollen mother cells from five stages of meiosis from plants in each treatment selected. The stages examined were diakinesis-metaphase I, telophse I, telophase II, tetrad stage, and the pollen grain stage. Meiotic divisions in the PMC's were examined from temporary acetocarmine squash preparations.

Mature caryopsis were collected in early summer from all treated plots. A greenhouse study was established in which 400 seeds per treatment were planted in a soil medium consisting of 4 parts loam soil, 1 part sand, and 1 part peat. Germinating seedlings were allowed to grow to a height of 10-12 cm. Germination counts were taken and the average calculated.

Results

Table 1 shows the types and number of aberrant pollen mother cells in diakinesis-metaphase I. Approximately 200-300 PMC's were examined for each treatment. Precocious anaphasic separation was observed in highest proportion of all aberrations classified in this stage. This type of aberration is of minor importance and will have little effect as the cell proceeds through meiosis. The fate of these cells will probably be no different than normal PMC's and will develop into fertile pollen grains. Less than 1% aberrant PMC's were observed in both the control and the treated material with the exclusion of the cells that were characterized by precocious anaphasic separation.

Table 1.

Frequency and distribution of chromosome aberrations in diakinesis-metaphase I from pollen mother cells in rye (Secale cereale) plants treated with chlorsulfuron.

	Number of aberrant pollen mother cells (PMC's)					
	1983			1984		
		Fall treatment	Spring treatment		Fall treatment	Spring treatment
	Control	140 g/ha	140 g/ha	Control	140 g/ha	140 g/ha
1 univalent + 1 fragment	0	1	0	1	1	2
2 univalents	0	0	0	0	1	0
2 univalents + 1 fragment	0	1	0	2	0	0
Sticky connections	2	0	0	0	0	0
Precocious anaphase division	0	22	0	0	0	0
Total aberrant PMC's	2 (358)*	24** (153)	0 (211)	3 (311)	2 (321)	2 (312)

*Number in parentheses indicates total number of PMC's examined.

**Significant to control at 0.05 level of probability (x^2 test).

Tables 2, 3, and 4 define the number and types of aberrations observed in telophase I and II, and in the tetrad stage. The most important aberration observed in telophase I was 1 chromatid bridge + 1 fragment. The frequency of this deviation was very low in all material analyzed. The total number of aberrant PMC's in the control and in the treated plants was less than 0.5%.

Table 2.

Frequency and distribution of chromosome aberrations in telophase I from pollen mother cells in rye (Secale cereale) plants treated with chlorsulfuron.

	Number of aberrant pollen mother cells (PMC's)					
	1983			1984		
		Fall treatment	Spring treatment		Fall treatment	Spring treatment
	Control	140 g/ha	140 g/ha	Control	140 g/ha	140 g/ha
1 lagging dyad	0	1	0	0	2	0
1 fragment	0	0	0	2	0	2
1 chromatid bridge	0	2	0	0	0	0
1 chromatid bridge + 1 fragment	0	0	3	1	2	2
1 lagging univalent	0	0	0	0	1	0
Total aberrant PMC's	0 (1056)*	3 (1353)	3** (263)	8 (1070)	5 (1022)	4 (1012)

*Number in parentheses indicates total number of PMC's examined.

**Significant to control at 0.05 level of probability (x^2 test).

Table 3.

Frequency and distribution of chromosome aberrations in telophase II from pollen mother cells in rye (Secale cereale) plants treated with chlorsulfuron.

	Number of aberrant pollen mother cells (PMC's)					
	1983			1984		
		Fall treatment	Spring treatment		Fall treatment	Spring treatment
	Control	140 g/ha	140 g/ha	Control	140 g/ha	140 g/ha
1 lagging univalent	7	0	0	7	3	5
1 lagging univalent + 1 fragment	0	0	0	0	0	2
2 lagging univalents	3	0	2	0	0	17
3 lagging univalents	3	0	0	0	0	2
4 lagging univalents	1	0	0	0	0	0
1 chromatid bridge	0	3	2	4	3	5
2 chromatid bridges	0	0	0	2	1	0
1 lagging dyad	3	0	0	0	0	0
1 fragment	0	0	2	0	0	4
Total aberrant PMC's	17 (1086)*	3 (573)	6 (760)	13 (1021)	7 (1053)	35 (2270)

*Number in parentheses indicates total number of PMC's examined.

Table 4.

Frequency and distribution of chromosome aberrations in the tetrad stage from pollen mother cells in rye (Secale cereale) plants treated with chlorsulfuron.

	Number of aberrant tetrads					
	1983			1984		
		Fall treatment	Spring treatment		Fall treatment	Spring treatment
	Control	140 g/ha	140 g/ha	Control	140 g/ha	140 g/ha
1 micronucleus	1	0	7	3	1	9
2 micronuclei	0	0	3	0	1	2
3 micronuclei	0	0	5	0	0	1
4 micronuclei	0	0	1	0	0	1
5 celled tetrad	1	1	3	0	0	0
1 lagging univalent	0	0	6	0	1	0
2 lagging univalents	0	0	6	0	1	1
3 lagging univalents	0	0	1	0	1	0
Total aberrant tetrads	2 (1074)*	1 (341)	32** (1432)	3 (1049)	5 (1048)	14** (1008)

*Number in parentheses indicates total number of tetrads examined.

**Significant to control at 0.05 level of probability (x^2 test).

An interesting phenomenon occured in telophase II. A higher aberration rate was observed in the control as compared to the treated plants. No statistical significance was observed between any treatments as compared to the control.

The aberrations observed in the tetrad stage ranged from 1-4 micronuclei and 1-3 lagging univalents. One micronucleus per tetrad was observed in highest frequency in this stage. Significance was calculated in each of the spring treatments as compared to the control. Overall, less than 1% of the cells analyzed in the control were aberrant and slightly more than 1% of the cells in the treated material were aberrant.

In comparison to the stages previously discussed a much higher aberration rate was observed in the tetrad stage. The aberrations were classified as sterile or infertile pollen grains (Table 5). Significance was observed in each of the fall and spring treated plants as compared to the control.

Table 5.

Number of sterile pollen grains from rye (Secale cereale) plants treated with chlorsulfuron.

	Number of sterile pollen grains		
		Fall treatment	Spring treatment
	Control	140 g/ha	140 g/ha
Sterile pollen grains	44 (1022)*	96** (1060)	166** (1420)

*Number in parentheses indicates total number of pollen grains examined.

**Significant to control at 0.05 level of probability.

Table 6 shows the percent germination of seeds from rye plants treated with several rates of chlorsulfuron. There was a high germination percentage in all seeds including the control. No statistical difference was calculated between any of the treatments.

Table 6.

Percent germination of seeds from Secale cereale plants treated with several rates of chlorsulfuron.

	% germination of 400 planted seeds	
g/ha	Fall treatment	Spring treatment
0	92 a*	93 a
35	96 a	94 a
70	91 a	93 a
140	95 a	94 a
280	94 a	92 a
560	96 a	93 a
1120	92 a	92 a

*Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Fishers LSD test.

Discussion

In this study, the chromosomes from pollen mother cells were examined to determine the effect of chlorsulfuron on meiotic cell division. In cytogenetic studies as this one, diakinesis-metaphase I are the most important stages for examination. It is in this stage that the products of zygotene in which synapsis or pairing of homologous chromosomes can be observed. From the results of this study, it has been determined that chlorsulfuron does not inhibit synapsis or cause asynapsis of homologous chromosomes. It has also been determined that chlorsulfuron does not arrest meiosis or cause chromosomal aberrations in the species under investigation. The chromosomes of pollen mother cells from treated plants were observed to proceed through meiosis without any deleterious effects which resulted from this herbicide. The high proportion of sterile pollen grains is a result of some effect other than chromosomal since the frequency of aberrant PMC's in the other four stages of meiosis were very low.

From a practical standpoint, the germination test gives more information about the effects of chlorsulfuron on meiosis and seed development. From the results of the germination test it appears that chlorsulfuron does not decrease seed viability or cause germination abnormalities in fall rye.

AN EVALUATION OF TERMINOLOGY USED TO DESCRIBE HERBICIDE INTERACTIONS

S.W. Howard and R.E. Whitesides[1]

Terminology such as synergism, antagonism, additivity and no effect can be used to accurately describe herbicide interactions; however, to substantiate such an effort, proper experimental design is necessary. Experiments where chlorsulfuron (2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide) was combined with bromoxynil (3,5-dibromo-4-hydroybenzonitrile), 2,4-D (2,4-dichloro-phenoxy-acetic acid), dicamba (3,6-dichloro-O-anisic acid), and MCPA ([(4-chloro-O-tolyl)oxy]acetic acid) are used to illustrate use of this terminology to properly assess herbicide combinations. For example, the assumption of no effect (where there is neither a decrease or an increase in observed control) can be very misleading if the experimental design does not include serial applications of the tank-mixture components.

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[1]Agronomy & Soils Department, Washington State Univ., Pullman, WA.

STARCH UTILIZATION BY LEAFY SPURGE (Euphorbia esula L.)

Scott Nissen and Mike Foley[1]

Introduction

Leafy spurge (Euphorbia esula L.) remains one of the most serious range weed problems in Montana, North and South Dakota, Wyoming, Idaho and southern Canada. Leafy spurge is spreading each year despite chemical, biological and cultural control efforts.

The persistence of leafy spurge is due, in large part, to the extensive root stystem which has numerous adventitious shoot buds and tremendous stored starch reserves. A unique aspect of starch storage in leafy spurge is that starch grains are found in the latex as well as chloroplasts and parenchyma cells. The objective of this research was to increase the understanding of how leafy spurge utilizes these starch reserves. Plants were light starved and the utilization of root, shoot, and latex starch was examined.

Methods and Materials

Light Starvation Study. Plants cloned from root cuttings were grown in a growth chamber at a constant temperature of 25 C and 16 hr day length. Uniform plants were selected and placed in a growth chamber without lights (25 C). Groups of five plants were removed from the dark growth chamber 2, 4, 6, 8, 11, 16, 21, and 44 days after the beginning of the light starvation period. At each sampling date latex samples were collected into 10 ul capillary tubes and the plants were divided into root and shoot. Plant and latex samples were quick-frozen with dry ice and kept at -40 C until the experiment was terminated. Root, leaf and latex starch was analyzed using enzymatic starch hydrolysis by amylogucosidase and determination of released glucose by a coupled hexokinase/glucose-6-phosphate dehydrogenase assay.

Scanning Electron (SEM) and Light Microscopy Examination of Latex Starch Grains. Latex samples were taken from normal and light-starved plants and examined by both scanning electron and light microscopy. Morphology and surface structure were determined using electron microscopy and size measurements were made using a light microscope equipped with a stage micrometer.

Latex samples were fixed for SEM in 4% glutaraldehyde, dehydrated with ethanol and then coated with gold. Light microscope latex samples were placed on a glass slide and mixed with a drop of I-KI before examination.

Determination of Alpha-Amylase Activity in Latex. Five hundred microliter aliquots of latex were collected from greenhouse grown plants. These aliquots were placed in 1.5 ml centrifuge tubes, diluted with an equal volume of phosphate buffer and centrifuged at 30,000 X g for one hour. This centrifugation separated the latex into three fractions. The lower, clear serum fraction was removed by syringe and analyzed for alpha-amylase activity. The assay for amylase consisted of adding 40 ul of isolated serum fraction containing 94 ug of protein to a solution of soluble corn starch (2 mg/ml). The enzymatic reactions were stopped by placing the mixture in a boiling water bath for three minutes. Maltose produced by

[1]Plant & Soil Science Dept., Montana State Univ., Bozeman, MT.

amylase activity was then hydrolyzed to glucose by alpha-glucosidase and glucose was determined bythe hexokinase/glucose-6-phosphate dehydrogenase assay.

Results

Figure 1 shows the results of the light starvation study. Root starch decreased from 1100 nmol glucose equivalence/mg dry weight to 600 nmol glucose equivalence/mg dry during the first 11 days and remained at this level until the last sampling date 44 days after the beginning of light starvation. Leaf starch declined from 600 to 200 nmol glucose equivalence/mg dry weight during the first six days of the experiment and remained at this level until complete leaf abscission. The fact that leaf starch did not decline to zero indicates that some starch was present but not utilized. Latex starch levels did not decline significantly from initial starting values during the first 11 days of the experiment. After this period insufficient amounts of latex were exuded for starch analysis.

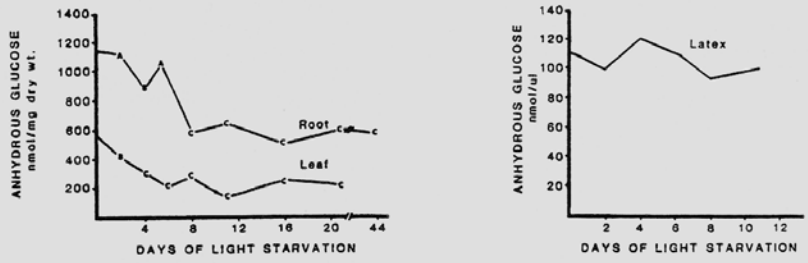

Figure 1. Analysis of root, shoot and latex starch by enzymatic hydrolysis. In all cases the initial starting value of starch is assigned the letter A and data points designated with other letters are significantly different (P = .05).

SEM showed no differences between the morphology of starch grains of normal and light-starved plants. High magnification (15,000X) indicated no differences in surface topography. Light microscope examination provided a statistical sample of starch grain length and width for the two treatments. Table 1 shows that no significant difference was found between latex starch grains of light-starved and normal plants. This is a further indication that latex starch grains are not being utilized as a food reserve.

Analysis of the serum protein fraction for amylase activity indicated that approximately 2 units of amylase activity were present per mg protein. A unit of activity is defined as the amount of enzyme required to release 1 mg of maltose from soluble starch in 3 minutes at 25 C.

Table 1. Average size of latex starch grains from normal and light-starved leafy spurge.

Treatment	Length (um)	Width (um)
Normal	30.1 (6.4)	4.1 (.47)
Light-Starved	31.1 (6.7) $\bar{x}$ (SE)	4.4 (.62) $\bar{x}$ (SE)
	n = 50	

Conclusions

Latex starch grains do not appear to function as a food reserve, however, they can account for 30-50% of the total plant starch. SEM and light microscopy verified that latex starch grains appeared unaltered after extended periods of light starvation. The presence of alpha-amylase activity may be an indication that (1) amylase inhibitors are present in the latex, or (2) starch grains are inaccessible to enzymatic degradation because of structural or conformational changes. It appears then that latex starch grains have evolved to perform some secondary function which has yet to be determined.

YIELD REDUCTIONS IN FIELD PEAS AND LENTILS RESULTING FROM VOLUNTEER CROP COMPETITION

R.G. Hornford and B.N. Drew[1]

Abstract. Wild oat (Avena fatua) and wild mustard (Brassica kaber) are two serious weeds of the northern prairies, both in relative abundance and competitive ability. Field experiments using domesticated species (Avena sativa and Brassica hirta) to simulate the effect of the wild species were conducted to determine yield reductions in field peas (Pisum sativum) and lentils (Lens culinaris). Increasing infestation density of individual weed species and combinations resulted in reduction of seed yield for both field peas and lentils. Lentils were less competitive than field peas; but volunteer crop populations of ten plants per meter square significantly reduced yields of both lentils and field peas.

Materials and Methods

This set of trials was conducted during the 1984 season at the University of Saskatchewan, Saskatoon, Sask., Canada. The experimental design was a factorial split randomized complete block design replicated four times. Separate trials were run to examine yield reductions in field peas,

[1]Crop Development Centre, Univ. of Saskatchewan, Saskatoon, Sask., Canada.

variety Trapper; and lentils, variety Laird. Crop seeding rates were selected to represent the normal recommended rate and a half of normal rate. To ensure germination 'Gisilba' yellow mustard and 'Cascade' oats were used to simulate the competitive action of weed populations. The weed population was seeded above the pulse crop and at ninety degrees to the direction of crop seeding. A hoe drill was used for all seeding.

Weed populations of yellow mustard at 0, 10, 25 and 50 plants/m^2, oats at 0, 10, 25 and 50 plants/m^2 and all possible combinations were established. Terbufos was seed placed with yellow mustard and diazinon applied to foliage to prevent damage by flea beetles. Over the growing season plots were hand weeded and counts done to verify plant densities.

At harvest a 2.8 m^2 area was machine harvested. Samples were initially cleaned in a dockage tester and finally by hand to separate seed into the different species components.

Results and Discussion

The summer of 1984 was hotter and drier than normal. Mean air temperature was +0.5, +3.6 and +3.1°C above normal through June, July and August, respectively. Precipitation for the same period was 87%, 23% and 27% of normal for the months of June, July and August, respectively. The poor growing conditions contributed to overall lower seed production of all species and intensified competition.

Equations were derived based on the square root transformation of weed density/m^2. Table 1 displays values used in equation derivation. Equations allow prediction of field pea and lentil yield in kg/ha at each seeding rate when in competition with a single weed species. Combinations of two weed species were not considered as they did not significantly reduce yields beyond reductions observed in single weed species treatments.

Table 1. Regression constants and correlation values for weed competition in field peas and lentils, Saskatoon.*t

Crop	Crop seeding rate kg/ha	Volunteer crop as the weed	y	a	b	r	
Field peas	62.5	Yellow mustard	1143	1048	145.0	0.9792	
Field peas	125.0	Yellow mustard	1453	1294	163.4	0.9165	$
Field peas	62.5	Oats	1143	1087	98.1	0.9590	
Field peas	125.0	Oats	1453	1362	147.0	0.9678	
Lentils	40.0	Yellow mustard	370	305	52.2	0.8885	NS
Lentils	80.0	Yellow mustard	345	302	49.8	0.9415	$
Lentils	40.0	Oats	370	353	44.9	0.9839	$
Lentils	80.0	Oats	345	367	43.0	0.9443	

*All correlations significant at P=0.05 except as marked $ which are significant at P=0.10 and NS which is not significant.

t y=observed yield for the weed-free treatment; a=predicted weed-free yield; b=regression coefficient; r=correlation $y \hat{y}$.

Field pea yields were dramatically reduced by an increase in volunteer crop density, Fig. 1. Field pea yields were reduced by a density of 50 yellow mustard plants/m^2 to 24% and 14% of the weed-free check for the normal seeding rate and the reduced seeding rate, respectively. The 50 plant/m^2 density for oats reduced field pea yields to 29% and 43% for the normal and reduced seeding rates, respectively.

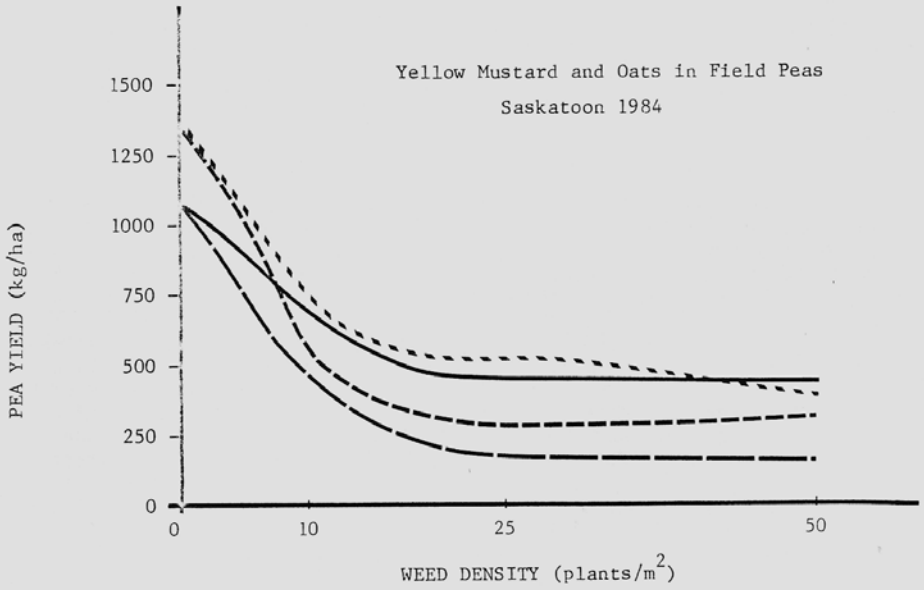

Fig. 1. Relation between volunteer plant population and field pea yield.

Field Pea Yield Equations

- Yield = 1294 - 163.4 X Yellow mustard at normal seeding rate
- Yield = 1048 - 145.0 X Yellow mustard at half seeding rate
- Yield = 1362 - 147.0 X Oats at normal seeding rate
- Yield = 1087 - 98.1 X Oats at half seeding rate

Lentil yield was greatly reduced by poor growing conditions, even in weed-free checks. Figure 2 shows the dramatic reduction in lentil yields with increasing weed density.

Competition from yellow mustard at a density of 50 plants/m^2 reduced lentil yield to essentially zero at both lentil seeding rates. Yellow mustard density of 10 plants/m^2 reduced yields to 25% and 11% of the weed-

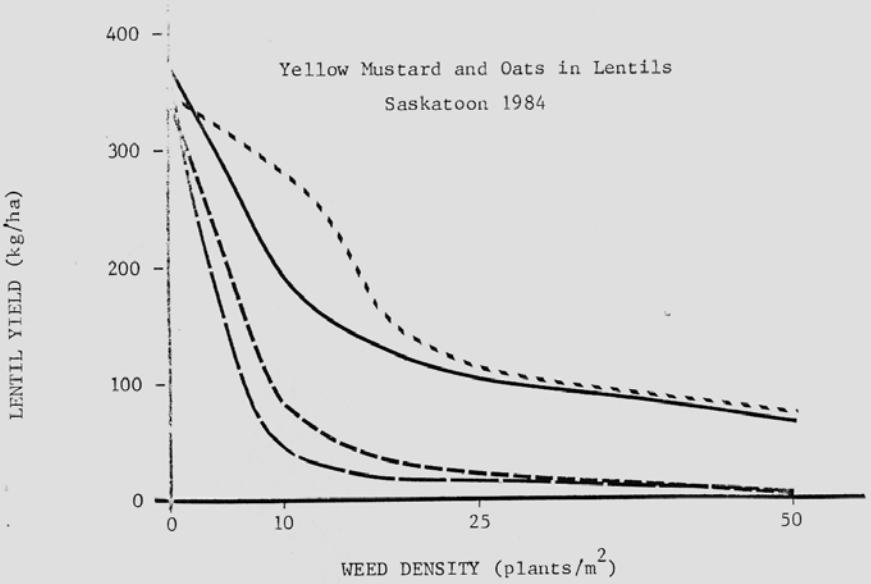

Fig. 2. Relation between volunteer plant population and lentil yield.

Lentil Yield Equations		
	Yield = 302 - 49.8 X	Yellow mustard at normal seeding rate
	Yield = 305 - 52.2 X	Yellow mustard at half seeding rate
	Yield = 367 - 43.0 X	Oats at normal seeding rate
	Yield = 353 - 44.9 X	Oats at half seeding rate

free check for the normal and reduced seeding rates, respectively. Volunteer oats at a 50 plant/m^2 density reduced lentil yields to 19% and 16% of the weed-free check for the normal and reduced seeding rates, respectively.

Conclusion

Field peas and lentils are poor competitors with weeds; lentils are especially non-competitive. Reducing crop seeding rate to half of normal significantly reduced field pea yield but not lentil yield. Lentil yield being unresponsive to seeding rate due to the crop's poor competitiveness and poor growing conditions. Yellow mustard tends to reduce crop yields more severely than do oats. Densities responsible for economic threshholds appear to be quite low in both peas and lentils.

Further work is suggested into the affect of lower weed densities to obtain more precise information on economic threshholds of weed competition in field peas and lentils.

HERBICIDAL CONTROL OF SILVERLEAF NIGHTSHADE

Robert E. Stubblefield and Ronald E. Sosabee[1]

Silverleaf nightshade (Solanum elaeagnifolium Cav.) has become a severe perennial weed problem on both croplands and rangelands infesting approximately 500,000 acres in Texas alone. This weed has become an economically important weed problem because it reduces harvestable crop yields through competition and has possible toxic effects when grazed by sheep.

The purpose of this study was to determine the total non-structural carbohydrates (TNC) at different phenological stages of growth, the influence of irrigation on TNC trends, and evaluation of the most appropriate time for control with a foliar applied herbicide. The experimental design was completely randomized consisting of four treatments and three replications. The treatments consisted of monthly applications (June through October, 1984) of glyphosate ([N-(phosphonomethyl) glycine]) at rates of 0, 1, 2, and 4% (v/v). A surfactant (AG 98) was added to each herbicide solution (1% v/v). Plots were 0.01 acre in size. Dryland plots received only precipitation while the irrigated plots were artificially watered periodically to maintain field capacity soil water and optimum growing conditions. Preliminary evaluations of shoot mortality were made 45 days post herbicide application and after frost. Ten plants were harvested from the irrigated and nonirrigated sites on each application date for TNC analysis. The plants were immediately dried in a forced-air oven at 60°C. They were subsequently dissected into stems and rhizomes, the major carbohydrate storage tissue. Each plant sample was ground to pass through a 40-mesh screen and stored in amber vials until they could be analyzed. TNC were extracted by acid hydrolysis and measured spectrophotometrically using anthrone as the reagent.

Environmental parameters measured at the time of herbicide application were soil temperature and soil water content. Both were measured at depth of 6, 12, and 18 inches. Soil temperature was measured with a glass, mercury-filled laboratory thermometer inserted at prescribed depths in a hole made with a 0.375-inch steel shaft. Soil water content was measured gravimetrically.

Soil water content appears to be the most influential environmental factor relating to silverleaf nightshade control with glyphosate. A linear relationship exists between soil water content (%) and mortality (%). On the dryland site, soil water content was higher (11.7%) in August than in any other month. Post spray evaluations on the dryland site revealed that herbicides applied in August produced a greater herbicidal response. All rates of glyphosate on the irrigated site were more effective (shoot mortality) than on the dryland site. TNC in both shoots (excluding leaves) and rhizomes were lowest in June and July and increased in August and September, especially in the irrigated plants, indicating translocation is throughout the entire plant and not to a particular sink such as shoot production, flowering, etc.

Timing of herbicide application to coincide with TNC translocation throughout the plant, particularly to perennating organs, and with environmental conditions, particularly a high soil water content, enhances the effectiveness of the herbicide and increases root mortality.

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[1]Range & Wildlife Mgt. Dept., Texas Tech. Univ., Lubbock, TX.

STATUS OF NIGHTSHADE (*Solanum spp.*) CONTROL RESEARCH FOR SAN JOAQUIN VALLEY GROWERS

Harold M. Kempen and Peter Belluomini[1]

For over a decade, University of California Cooperative Extension researchers have focused on control of nightshades in several annual crops. the black nightshades *Solanum nigrum* L. and/or *S. americanum*, usually are intermixed, most widely spread and most prolific in their seed production. Hairy nightshade (*S. sarrochoides* Sendt.) is as prolific but not so widespread. *Solanum* species have been the major problem weeds in cotton, beans, tomatoes, onions, garlic, potatoes, peppers, and melons since control of summer grasses and pigweeds was achieved with selective herbicides, such as trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine), EPTC (*S*-ethyl dipropylthiocarbamate), napropamide (2-(α-napthoxy)-*N*,*N*-diethylpropionamide), and DCPA (dimethyl tetrachloroterephthalate). In beets and tomatoes, pebulate (*S*-propyl butylethylthiocarbamate) will control hairy nightshade as will EPTC in potatoes, if timing and application are appropriate.

Our research effort has led to grower acceptance of the following practices. 1. Beans: alachlor (2-chloro-2',6'-diethyl-*N*-(methoxymethyl) acetanilide)), metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl-*N*-(2-methoxy-1-methylethyl) acetamide), or ethalfluralin (*N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine). 2. Cotton: prometryne (2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine), followed by sprinkling (control is erratic if no overhead moisture is applied after planting into moist soil). 3. Beets: pyrazon (5-amino-4-chloro-2-phenyl-3(2H)-pyridazinone) or ethofumesate ((±)-2-ethoxy-2, 3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate) has been an established practice. 4. Garlic: bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) or DCPA (DCPA works if sprinkled repeatedly). 5. Lettuce: pronamide has been a standard for years. 6. Melons: no herbicides. 7. Onions: oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) was recently added to our arsenal; bromoxynil, sulfuric acid and chloroxuron (3-(*p*-(*p*-chlorophenoxy)phenyl)-1.1-dimethylurea) were usually too early or provided no lasting control. 8. Peppers: no herbicides. 9. Tomatoes: no herbicides.

Since cotton is our major crop, finding an economical control technique was most important. Growers reported spending as much as $100/A when prometryne failed. Research has shown that MSMA (monosodium methanearsonate) or DMSA (disodium methanearsonate) applied over-the-top (OT) on cotton at the 1-2 leaf stage, followed by a second post-directed-spray (PDS) 2-4 weeks later could control black nightshades. Previous studies on yellow nutsedge control have shown that yield reduction does not occur when one OT treatment is used and that PDS treatments are safe and acceptable (residue is limited) to first bloom. This technique offers great potential as an alternative to prometryne when no rains occur after planting.

On tomatoes, research by Dr. Art Lange and us has been adapted by innovative growers. The technique involves applying metham (sodium methyldithiocarbamate) on a 6-inch band, then covering over with 8-16 inches of soil, removing it two weeks later when planting. Soils need to be very moist before treatment. A rate of 7 gallons/crop acre seems adequate (70 gpa broadcast).

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[1]Univ. of California Cooperative Extension, Bakersfield, CA.

This same technique can be used on melons, but would be more expensive on peppers because the beds are less wide. On onions, research has refined the usage of oxyfluorfen to permit safe usage by splitting applications and applying by chemigation. When rates of ¼ lb/A are applied, excellent residual control is effected. Research and commercial usage also confirm that bromoxynil is safer and more effective as a chemigation treatment.

EFFECTS OF MOISTURE STRESS ON THE REPRODUCTIVE ABILITY OF DOWNY BROME

J.M. Richardson, L.A. Morrow and D.R. Gealy[1]

Hydroponically-grown downy brome (Bromus tectorum L.) plants were stressed by adding PEG-8000 to the nutrient solution. Solution water potentials of -0.1, -0.5, and -1.1 MPa were maintained for 7-day intervals at tiller elongation, anthesis, or seed fill. On day 7, apparent photosynthesis (AP) and diffusive resistance (DR) of flag leaves were not affected by the -0.1 MPa treatment. The -0.5 MPa treatment reduced AP by more than 50% and increased DR by more than 300%, compared to control plants. The -1.1 MPa treatment reduced AP by more than 80% and increased DR by more than 2000%, compared to control plants. Plants were released from moisture stress and allowed to complete their life cycles. Mature panicles of plants subjected to -1.1 MPa at culm elongation and anthesis had partial to total loss of seed formation. Photomicrographs of paraffin-embedded spikelets from stressed plants indicate that pollen abnormalities may preclude seed formation.

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[1]Agron. & Soils, Dept., Washington State Univ., and USDA-ARS, Pullman, WA.

EFFECT OF SUBLETHAL RATES OF 2,4-D ON FIELD BINDWEED (Convolvulus arvensis L.) MERISTEMS AND GLYPHOSATE TRANSLOCATION

T.C. Laridson, E.E. Schweizer, and G.L. Orr[1]

Apical dominance exerted by field bindweed (Convolvulus arvensis L.) shoots may be a factori regulating dormancy of root buds. Because 2,4-D (2,4-dichlorophenoxyacetic acid) is known to affect apical dominance, greenhouse studies were undertaken to determine the effect of 2,4-D on meristems and translocation of glyphosate (N-(phosphonomethyl)glycine) on field bindweed. Six-week-old field bindweed plants were sprayed with 0, 1, 5, 10, 50, 100, 500, 1000, and 5000 ppmw of 2,4-D in water. Two weeks after

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[1]Colorado State Univ. and USDA-ARS, Fort Collins, CO.

spraying, the percentage of leaves having axillary meristems increased from 8.5% at 0 ppmw 2,4-D to 15.8% at 1000 ppmw. Visible buds per root increased from 10.8 at 0 ppmw 2,4-D to 28.3 at 100 ppmw, then declined at higher rates. In order to study the effect of 2,4-D on glyphosate translocation, 6-week-old plants were sprayed first with 0, 25, 50, 100, and 200 ppmw 2,4-D; 4 days later 0.1 uCi ^{14}C-glyphosate was applied to each plant. Three days after glyphosate application ^{14}C found in the roots increased from 3.5% of total ^{14}C at 0 ppmw 2,4-D to 11.3% at 200 ppmw. Percent ^{14}C in meristems declined from 2.7% at 0 ppm 2,4-D to 0.7% at 200 ppm. Sublethal rates of 2,4-D may alter normal patterns of glyphosate distribution in field bindweed, resulting in an increased concentration of glyphosate in the roots. Changes observed in glyphosate translocation due to application of 2,4-D may result from disrupted apical dominance.

UV-A INITIATION OF FREE RADICALS IN VITRO BY NITRODIPHENYL ETHER HERBICIDES

M.E. Hogan and G.L. Orr[1]

Photooxidation of ß-carotene in micelles is stimulated by nitroDPEs. NitroDPEs act catalytically; i.e., undergo reduction to the nitro radical anion and re-oxidation aerobically. Oxygen is consumed during the course of the reaction. Oxygen participation likely involves the nitro radical anion. Particular oxygen species have been probed using scavengers of hydroxyl radicals, molecules with superoxide dismutating activity, compounds which alter singlet oxygen chemistry and catalase. ß-Carotene photooxidation is inhibited by α-T, BHA/BHT, DPPD, ethoxyquin, and ascorbate. Inhibition with ascorbate, GSH, cysteine, DTT, and d-penacillamine suggest the chemistry of this system occurs near the micellar surface. Confirmation of phosphorescent product(s) has been made. Thus, it is believed ground state ß-carotene acts as an electron donor to the excited singlet state of the nitroDPE yielding a charge complex. The presence of PUFA in the ß-carotene/detergent micelle results in initiation, propagation, and termination of radical reactions with this components of membrane lipids. A model to explain the chemistry of nitroDPE action <u>in vitro</u> is presented.

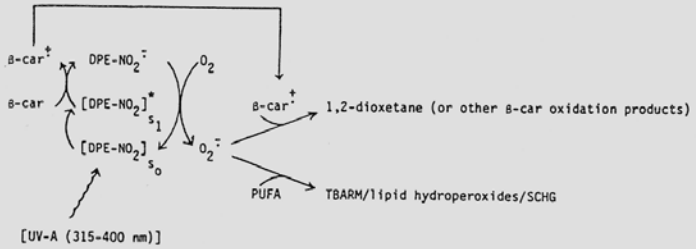

Fig. 1. Working hypothetical model used to explain UV-A photooxidation of ß-car in Triton X-100 micelles by nitroDPE herbicides and initiation of lipophilic free radical reactions with PUFA.

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[1]Colorado State Univ., Fort Collins, CO.

AC 252,925: A NEW, BROAD-SPECTRUM, NON-SELECTIVE HERBICIDE FOR NONCROP USES

D.R. Colbert, R.S. Nielsen and A.M. VanCantfort[1]

Abstract. AC 252,925 is a broad-spectrum, non-selective herbicide developed by American Cyanamid Company for total vegetation control. Results of trials established in several Western states demonstrated AC 252,925 to be effective in controlling a large variety of annual and perennial grasses and broadleaves, including many difficult-to-control species. Annual sowthistle (Sonchus oleraceus), hare barley (Hordeum leporinum), little mallow (Malva pariflora), henbit (Lamium amplexicaule), stinging nettle (Urtica dioica), shepherds purse (Capsella bursa-pastoris), fiddleneck (Ampsinckia spp.) and annual bluegrass (Poa annua) were controlled with 1.0 lb ai/acre. Lower rates controlled field bindweed (Convolvulus arvensis), yellow starthistle (Centaurea solstitialis), milk thistle (Silybum marianum), common chickweed (Stellaria media), wild mustard (Sinapis arvensis), prickly lettuce (Lactuca serriola), filaree (Erodium spp.) and common groundsel (Senecio vulgaris).

The herbicide provides foliar systemic activity as well as soil residual control of weeds and can be applied pre- or postemergence. However, postmergence application is the method of choice. The active ingredient is absorbed readily by both roots and foliage. Translocation occurs rapidly with accumulation in the meristematic regions. Although plant growth ceases shortly after application, kill is slow. Applications when plants are actively growing are most effective and give rapid evidence of activity.

[1]American Cyanamid, Princeton, NJ.

EFFECTS OF PROMETRYN APPLIED IN THE IRRIGATION WATER ON FURROW IRRIGATED COTTON AND RESIDUE PERSISTENCE

William H. Rademacher and Keith C. Hamilton[1]

Herbigation, or the application of herbicides in the irrigation water, is a relatively new concept in weed control technology. Increased interest in herbigation has been shown in the last five years due to rising fuel, labor and equipment costs associated with herbicide application. Most current research has focused on sprinkler irrigation systems for use in applying herbicides. Some work has been done using drip or trickle irrigation. Since the late 1960's a gravity flow system, flood irrigation, has been used to appoly the herbicide EPTC (S-ethyl dipropyl carbamothiote).

Recently many individual farmers have begun using the irrigation water in furrow irrigated cotton (Gossypium hirsutum L.) to apply a selected group of pre-emergence herbicides. Weed control has been reported to be good but concern has been expressed over possible residue carryover to a subsequent planted small grain crop.

[1]Plant Science Dept., Univ. of Arizona, Tucson, AZ.

Prometryn (N,N'-bis(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine) is one of the herbicides being used by these farmers. This study was undertaken to look at the affects of prometryn applied in the irrigation water on furrow irrigated cotton and possible residue carryover.

Two locations were selected for the study. A field of 3.3 ha with a soil type of sandy loam was chosen at the University of Arizona Maricopa Agricultural Research Center. The other location selected was a field 2.1 ha in size, with a clay loam soil and was located at the University of Arizona Marana Agricultural Research Center. Plots at both locations were twelve rows wide and ran the length of the field. There were four treatments at Maricopa consisting of:

Treatment 1: 2.3 kg/ha prometryn postemergence directed spray.
Treatment 2: 4.5 kg/ha prometryn water run at the 4th irrigation.
Treatment 3: 4.5 kg/ha prometryn water run at the 5th irrigation.
Treatment 4: 2.3 kg/ha prometryn water run at the 4th and 5th irrigation.

Three treatments were used at the Marana location:

Treatment 1: 2.3 kg/ha prometryn postemergence directed spray.
Treatment 2: 4.5 kg/ha prometryn water run at the 2nd irrigation.
Treatment 3: 2.3 kg/ha prometryn water run at the 2nd and 3rd irrigations.

The treatments at Marana were made 2-4 weeks later than those at the Maricopa lcoation. This occured due to a high amount of precipitation (18 cm) that fell at Marana. This decreased the number of irrigations needed at Marana and increased the time interval between irrigations. Also the cotton at Marana was planted approximately 2 weeks later than the cotton at Maricopa.

The commercial formulation Caporal 4L was used in the study. It was mixed in a 1:1 ratio with water in a 13 liter knapsack sprayer under constant pressure and applied through a single boom with an 8003 nozzle tip. A timed application was made to the water in each furrow. The point of application was adjacent to the first cotton plant at the ditch end of each field. The prometryn was applied after two-thirds of the time required to irrigate a plot had elapsed.

Three factors were evaluated in the cotton study: weed control, prometryn phytotoxic symptoms in the cotton, and seed cotton yield. The weeds evaluated were Wrights groundcherry (Physalis wrightii Gray) and woolly morningglory (Ipomea hirsutula Jacq. f.). Initial weed estimations were performed in all plots prior to any treatment applications. Weed estimations of morningglory were difficult because of a low population and thus rating control of this weed was inconclusive. Within two weeks after the application of 2.3 kg/ha prometryn water run and 4.5 kg/ha prometryn water run all Wright's Groundcherry plants were killed. Individual morningglory plants observed were less severely injured. Seedling morningglory was killed but older plants were not. Symptoms in the older plants ranged from slight chlorosis of leaves to complete dissication of leaves. Control of all weeds present was nearly 100% across all treatments at both locations.

The second factor evaluated in the cotton study was phytotoxic symptoms in the cotton due to prometryn. The following tables summarize the ratings of symptoms at both locations.

Ratings of Prometryn Symptoms in Cotton, Maricopa

	Mean[a]
2.3 kg/ha prometryn postemergence directed spray	0.4A
4.5 kg/ha prometryn water run at 4th irrigation	0.1B
4.5 kg/ha prometryn water run at 5th irrigation	0B
2.3 kg/ha prometryn water run at 4th & 5th irrigations	0B

[a]0 = no symptoms; 10 = death
[a]Means followed by same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Ratings of Prometryn Symptoms in Cotton, Marana

	Mean[a]
2.3 kg/ha prometryn postemergence directed spray	0.6A
4.5 kg/ha prometryn water run at 2nd irrigation	0.3A
2.3 kg/ha prometryn water run at 2nd & 3rd irrigation	0.5A

0 = no symptoms; 10 = death
[a]Means followed by same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

The third factor evaluated was seed cotton yield. Whole plots were harvested and weighed. No statistical difference in yield between the treatment at Maricopa was observed. No statistical difference in yield between the treatments was observed at the Marana location.

For the residue study barley was planted at both locations following the harvest of the cotton. Damage to the barley from prometryn residue was rated when the barley was 8-10 cm tall. Significant damage was seen at the Marana location in the plots where prometryn was water run during the cotton study. However, no damage to the barley was seen at the Maricopa lcoation except for a very slight amount of damage at the head end of the field where the prometryn had been applied to the water in the furrow during the cotton study. The following table is a summary of the barley damage ratings at the Marana location.

It was noted that at the Marana location there was significantly less damage to the barley in the last one-third of the water run plots compared to the upper two-thirds of these plots. Two possible reasons are given for this phenomenom. The first reason is that the prometryn settled out from the irrigation water in the first one-half to two-thirds of the plot and never reached the lower end. The second reason is that if the chemical did reach the lower end of the field it was degraded more because this part of the field was kept at a higher moisture level. This higher moisture level resulted from the field being lower at that end and water tended to acumulate there from the rain and irrigations.

Barley Rating Means, Marana

	Jan. 16[a]	Feb. 13
2.3 kg/ha prometryn postemergence directed spray	1 A	1 A
4.5 kg/ha prometryn water run at the 2nd irrigation	6 B	5 B
2.3 kg/ha prometryn water run at the 2nd & 3rd irrigation	6 B	7 B

0 = no damage; 10 = death

[a]Means withn same column and followed by same letter are not significantly different and 1% level as determined by Duncan's multiple range test.

In trying to determine why there was no damage to the barley crop at Maricopa while a significant amount was seen at Marana, we came to two conclusions. First, the barley at Marana was planted on beds while the barley at Maricopa was planted on the flat. The barley planted on beds was more susceptable to any residue present in the soil. The second conclusion is that because the prometryn was applied 2-4 weeks earlier at Maricopa there was more time for degradation to occur at that location.

In summary, we conlcuded that prometryn can be applied in the irrigation water to furrow irrigated cotton safely. Excellent control of Wrights groundcherry cna be achieved while control of woolly morningglory is inconclusive. No adverse affects on yield will occur. However, because of the significant amount of damage that occured to the barley at one location from residue carryover, caution must be exercised when planting a small grain crop in rotation when prometryn has been applied in the irrigation water to a previous crop. If prometryn is to be applied in the irrigation water it should be applied early enough in the cotton growing season to allow enough time for degradation to occur if a small grain crop is to follow the cotton.

LENTIL YIELD AS INFLUENCED BY DURATION OF WILD OAT INTERFERENCE

W.S. Curran, L.A. Morrow, and R.E. Whitesides[1]

Studies were conducted to evaluate the effect of wild oat (Avena fatua L.) interference in lentils (Lens culinaris Medik). In the field, two wild oat densities, 32 and 65 plants/m^2, and 5 removal intervals, 0, 3, 5, 7 weeks and full season interference were used. A wild oat density of 32 plants/m^2 reduced lentil yield 34% by the 7th week and 42% with full season interference. With 65 plants/m^2, lentil yield decreased 59% by the 7th week and 67% with the full season duration treatment. In addition, biological yield, plant dry weight, and pods/plant were significantly reduced after 5 weeks. Growth chamber experiments showed no differences in lentil dry weight up to 4 weeks of wild oat interference. Based on the weed densities in this study, wild oat control measures may be delayed for several weeks after crop emergence without reducing lentil yield.

[1]Agronomy & Soils Dept., Washington State Univ., Pullman, WA.

WINTER WHEAT RESPONSE TO TEN HERBICIDES APPLIED AT THREE GROWTH STAGES

D.A. Martin, S.D. Miller and H.P. Alley[1]

Abstract. Phenoxy herbicides have been widely used in small grain production since the late 1940's. Subsequently, these compounds have been thoroughly researched in their effects on crop plants. However, more recent cereal herbicides have not been researched as thoroughly. This deficiency of information promoted the initiation of research to evaluate the response of winter wheat to several herbicide treatments.

'Buckskin' winter wheat was established at Chugwater, WY in October 1983 to evaluate its response to ten herbicide treatments applied at three growth stages. Herbicide treatments were applied at maximum recommended rates to produce observable effects. The growth stages at herbicide application were 2-4 leaf, 5-7 tillers, and early boot. Treatments were made with a CO_2 pressurized knapsack sprayer which delivered 20 GPA at 40 psi. Plots were kept weed free throughout the season by hand-hoeing to remove the influence of weed competition on crop response evaluations. The experiment was designed as a randomized complete block in a factorial arrangement, and analyzed as the factorial plus an added check. Means were separated using the Least Significant Difference at the .05 level of significance. Plots were harvested in August 1984 with a KEM plot combine. Prior to harvest, ten heads were taken from each plot to evaluate yield components. Seed protein content was determined using a Technicon Auto-analyzer for quantitative analysis.

2-4 Leaf Stage. Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) + MCPA ((4-chloro-2-methylphenoxy)acetic acid) at 0.4 lb/A was the only treatment which did not decrease yield. Bromoxynil + MCPA at 0.5, 2,4-D amine at 1.0, 2,4-D ((2,4-dichlorophenoxy)acetic acid) ester at 0.375, and dicamba (3,6-dichloro-2-methoxybenzoic acid) + MCPA at 0.125 + 0.375 lb/A decreased heads/meter, while 2,4-D amine at 1.0 lb/A increased seeds/head. Differences in weight of 200 seeds were not significant. Bromoxynil + MCPA at 0.5 and 2,4-D ester at 0.375 lb/A increased seed protein content.

5-7 Tiller Stage. Bromoxynil at 0.5, dicamba at 0.125, MCPA at 0.5, picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) + 2,4-D amine at 0.0156 + 0.375, and dicamba + 2,4-D amine at 0.125 + 0.375 lb/A decreased yield. Bromoxynil + MCPA at 0.5, 2,4-D amine at 1.0, and 2,4-D ester at 0.375 lb/A decreased heads/meter, while MCPA at 0.5 lb/A increased seeds/head. Differences in weight of 200 seeds were not significant. Bromoxynil + MCPA at 0.5, dicamba at 0.125, and picloram + 2,4-D amine at 0.0156 + 0.375 lb/A increased seed protein content.

Early Boot Stage. Dicamba + 2,4-D amine at 0.125 + 0.375 lb/A was the only treatment that did not decrease yield. Bromoxynil + MCPA at 0.5 and chlorsulfuron at 0.042 lb/A decreased heads/meter, while bromoxynil + MCPA at 0.5, dicamba at 0.125, 2,4-D ester at 0.375, MCPA at 0.5, and dicamba + MCPA at 0.125 + 0.375 lb/A increased weight of 200 seeds. Dirferences in seeds/head were not significant. Bromoxynil at 0.5, dicamba at 0.125, 2,4-D ester at 0.375, picloram + 2,4-D amine at 0.0156 + 0.375, dicamba + 2,4-D amine at 0.125 + 0.375, and dicamba + MCPA at 0.125 + 0.375 lb/A increased seed protein content.

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[1]Plant Science Division, Univ. of Wyoming, Laramie, WY.

Herbicide treatments decreased winter wheat yield in applications at all three stages of growth, when applied at maximum recommended rates under weed free conditions, though all differences were not significant. Herbicide applications at the 2-4 leaf stage showed the greatest reduction in yield, while the 5-7 tiller stage was shown to be the safest time for application of herbicides in this study. Herbicide treatments increased seed protein content under conditions in this experiment, though all were not significantly different from the untreated check. Increases in seed protein content were most evident in treatmnets made at the early boot stage of growth.

PATTERNS OF SOIL MOISTURE DEPLETION BY DOWNY BROMEGRASS, JOINTED GOATGRASS AND RYE

D.L. Coble and P.K. Fay[1]

Introduction

Dryland small grain production is the principle form of crop production practiced in Montana where over 5.2 million ha of land is in production. Montana receives low amounts of seasonal rainfall and frequent droughts. These factors make water the most limiting resource for small grain production.

Crop water requirements usually exceed growing season precipitation, therefore, grain producers must rely on stored soil moisture for production. Weed competition with crops for valuable stored soil water often limits crop yields. Presently, little information is available indicating the amount of water lost to weed use and the effect water competition has on crop production. The amount of water lost to weeds must be determined to help efficiently manage water resources and enhance grain production.

Materials and Methods

A program to determine the patterns of soil moisture depletion by downy brome (*Bromus tectorum*), jointed goatgrass (*Triticum cylindrica*), and rye (*Secale cereale*) has been initiated at Montana State University. The objectives of the program are to measure the amount and patterns of weed water use and to determine the effects of water competition on crop production.

Field plots were established in Bozeman, MT in the fall of 1983. Plot design was a split block with weeds the main treatment and winter wheat, planted at 60 lbs/A, the subplot treatment. Plot size was 8 ft x 8 ft with an 8 ft buffer tilled around each plot. Treatments were a fallow check plot, downy brome, downy brome with wheat, jointed goatgrass, jointed goatgrass with wheat, rye, and rye with wheat. Each treatment was replicated four times.

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[1]Plant and Soil Science Dept., Montana State Univ., Bozeman, MT.

Soil moisture was measured on each plot weekly throughout the growing season with a Troxler neutron probe. Access tubes were installed in the center of each plot. The access tubes allowed for neutron probe readings to a depth of 150 cm. An initial probe reading was made at a depth of 23 cm and subsequent readings were made every 15 cm to a depth of 150 cm. Grain yields and above-ground biomass were harvested from each plot at the end of the growing season.

Results and Discussion

Water use and biomass production were used to determine the water use efficiency (WUE) of each treatment. Rye had the highest WUE rating of 1001 kg/ha/cm of water followed by wheat at 840 kg/ha/cm. Plots containing wheat/rye and wheat/jointed goatgrass had significantly lower WUE ratings than plots with wheat growing alone.

Winter wheat production was significantly reduced when wheat had to compete with rye or jointed goatgrass. Rye reduced winter wheat yields by over 50%.

Effective root growth was determined for each treatment by comparing soil water content by depth for each sampling date. A significant reduction in water content at a depth indicated effective root growth and plant water use at that zone. Wheat plots with weed competition tended to have reduced rates of effective root growth when compared to wheat plots without weeds.

Total water extracted from each depth was determined for all treatments. All crop and crop/weed obtained 50% treatment of their water from the top 60 cm of soil. Weed competition had no effect on the ultimate pattern of water use by wheat when compared to wheat grown without weed competition.

Conclusion

Monitoring water use patterns and patterns of soil water depletion will aid in the efficient management of this valuable resource. Quantification of weed water use will additionally aid crop production.

CONTROL STRATEGIES FOR YELLOW FOXTAIL (*Setaria lutescens*) IN ESTABLISHED ALFALFA HAY

Ron Vargas[1]

Yellow foxtail (*Setaria lutescens*) is becoming one of the number one summer annual grassy weed pests in a majority of th ealfalfa producing areas of California. Twenty counties, representing approximately 60% of the alfalfa hay acreage, recognize yellow foxtail as either the number one or one of the top three grassy weed problems during the summer months. Infestations can lead to early crop removal or at the very least, minimize alfalfa yields and quality to such an extent that the crop becomes

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[1]U.C. Cooperative Extension, Madera County, University of California.

economically unfeasible to produce. The sharp awns on the flower head reduce palatability by irritating or ulcerating the insides of the mouths of livestock.

Control strategies and programs have not given acceptable or satisfactory results. The use of soil residual herbicides applied in combination with a contact herbicide has given growers excellent control of many winter annual weeds and early germinating summer annual broadleaves, but has little effect on the control of early germinating yellow foxtail. In some situations germination can be earlier and population greater due to the open canopy and warmer soil temperatures created by the use of herbicides. Control can be achieved of grasses not yet germinated by the use of herbicides applied in the irrigation water, but due to early germination (mid February) and the timing of the first irrigation this practice is not effective against early germinating yellow foxtail.

Even though yellow foxtail does not start contaminating hay until possibly the third or fourth cuttings, germination occurs early in the spring. Emergence has been documented as early as mid February. Further emergence and growth continues through March and April with tillering and elongation beginning in May. Seedhead production begins in June and continues into November or until the first frost.

A reduction in price for contaminated hay has been documented for both 1983 and 1984. A Sacramento county grower was receiving $40/ton less for contaminated hay when good quality hay was selling for $110.00/ton. In 1984 when good quality hay was selling of $74/ton a Madera County grower was receiving $50/ton for contaminated hay. This is an average loss of $30/ton. Projecting these figures for the twenty counties having a yellow foxtail problem and assuming 4½ tons of infested hay/acre the statewide dollar loss (not including loss of yield due to competition) can be estimated to be 20 million dollars.

Because this grassy weed is becoming a major concern of many alfalfa hay producers and current control programs do not always give satisfactory results, tests have been established throughout the San Joaquin and Sacramento Valleys to compare the efficacy of preemergence and selective postemergence herbicides. Trifluralin (α,α,α-trifluoro-2,6-dinitro,N,N-dipropyl-p-toluidine), pendimethalin (N-1-ethylpropyl)-3,4,dimethyl-2, 6 dinitrobenzenamine), oryzalin (3,5-dinitro-N^4,N^4-dipropylsulfanilamide), prodiamine (2,4-dinitro-N^3,N^3-dipropyl-6-(trifluoromethyl)-1,3-denzenediamine), clopropoxydin ((E,E)-2-1[[1-[(3-Chloro-2-propenyl)oxy]imino]butyl1]-5-[2-(ethylthio)propyl1] 3 hydroxy-2-cyclohexen-1-one), sethoxydim (2-[1-(ethoxyimino)-butyl1]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexene-1-one), fluazifop-P-butyl (butyl(R)-2[4-[[5-(trifluoro-methyl)-2 pridinyl]oxy phenoxy propanate), haloxyfop-methyl (2-[4-(chloro-5-(trifluoro-methyl)-2-pyridinyl)oxy)phenoxy]propionic acid, methyl ester), fenoxoprop-ethyl ((RS)-2-[4-(chloro-1,3-benzoxazol-2-yloxy)phenoxy]propionic acid, ethyl ester), and DPX-Y6202 (2-[4-((6-chloro-2-quinoxalinyl)oxy)phenoxy]propionic acid, ethyl ester) were tested.

Results have indicated that effective yellow foxtail control can be achieved with the DNA herbicides trifluralin granules, pendimethaline and prodiamine when applied during December and January at 2 pounds ai/A and .5 to .75 inches of rainfall or irrigation occurs within 3-5 days after application. Oryzalin gives only early season control, then breaks down to unacceptable control by the end of the growing season. Evaluation in 1984 (Table 1) indicated 80-92% control with trifluralin, prodiamine and pendimethalin on 4/26/84 whereas oryzalin was only exhibiting 70% control at the

TABLE 1

PREEMERGENCE YELLOW FOXTAIL CONTROL IN ALFALFA HAY

DATE OF APPLICATION - 2/2/84
ALFALFA - 4th year, 1-6 inches regrowth

TREATMENTS	#ai/A	Percent Yellow Foxtail Control 4/26/84	Percent Yellow Foxtail Control 8/22/84	Yellow Foxtail Seedheads Per Square Yard 7/16/84
trifluralin (4% granules)	2	92	86	0
trifluralin	3	92	87	0
prodiamine	1	80	70	4.25
prodiamine	2	80	84	.25
pendimethalin	2	87	42	4.25
pendimethalin	3	92	65	.75
oryzalin	2	63	0	35.75
oryzalin	3	70	2	2.5
check	-	0	0	54.0

3 lb/A rate. Seedhead counts in July again indicated excellent control with all materials except oryzalin. Late season evaluations in 8/22/84 indicated good control with trifluralin and prodiamine. Pendimethalin was starting to break down and oryzalin was giving unacceptable control.

This class of dinitroaniline herbicides cna give the alfalfa grower commercially acceptable season long control when applied at the proper time and rates. Good field conditions, uniformity of applications, and timely incorporation by rainfall or irrigation will result in clean, high quality hay cuttings all season long.

Acceptable postemergence control has also been achieved with two sequential applications of clopropoxydin and sethoxydim at .38 lb/ai/A applied after the second and fourth cuttings. Other materials tested have not given acceptable control. Evaluations in 1984 (Table 2) indicated 80-86% control with sethoxydim and clopropoxydin on 6/26/84 with one application of .38 lbs/ai/A just after the second cutting. Fluazifop-P-dibutyl, haloxyfop-methyl, fenoxaprop-ethyl and DPX-Y6202 were only exhibiting 40-50% control. Due to the profuse tillering of the remaining plants and new germination, control of one application of clopropoxydin and sethoxydim were unacceptable by 8/14/84. A second application of .38 lb/ai/A after the fourth cutting maintained control between 88 and 90% with sethoxydim and clopropoxydin. All other materials were exhibiting unacceptable control.

TABLE 2

POSTEMERGENCE YELLOW FOXTAIL CONTROL IN ALFALFA HAY

DATE OF APPLICATION - 1st - 5/24/84 - after second cutting
Yellow foxtail - 2-6" tall with 1-5 tillers
2nd - 7/24/84 - after fourth cutting
Yellow foxtail - tillered

	#ai/A		Percent Yellow Foxtail Control		Yellow Foxtail Seedheads Per Square Yard	
TREATMENTS*	5/24/84	7/24/84	6/26/84	8/14/84	7/17/84	9/17/84
clopropoxydin	.38		86	60	.8	115.5
clopropoxydin	.38	+ .38	86	90	-	15.6
sethoxydim	.38		80	61	.1	70.6
sethoxydim	.38	+ .38	80	88	-	8.3
fluazifop-P-dibutyl	.25		40	33	29.5	1/
haloxyfop-methyl	.25		50	30	10.3	1/
fenoxaprop-ethyl	.25		46	41	31.0	1/
DPX-Y6202	.25		46	30	24.1	1/
check	-		0	0	82.6	302.0

*All treatments - 1 qt. per acre of a paraffin base, petroleum oil, fatty acid surfactant

1/ Visual seedhead numbers were equal to check plot, so counts were not made

Seedhead counts indicated that if a second application was not made, seedhead production is greatly increased within a 60 day period. The untreated control plot increased from 82.6 to 302.0 plants/square yard. Two applications of clopropoxydin at .38 lbs/ai/A reduced the seedhead population from 115.5 to 15.6 and sethoxydim reduced the population from 70.6 to 8.3/square yard.

In summary, effective yellow foxtail control, in established alfalfa hay growing in the Sacramento and San Joaquin Valleys, with postemergence selective grass herbicides can be obtained when:

1. Herbicides are applied to foxtail 2-6 inches tall.
2. Applications are made soon after bale removal, so alfalfa regrowth does not interfere with coverage.
3. Foxtail is not severely stressed for moisture. Applications just after bale removal and previous to irrigation give acceptable control.

4. Sequential applications are made based upon foxtail germination and growth. Applications would normally occur after the second and fourth cuttings when new germination is at its minimum. In areas where seedheads do not contaminate the hay until the fourth cutting one application may be all that is necessary.

EFFECT OF CUTTING FREQUENCY AND TIMING OF IRRIGATION ON GROWTH OF ALFALFA (*Medicago sativa*) AND YELLOW FOXTAIL (*Setaria glauca*).

Robert F. Norris[1]

Abstract. Alfalfa (*Medicago sativa* L. 'Moapa 69') was harvested on 25-, 31-, or 37-day cutting interval. Irrigations following each cutting were the same day as cutting (0-day delay), 7 days after cutting, or 14 days after cutting. A second irrigation was applied per cutting approximately 7 days before the next harvest. Cutting and irrigation schedules were combined in a factorial design, using a randomized complete block layout with four replications. Plot size was 3 m x 10 m. Each plot was in the form of a basin surrounded by a levee, and contained an irrigation riser. Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) was applied to all plots at 0.8 kg/ha during January to control winter annual weeds; no other herbicides were applied. The experiment was continued for three years. Harvesting was by mowing the whole plot area, weighing the total fresh biomass, and taking a subsample on which percent moisture and percent weeds was determined. Timing of irrigation did not alter alfalfa yield. The 25-day cutting cycle resulted in a three-year total yield of 34,000 kg/ha of alfalfa; at the 31-day cutting interval the alfalfa yield was 52,000 kg/ha and at the 37-day interval the yield was 59,000 kg/ha. This yield pattern was seen at all cuttings throughout the duration of the experiment. Yellow foxtail (*Setaria glauca* (L.) Beauv.) cover was visually estimated in mid-summer each year. In the last year the cover was 25, 23, and 20% respectively for the 0-, 7-, and 14-day irrigation regimes. The yellow foxtail cover was 42, 19, and 8% respectively for the 25-, 31-, and 37-day cutting cycles. Yield data showed similar relationships between cutting and irrigation. The three-year grass yields were 2000, 1500, and 1300 kg/ha respectively for the 0-, 7-, and 14-day irrigation regimes. For the 25-, 31, and 37-day cutting intervals the grass yeilds were 3110, 1370, and 380 kg/ha respectively. Yellow foxtail invasion showed an interaction between cutting interval and irrigation regime. At the 31-day cutting interval the grass invasion was greatest when irrigation was immediately following cutting, and was least when irrigation was delayed by 14 days. At the 25-day cutting interval different irrigation regimes had little effect on grass invasion; the effect of short cutting interval not influenced by irrigation. Likewise, there was little effect of irrigation regime at the 37-day cutting interval as grass invasion was too low to measure differences. Estimates of alfalfa vigor were made mid-season by counting the number of stems per crown. In the last year of the experiment delayed irrigation caused only a slight reduction in number of stems per crown, but the 25-, 31-, and 37-day cutting intervals resulted in 7, 14,

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[1]Botany Department, Univ. of California, Davis, CA.

and 16 stems/crown respectively. Alfalfa crowns were exhumed and measured at the end of the experiment. There was no effect of any treatment on crown density. The dry weight per crown was not altered by irrigation regime. At the 25-day cutting cycle the dry weight of each crown was 1.9 g at the 31-day cutting cycle the crowns weighed 2.7 g, and at the 37-day cutting interval each crown weighed 3.3 g. Short cutting interval thus reduced alfalfa yield and crown vigor by approximately 50%. Invasion of yellow foxtail was determined by two different factors. Alfalfa vigor was the largest factor, and was changed in response to harvest interval. Irrigation regime also regulated yellow foxtail invasion, but had no affect on the alfalfa. Invasion of yellow foxtail in California alfalfa was minimized by cutting intervals of 31 or 37 days, and by delaying irrigation following cutting.

TIMING OF NEW PRE-EMERGENCE HERBICIDES FOR YELLOW AND GREEN FOXTAIL CONTROL IN ALFALFA

Jack Orr, Don Colbert and Mick Canevari[1]

Abstract. Yellow foxtail (Setaria glauca) and green foxtail (Setaria viridis) cause severe loss in alfalfa yield and quality. Trifluralin (2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine) 10% granular, 2.0 lbs/A a.i. applied in December gave good foxtail control through September. Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine), emulsifiable concentrate at 2.0 lbs/A a.i. applied at the same time gave good control through June. There was no injury to the alfalfa with either treatment.

Yellow foxtail and green foxtail are the number one weed pests of alfalfa in the Sacramento and San Joaquin Valleys. These weeds cause a severe loss in alfalfa yield, reduce quality and result in severely reduced hay prices.

In 1983, treatments consisting of trifluralin five percent granular, penimethalin and oryzalin (4-(dipropylamino)-3,5-dinitrobenzenesulfonamide) were made the first week in march. Paraquat was added to each treatment since the foxtail had already started germinating the last week in February. Rainfall incorporated the herbicides into the soil. All three herbicides gave excellent control through October of 1983 with no alfalfa injury. The question arose as to the proper time to apply these pre-emergence herbicides for best control.

The study in 1984 consisted of applications being made December 20, 1983, Junuary 20, 1984 and February 20, 1984. December and Junuary treatments were trifluralin at 2.0 and 4.0 lbs/A ai.i.; pendimethaline 2.0 and 4.0 lbs/A a.i.; and oryzalin 2.0 and 4.0 lbs/A ai. February treatments were made with the addition of 1.0 lb/A a.i. treatment of each herbicide. Rainfall was considerably less on the January and February treatments compared to December (Fig. 4).

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[1]Univ. of Calif. Coop. Extension, Sacramento and San Joaquin Counties and American Cyanamid, Lodi, CA.

Results and Discussion

Trifluralin applied in December at 2.0 lbs/A a.i. gave the most consistent season foxtail control, ranging from 86% in April to 88% in June and 80% in October. The January application resulted in 79% control in June, 83% in September and 64% in October. The February application of 2.0 lb/A gave 90% control in June, 92% in September and 75% in October. The 1.0 lbs/A February application gave good control through September, then dropped to 61% in October. There was no injury to the alfalfa with any of the treatments (Fig. 1).

Pendamethalin applied in December at 2.0 lb/A a.i. gave 92% control of foxtail in April, 92% in June and 65% in October. The January treatment resulted in a high of 79% control in July, 61% in August and 38% in October. There was no injury to the alfalfa (Fig. 2).

Oryzalin at 2.0 lbs/A a.i. generally gave poor control (Fig. 3). Oryzalin at 4.0 lbs/A a.i. applied in December was equal to pendamethalin at the 2.0 lbs/A a.i.

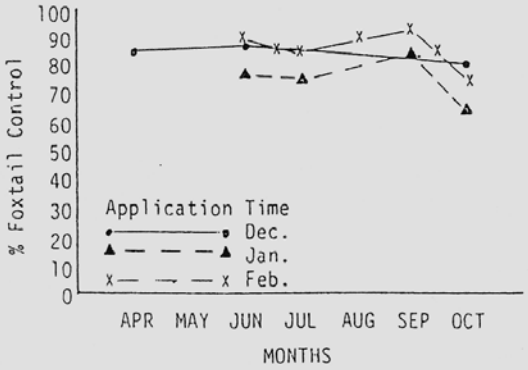

Figure 1. Effects of trifluralin at 2.0 lbs/A on yellow and green foxtail applied in December, January and February to alfalfa.

The results of two years testing indicate trifluralin at 2.0 lbs/A a.i. will give excellent to good control of yellow and green foxtail for the season. Application should be made in mid-December to mid-January, since the foxtail starts germinating towards the end of February. A mid-December to January application would insure rainfall to incorporate the herbicide into the soil.

All three herbicides were tested at the 4.0 lbs/A a.i. rate with significantly increased foxtail control and no injury to the alfalfa.

New pre-emergence herbicides showing promise for foxtail control include cinmethylin (exo-1-methyl-4-(1-methylethyl)-2-[(2-methylphenyl) methoxy]-7-oxabicyclo[2.2.1]heptane) at 2.0 lbs/A a.i.; American Cyanamid 263,499 at 0.1 to 0.4 lb/A a.i. and prodiamine at 1.5 lbs/A a.i. American Cyanamid 264,499 gave initial alfalfa vigor reduction. The alfalfa grew out of this vigor reduction.

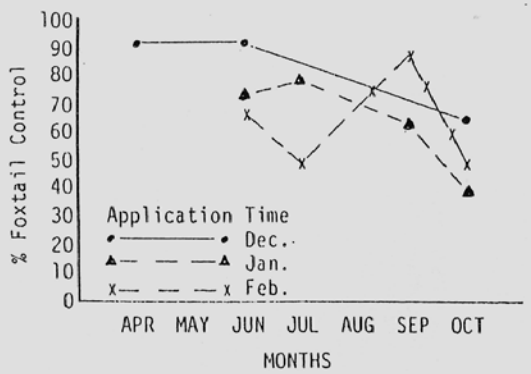

Figure 2. Effects of pendamethalin at 2.0 lbs/A on yellow and green foxtail applied in December, January and February to alfalfa.

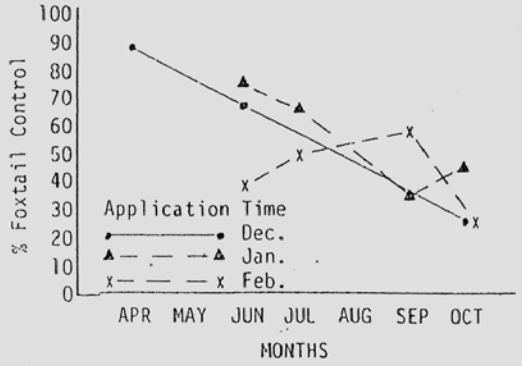

Figure 3. Effects of oryzalin at 2.0 lbs/A on yellow and green foxtail applied in December, January and February to alfalfa.

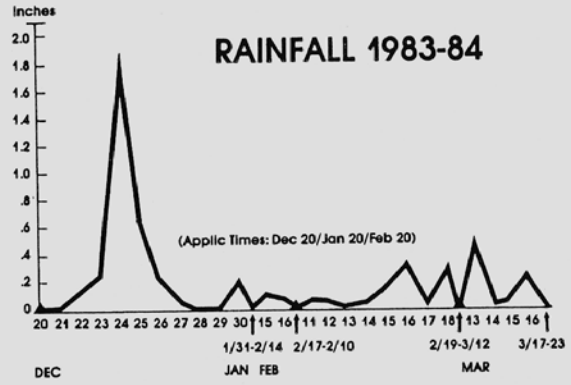

Figure 4.

SYSTEMS FOR THE CONTROL OF JOHNSONGRASS (*Sorghum halepense*)

R.J. Thullen, C.H. Carter, P.E. Keeley and J.H. Miller[1]

Abstract. Trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine), fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone), DSMA (disodium methanearsonate), MSMA (monosodium methanearsonate), and glyphosate (*N*-(phosphonomethyl) glycine) were used singly or in various combinations for the control of johnsongrass (*Sorghum halepense* (L.) Pers. #[2] SORHA). Trifluralin, fluridone, DSMA and MSMA were applied according to the manufacturers' recommendations. Glyphosate was applied by a sprayer as a general over-all spray, by recirculating sprayer, roller applicator, or wiper applicator which restricted the herbicide application to parts of the johnsongrass growing above cotton. Average yields of seed cotton (*Gossypium hirsutum* L. 'Acala, SJ2') from treated plots, except for October-applied glyphosate, were significantly less than the weedfree control. Glyphosate that was sprayed in October (3.4 kg ai/ha) on growing, intact johnsongrass almost eradicated it. This treatment resulted in seed cotton yields in the year after treatment that equalled the yields of cotton grown without johnsongrass competition.

Introduction

Glyphosate, fluridone, trifluralin, DSMA, and MSMA singly or in combination can be used to control johnsongrass in cotton (5, 7, 9, 10) and other crops such as soybeans (1, 2, 3, 8), particularly in the southeastern United States. Even though some of these treatments are registered for the southwest, they have not been satisfactory, especially in California.

Glyphosate does control johnsongrass, but Keeley et al. (6) reported that the yields of cotton were not increased enough to make it a satisfactory control method. In heavily infested fields, overspray or splash from recirculating sprayers injured the cotton itself. Rope-wick applicator treatments were applied too late to prevent early competition between the johnsongrass and the cotton, and many johnsongrass plants escaped treatment.

Fluridone provided excellent control of johnsongrass at Fresno, California (9). A 2.2 kg ai/ha rate of fluridone gave 100% control of johnsongrass grown from rhizomes after a single treatment in two successive years.

While there was interest in using trifluralin at a rate double that used for annual grass control for the control of johnsongrass, such a use was not registered for Arizona or California. However, in the Southeast cotton growing region such double rates of trifluralin were recommended and they were reported as effective if used over 2 or more years (4).

Even though the use of DSMA and MSMA with cultivation to control johnsongrass increased the yield of cotton over cultivation alone, Keeley and Thullen (5) reported that the yield was 40% less than that of johnsongrass free cotton.

Because no one control method for johnsongrass had been found satisfactory, various chemicals were combined and tested as systems for the control of johnsongrass.

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[1]USDA-ARS, Shafter, CA.

[2]WSSA-approved computer code from Important Weeds of the World, 3rd Ed., 1983. Available from WSSA, 309 West Clark St., Champaign, IL 61820

Materials and Methods

In the spring of 1977, a field of Wasco fine sandy loam soil (nonacid, thermic, Typic Torriorthent, 0.5% organic matter) was fumigated with methyl bromide (methyldibromide) and planted with johnsongrass seed in a single row per bed on beds 1 m apart. After the johnsongrass seedlings were growing and the plants were becoming established, 24 plots were etablished in the field, but the treatments were not designated at this time. The plots were eight rows wide and 24.4 m long with 2 additional unplanted rows separating the plots.

As the johnsongrass became established, it was thinned to 10-12 plants per row. At this time, johnsongrass was eliminated in the first and eighth row of each plot and other weeds were removed from the entire plot. Cultivation, hoeing, and trifluralin (preplant, incorporated, 0.7 kg ai/ha unless otherwise stated) were used to keep other weeds and seedling johnsongrass out of the plots. In three of the systems trifluralin was used at various rates (Table 1) as a treatment to control established johnsongrass as well as for general weed control.

Table 1. The treatments and crop used in the Systems in the individual years.

System		Treatment			
name	Year	Herbicide	Appl. method	Rate	Crop
				(kg/ha)	
Weedfree	1978	Trifluralin	Preplant[a]	1.1	Cotton
	1979	Trifluralin	Preplant[a]	0.7	Cotton
	1980	Trifluralin	Preplant[a]	0.7	Cotton
	1981	Trifluralin	Preplant[a]	0.7	Cotton
October-glyphosate	1978	Glyphosate	October Over-the-top[b]	3.4	None
	1979	Trifluralin	Preplant[a]	1.1	Cotton
	1980	Glyphosate	October Over-the-top[b]	3.4	None
	1981	Trifluralin	Preplant[a]	0.7	Cotton

2X-trifluralin	1978	Trifluralin	Layby	1.1	None
	1979	Trifluralin	Preplant[a]	1.4	Cotton
	1980	Trifluralin	Preplant[a]	1.4	Cotton
	1981	Trifluralin	Preplant[a]	1.4	Cotton
Fluridone	1978	Fluridone	Preplant[a]	0.9	
		Trifluralin	Preplant[a]	0.7	Cotton
	1979	Fluridone	Preplant[a]	0.3	
		Trifluralin	Preplant[a]	0.7	Cotton
	1980	Fluridone	Preplant[a]	0.3	
		Trifluralin	Preplanta	0.7	Cotton
	1981	Fluridone	Preplant[a]	0.3	
		Trifluralin	Preplant[a]	0.7	Cotton
2X-trifluralin-plus	1978	Trifluralin	Preplant[a]	1.4	
		DSMA	Over-the-top[b]	3.1	
		MSMA	Directed	3.4	
		Glyphosate	Recirculating Sprayer	3.4	Cotton
	1979	Trifluralin	Preplant[a]	1.4	
		Glyphosate	Roller	(5% v/v)	Cotton
	1980	Trifluralin	Preplant[a]	1.4	
		Glyphosate	Wick[c]	(33% v/v)	Cotton
	1981	Trifluralin	Preplant[a]	1.4	
		Glyphosate	Wick[d]	(33% v/v)	Cotton
Trifluralin-plus	1978	Trifluralin	Preplant[a]	0.7	
		Glyphosate	Spring, preplant		

		Over-the-top[b]	2.2	
	DSMA	Over-the-top[b]	3.1	
	MSMA	Directed	3.4	
	Glyphosate	Recirculating Sprayer	3.4	Cotton
1979	Trifluralin	Preplant[a]	0.7	
	Glyphosate	Roller	(5% v/v)	Cotton
1980	Trifluralin	Preplant[a]	0.7	
	Glyphosate	Wick[c]	(33% v/v)	Cotton
1981	Trifluralin	Preplant[a]	0.7	
	Glyphosate	Wick[d]	(33% v/v)	Cotton

[a]Incorporated to 7.6 cm depth with a power driven-tiller.

[b]'Over-the-top' is a spray pattern that covers all vegetation in the plot.

[c]Gravity-fed ropewick, 38 cm of head, two passes per row in opposite directions.

[d]Ropewick pressurized to 51 cm of head, two passes per row in opposite directions.

In the fall of 1977, johnsongrass rhizome samples were taken from three plots to check for uniformity of stand. The weight of the rhizomes were 12.3, 12.6 and 12.2 mg/ha for each of the three sample areas. However, it was decided that the population of johnsongrass was unrealistically large. Twelve plots were treated with glyphosate (3.4 kg ai/ha) in October, 1977 to reduce the population. The was not considered an experimental treatment at this time, but was thought of as a management tool to control just enough johnsongrass so the plots would have a realistic population in the spring of 1978. This single application to intact, growing johnsongrass almost eradicated the stand.

In the spring of 1978, 4 plots were selected as the Weedfree System (Weedfree) from the above glyphosate treated plots which were now free of johnsongrass. The details of all treatments for each system are in Table 1. Four other plots were designated as the October-glyphosate System (October-glyphosate) and replanted with johnsongrass rhizomes. The johnsongrass was allowed to grow without a competing crop or herbicide treatment during the 1978 growing season. In October 1978, after the johnsongrass was well established, these plots were sprayed with glyphosate (3.4 kg ai/ha) duplicating the conditions and treatment used in October

1977. In the spring of 1979, these plots were treated with preplant, incorporated trifluralin (1.1 kg ai/ha) and planted to cotton. In the spring of 1980, the October-glyphosate System was replanted with johnsongrass rhizomes and not treated with a herbicide or planted with a crop. Again, the johnsongrass was allowed to grow during the summer and the plots were sprayed with glyphoste (3.4 kg ai/ha) in October 1980. In the spring of 1981, they were treated with trifluralin (0.7 kg ai/ha) and planted to cotton.

The four plots which remained from the original 12 glyphosate treated plots were designated as Double-rate-trifluralin System (2X-trifluralin) and were replanted with johnsongrass rhizomes in the spring of 1978. Although no crop was planted, it was treated with trifluralin (1.1 kg ai/ha) in mid June. In succeeding years, the 2X-trifluralin System was treated with preplant trifluralin (1.4 kg ai/ha) and planted with cotton.

From the 12 johnsongrass plots not treated with glyphosate in October 1977, 4 plots for each system were designated as the Fluridone-trifluralin System (Fluridon), Double-rate-trifluralin-plus System (2X-trifluralin-plus), and Single-rate-trifluralin-plus System (Trifluralin-plus). See Table 1 for the herbicides, rates and methods of application. All herbicides were applied following manufactures' recommendations and were incorporated by a power tiller to 7.6 cm when it was necessary.

Cotton was planted between March 15 and April 15 of each year. The cultural practices used in this experiment were those typically used by farmers for cotton in the Shafter area. Irrigation was by furrow-run water. Cotton and cotton/johnsongrass plots were irrigated when the cotton plants began to turn blue and wilted slightly in the afternoon. The plots with johnsongrass and without cotton (all plots in 1977 and October-glyphosate in some years) were irrigated on the same schedule as cotton with an additional irrigation in late September. In this area, cotton is not irrigated after the first 7-10 days of September. All plots were cultivated to make and maintain beds for irrigation. However, to protect the johnsongrass, cultivation was confined to the furrow and lower portion of the beds.

About 2 weeks after the glyphosate was applied to the October-glyphosate System, johnsongrass was rated for visual injury in all systems. The rating was from 0-10, with 0 being no visual injury and 10 being dead. Cotton was harvested by a mechanical harvester equipped with spindle picker-heads from six center rows in 1978 and four center rows in other years. Seedcotton weights were changed to percent of the Weedfree and converted to arcsine for analysis. Johnsongrass rhizomes were dug from four sample areas of each plot after cotton harvest. One sample was taken from each of the four center rows beginning on one of the outside rows of the group of four and proceeding diagonally across the plot. The sample areas each measured 30 cm wide, 20 cm deep and 1 m long. The effectiveness of a system in controlling johnsongrass was measured by comparing the fresh weight of rhizomes. All data were analyzed by the "F" test, and means were separated by Duncan's multiple range test.

Results and Discussion

The average cotton yields over the 4 year for 2X-trifluralin, Fluridone, 2X-trifluralin-plus, and Trifluralin-plus Systems were significantly less ($P = 0.05$) than the yields of the Weedfree and October-glyphosate Systems (Table 2). However, the cotton yields for individual

Table 2. The average yield of seed cotton in percent of the weedfree system and the visual rating of johnsongrass.

System name	Cotton yield percent of weedfree	Johnsongrass visual injury[a]
	(%)	
Weedfree	100 a[b]	---[c]
October-glyphosate	103 a	9.6 a
2X-trifluralin	42 b	2.8 c
Fluridone	78 b	9.1 a
2X-trifluralin-plus	64 b	6.7 b
Trifluralin-plus	54 b	6.1 b

[a]All visual injury ratings were made about 2 weeks after the application of glyphosate to the October-glyphosate System. Rating, 0 = no visual injury, 10 = dead.

[b]Numbers in each column followed by the same letter are not significantly different at P = 0.05 according to the Duncan's multiple range test.

[c]There was no johnsongrass.

years for the above four Systems were not significantly less in some years than the Weedfree, but were less than the yields of the October-glyphosate in all years (Table 3).

Based on visual injury ratings and low rhizome weight in October, control of johnsongrass in the Fluridone System was good at this time of the year (Table 3). Both visual injury and rhizome weight were equal to those of October-glyphosate. However, visual injury caused by fluridone did not appear on the johnsongrass until after the first irrigation, about the first of June. Until the first irrigation, johnsongrass appeared to compete freely with the cotton and this was reflected in significant cotton yield reductions for some individual years (Table 3) and the 4-year average (Table 2). No visual injury was seen on the cotton at any time.

Table 3. Cotton yield in percent of the weedfree, weight of johnsongrass rhizomes, and visual injury rating of johnsongrass for individual years.

System name	Year	Cotton yield	Johnsongrass	
		percent of weedfree	Rhisome weight[a]	Visual injury[b]
		(%)	(Mg/ha)	
Weedfree	1978	100 ab[c]	--[d]	
	1979	100 ab	--[d]	
	1980	100 ab	--[d]	
	1981	100 ab	--[d]	
October-glyphosate	1978	--[e]	.8 ef	9.7 ab
	1979	102 a	--[d]	
	1980	--[e]	2.7 def	9.4 ab
	1981	104 a	--[d]	
2X-trifluralin	1978	--[e]	10.5 bc	4.0 hij
	1979	65 cde	21.8 a	3.5 ij
	1980	44 defg	10.4 bc	2.8 j
	1981	18 fg	26.0 a	1.0 k
Fluridone	1978	79 bce	1.7 ef	9.2 ab
	1979	79 bc	.1 f	9.5 ab
	1980	71 cd	4.1 def	8.7 abc
	1981	59 cde	3.1 def	8.8 abc
2X-trifluralin-plus	1978	28 efg	3.5 def	8.0 bcd
	1979	84 bc	6.8 cde	6.0 efg

	1980	78 bc	2.8 def	5.5 fgh
	1981	68 cde	4.1 def	7.3 cde
Trifluralin-plus	1978	13 g	1.6 ef	7.1 cdef
	1979	79 bc	15.4 b	5.8 efg
	1980	68 cde	7.9 cd	4.8 ghi
	1981	58 cde	5.8 cdef	6.7 def

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[a]Rhizomes were sampled and fresh weights were taken in the fall of each year.

[b]All visual injury ratings were made about 2 weeks after the application of glyphosate to Treatment C in October. The rating is 0 to 10, 0 = no visual injury and 10 = dead.

[c]Numbers in each column followed by the same letter(s), are not significantly different at P = 0.05 according to the Duncan's multiple range test.

[d]There was no johnsongrass.

[e]No cotton grown in these years.

Even though some rhizomes were recovered in samples of the October-glyphosate System in the fall of 1978 and 1980 (Table 3), johnsongrass plants were rare in the plots in the spring of 1979 and 1981. It was thought that the rhizomes died during the winter. Because johnsongrass was controlled by glyphosate that was sprayed in October, cotton yields in the next year equalled those of the Weedfree System. It should be noted that johnsongrass was growing and had intact rhizomes at the time of the glyphosate application.

Based on visual injury and weight of rhizomes, 2X-trifluralin and 2X-trifluralin-plus did not control johnsongrass (Tables 2 and 3). Likewise, Trifluralin-plus was a failure.

Based on yield, Fluridone, 2X-trifluralin-plus, and Trifluralin-plus showed promise in some years as control methods when compared to the Weedfree (Table 3). However, cotton yields were significantly reduced in other years. The yield of the 2X-trifluralin System did not equal the Weedfree yields in any year. Also, the average cotton yield for the 4 years for the above Systems was reduced when compared to the Weedfree (Table 2). Based on the yield data and the absence of johnsongrass after treatment, the only system that controlled johnsongrass was October-glyphosate.

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CONTROL OF PERENNIAL GRASSES IN COTTON WITH FLUAZIFOP-P-BUTYL

S.D. Watkins and L.C. Hearn[1]

Abstract. Fluazifop-p-butyl (butyl (R)-2]4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate), is a highly selective grass herbicide being developed by ICI Americas Inc. under the code number PP005.

PP005 consists of the (R) enantiomer of fluazifop- butyl, (RS)-2[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate, the active ingredient in Fusilade herbicide, which is actually a racemic mixture of two optically active enantiomers. Field trials were conducted in California

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[1]ICI Americas Inc., Yuma, AZ and Visalia, CA.

and Arizona cotton (Gossypium hirsutum L.) during 1983 and 1984 to determine the effectiveness of PP005 against bermudagrass (Cynodon dactylon (L.) Pers.) and johnsongrass (Sorghum halepense (L.) Pers.) and to compare the relative activity of PP005 versus fluazifop-butyl. Sequential postemergence applications of 0.21 + 0.21 kg/ha and 0.28 + 0.28 kg/ha, separated by four to six week, consistently provided excellent seasonal control of johnsongrass and bermudagrass, respectively. PP005 provided grass control which was equal to fluazifop-butyl at rates which were lower than fluazifop-butyl. No significant injury to cotton was observed from dosages as high as 0.84 kg/ha.

Introduction

Fluazifop-p-butyl is a highly selective grass herbicide being developed by ICI Americas Inc. under the code number PP005. PP005 consists of the (R) enantiomer of fluazifop-butyl, the active ingredient in Fusilade herbicide, which is actually a racemic mixture of two optically active enantiomers. The herbicidal activity of fluazifop-butyl itself has been shown to reside principally in the (R) enantiomer.

Field trials were conducted in California and Arizona cotton during 1983 and 1984 to determine the effectiveness of PP005 against bermudagrass and johnsongrass and to compare the relative activity of PP005 versus fluazifop-butyl.

Materials and Methods

Nine field experiments were conducted in Yuma, Mohave, Maricopa County, Arizona and Tulare and Kern County, California. Normal cultural practices such as discing, chiseling, bed preparation, preirrigation, and preplant incorporated treatments of dinitroaniline and/or diamino-s-triazine herbicides preceded the initiation of each study. Soil textures ranged from sandy loam to clay loam with less than 2.0 percent organic matter.

Experiments were established in cotton fields moderately to severely infested with rhizomatous johnsongrass and/or bermudagrass. Generally, initial treatments were administered during May and June to johnsongrass 5-60 cm in height (30 cm average) and to bermudagrass 5-15 cm in height. Bermudagrass stolon length ranged from 5-50 cm (25 cm average). Applications on grasses in more advanced stages of growth occured in selected studies. Treatment of grasses displaying signs of moisture stress was avoided. Cotton was generally 5-35 cm in height at initial herbicide treatment. The cotton cultivars included in Arizona were 'DPL 61', 'DPL 62', 'DPL 90', and Stoneville 825. Cultivars in California were 'Acala SJ-2' and 'Acala SJ-5'.

All initial treatments of PP005 and fluazifop-butyl were applied broadcast at 188-376 l/ha with a tractor-mounted, compressed-air sprayer. Flat fan nozzles (Teejet 8003-8004) attached to a four-row boom were used in all experiments. For maximum coverage, directed sprays utilizing drop-pipe nozzles were used in subsequent treatments on bermudagrass in California trials. Plot size was 4m by 15 or 30m and all treatments were replicated four times in a randomized block design. A crop oil concentrate was added to all chemical treatments at 1.0% v/v. Crop oil concentrates used included Moract and Agridex.

Sequential over-the-top treatments of fluazifop-butyl were administered at 0.42-0.56 kg/ha and compared to sequential applications of PP005 at 0.21-0.42 kg/ha. For comparison a single treatment of PP005 was also included at 0.42 kg/ha.

Weed control and crop injury evaluations were visually estimated and conducted at frequent intervals until harvest. Ratings were based on a scale of 0 = no injury and 10 = complete kill. Analyses of variance were calculated for all efficacy data. Duncan's Multiple Range Test was used to determine significant differences among means at the 0.05 level of probability.

Results and Discussion

Johnsongrass Control. The effectiveness of PP005 for johnsongrass control was studied at six California and Arizona locations. Two trials at Visalia compared sequential treatments of PP005 at varied rates. The "early" trial, initiated when johnsongrass was 20-30 cm in height, compared split applications with dosage totals ranging from 0.42-0.56 kg/ha and a single application of 0.42 kg/ha (Table 1).

TABLE 1 - Control of johnsongrass with sequential treatments of PP005. Visalia, CA.

		Percent control at weeks after first treatment for timing shown.							
	Rate	Early a/				Late b/			
Treatment	kg/ha	2	4	7	14	3	7	10	15
PP005	0.21 + 0.21	78	79	89	85	83	86	75	73
PP005	0.28 + 0.28	80	85	93	91	88	95	91	89
PP005	0.42	81	88	86	64				
PP005	0.42 + 0.42					86	94	94	91
Untreated		0	0	0	0	0	0	0	0
LSD(0.05)		4.3	3.3	3.5	9.6	3.3	2.7	4.2	3.0

a/ Johnsongrass 20-30cm at first treatment, retreated 28 days later.
b/ Johnsongrass 45-60cm at first treatment, retreated 22 days later.

Split applications provided good to excellent control through 14 weeks posttreatment. The single application of 0.42 kg/ha provided good control through 7 weeks posttreatment; however, at 14 weeks, the single application was failing to provide acceptable control and was statistically inferior to a split application of the same total dosage. These data are consistent with previous studies comparing single and sequential applications of fluazifop-butyl (1, 2). A "late" trial conducted in the same field near Visalia was initiated when johnsongrass was 45-60 cm in height with 10% of the plants in the boot stage of growth. Split applications totaling 0.56-0.84 kg/ha provided excellent seasonal control while the lower rate, totaling 0.42 kg/ha provided only marginally acceptable control of the larger johnsongrass. It is noteworthy that split applications applied to large johnsongrass were numerically superior to the single application made at what we consider a near optimum growth stage.

Two field studies in Arizona compared sequential treatments of PP005 and fluazifop-butyl (Table 2)

TABLE 2 - Control of johnsongrass with sequential treatments of PP005 and fluazifop-butyl.

		Percent control at weeks after first treatment at locations shown a/						
	Rate	Avondale, AZ				Casa Blanca, AZ		
Treatment	kg/ha	2	4	9	12	2	4	11
PP005	0.21 + 0.21	60	65	81	86	84	88	96
PP005	0.28 + 0.28	66	73	83	89	86	91	100
PP005	0.42 + 0.42	70	74	85	93	90	95	100
Fluazifop-butyl	0.42 + 0.42	69	75	83	85	83	88	100
Untreated		0	0	0	0	0	0	0
LSD(0.05)		6.4	13.7	5.3	6.4	3.0	2.4	3.3

a/ Sequential treatments applied 45 and 54 days apart, respectively.

PP005 was applied at dosages totaling 0.42-0.84 kg/ha while the fluazifop dosage totaled 0.84 kg/ha. Excellent seasonal control was obtained with all treatments. PP005 provided control equal to fluazifop-butyl at rates which were lower than fluazifop-butyl.

Additional trials in Arizona and California allowed the comparison of higher rates of fluazifop-butyl with PP005 (Table 3).

TABLE 3 - Control of johnsongrass with sequential treatments of PP005 and fluazifop-butyl.

		Percent control at weeks after first treatment at locations shown a/							
	Rate	Maricopa, AZ				Visalia, CA			
Treatment	kg/ha	2	4	7	11	2	4	7	12
PP005	0.28 + 0.28	74	78	86	94	79	79	93	86
PP005	0.42 + 0.42	75	83	93	98				
Fluazifop-butyl	0.42 + 0.42	71	69	83	84				
Fluzaifop butyl	0.56 + 0.56	75	76	86	94	77	77	88	81
Untreated		0	0	0	0				
LSD(0.05)		3.4	3.6	3.7	12.4				

a/ Sequential treatments applied 35 and 47 days apart, respectively.

Again, comparable lower dosages of PP005 were as effective or more effective than fluazifop-butyl.

Bermudagrass Control. Three field studies were conducted in Arizona and California to evaluate PP005 for bermudagrass control. At Earlimart, sequential applications totaling 0.42 kg/ha provided good suppression of bermudagrass 17 weeks posttreatment while higher dosages provided a significant increase in seasonal control (Table 4).

TABLE 4 - Control of bermudagrass with sequential treatments of PP005. Earlimart, CA.

Treatment	Rate kg/ha	Percent control at weeks after first treatment a/ 2	4-5	17-18
PP005	0.21 + 0.21	70	79	75
PP005	0.28 + 0.28	71	83	83
PP005	0.42 + 0.42	74	88	85
Untreated		0	0	0
LSD(0.05)		6.6	4.3	4.0

a/ Sequential treatments applied 31 days apart.

Excellent bermudagrass control was achieved at Mohave Valley 11 weeks posttreatment with no significant differences due to the rate of PP005 (Table 5).

TABLE 5 - Control of bermudagrass with sequential treatments of PP005 and fluazifop-butyl.

Treatment	Rate kg/ha	Percent control at weeks after first treatment at locations shown a/ Mohave Valley, AZ 2	4	6	11	Avondale, AZ 2-3	4	7-8	9-10
PP005	0.21 + 0.21	69	73	66	90	69	74	80	83
PP005	0.28 + 0.28	71	78	71	96	73	76	84	86
PP005	0.42 + 0.42	74	84	79	99	83	81	88	90
Fluazifop-butyl	0.42 + 0.42					63	60	71	78
Fluazifop-butyl	0.56 + 0.56	69	76	63	94	75	73	80	79
Untreated		0	0	0	0	0	0	0	0
LSD(0.05)		2.5	3.4	3.7	6.9	3.5	7.7	5.0	4.2

a/ Sequential treatments applied 33 and 43 days apart, respectively.

Comparing PP005 and fluazifop-butyl, PP005 at a total dosage of 0.56 kg/ha was as effective as fluazifop-butyl at a total dosage of 1.12 kg/ha. The study at Avondale allowed direct comparisons of PP005 with two dosages of fluazifop-butyl. Excellent seasonal control was achieved 9-10 weeks posttreatment with all chemical treatments.

Results from the arid southwest indicate that PP005 is a highly efficacious postemergence grass herbicide. Comparisons between PP005 and fluazifop-butyl have shown PP005 to provide excellent perennial grass control at lower dosages than required for fluazifop-butyl. Sequential applications made to actively growing johnsongrass at dosages of 0.21 + 0.21 kg/ha, separated by 4-6 weeks, have provided excellent season-long grass control. Bermudagrass has been well controlled by timely sequential applications of 0.28 + 0.28 kg/ha. No significant injury to cotton has been observed from PP005 dosages as high at 0.84 kg/ha.

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THE USE OF OXYFLUORFEN FOR WEED CONTROL ON COTTON FALLOWBEDS

M.F. Jehle and L.D. West[1]

Abstract. Field trials were established in 30 locations in the San Joaquin Valley during the 1983-84 season to evaluate the effectiveness of oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene), applied by ground and air equipment, for weed control on cotton fallowbeds. The ground trials were nonrandomized blocks of 2-5 acres per treatment applied in 20 gpa at 0.25, 0.38, and 0.5 lb ai/A. The air trials were 6 acres per treatment in size and were applied using both fixed wing and helicopters. Oxyfluorfen was applied at 0.25 and 0.5 lb ai/A in a spray volume of 10 gpa.

Residual broadleaf weed control was obtained for at least 3 months when oxyfluorfen was applied at 0.5 lb ai/A in November whether applied by ground or air. The 90 day after treatment weed control evaluations showed oxyfluorfen at 0.25 lb ai/A to be providing preemergence control (85-95%) of london rocket (Sisymbrium irio), shepherdspurse (Capsella bursa-pastoris), black mustard (Brassica nigra) and groundsel (Senecio vulgaris). At the same evaluation timing oxyfluorfen at the 0.5 lb ai/A rate provided virtually 100% control of these same broadleaf weeds.

[1]Rohm and Haas Company, Fresno, CA.

SETHOXYDIM FOR GRASS CONTROL IN SUGARBEETS

D.C. Wiley and L.C. Darlington[1]

Abstract. 1984 trial objectives varied depending on the area where sugarbeets are grown. In the pacific northwest (PNW), they targeted on the rate studies to control wild oats (Avena fatua). Oregon and Idaho have reported wild oats to be an economic problem in many of their beet fields. In

[1]BASF Wyandotte, Corp., Parsippany, NJ.

California, large air-applications were applied next to ground applications of equal rate to prove to the California Department of Food and Agriculture (CDFA) that sethoxydim (2-(1-(ethoxyimino)butyl)-5-(2-(ethylthio)propyl-3-hydroxy-2-cyclohexen-1-one) was equally effective using either method of application. Also, in California, a university cooperative extension trial was applied to observe various tank mixtures of sethoxydim and phenmedipham-desmedipham. These products are registered on sugarbeets and sold under the trade name Poast and Betamix, respectively.

The main grasses encountered were barnyard grass (Echinochloa crusgalli), wild oats (Avena fatua), and johnson grass (Sorghum halepense). In the PNW excellent control of 2-8" wild oats was obtained (94%) using 0.2# ai/A of sethoxydim. Ninety eight percent control was obtained with a 0.3# ai/A rate. Performance ratios, based on rate, stayed about the same even when wild oats reached 13 inches tall.

Results observed in California showed no control differences when comparing air to ground applications using three different rates: 0.3, 0.4, or 0.5# ai/A of sethoxydim. Barnyardgrass at 1-6", which was present in 5 out of the 7 trials, was controlled sufficiently well at the lowest rate tested (0.3# ai/A) using either method of application. Johnson grass required two applications with the first one at the high rate of 0.5# ai/A.

The tank mix study, involving barnyardgrass, indicated a mixture of Poast and Betamix, at label rates can reduce grass control. I refer to a mixture of 0.3# + 1.0# ai/A, respectively. When the sethoxydim rate was increased to 0.4# ai/A, and the Betamix rate held constant, grass control improved.

No phytotoxicity was reported on the sugarbeets in any of the large-scale trials in either the PNW or California.

Sethoxydim is now fully registered for use on sugarbeets in all parts of the USA including California. The label states a maximum of 5 pints of commercial product/A is all that can be applied in one season.

EARLY PREPLANT HERBICIDE APPLICATIONS IN CORN

S.D. Miller and H.P. Alley[1]

Abstract. Field studies were conducted at the Torrington and Powell Research and Extension Centers in 1983 and 1984 to determine whether early preplant applications of residual herbicides would prevent weeds from becoming established prior to planting corn (Zea mays L.). Treatments consisted of early preplant applications applied 15 and 30 days prior to corn planting or preemergence treatments applied at planting. The application of individual and/or combinations applied 15 and 30 days prior to corn planting performed as effectively as similar treatments applied preemergence at planting. Herbicide combinations gave broader spectrum weed control than individual herbicide treatments and should be considered when developing an early preplant weed control program in corn.

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[1]Plant Science Division, University of Wyoming, Laramie, WY.

HERBICIDE APPLICATION THROUGH SPRINKLER IRRIGATION SYSTEMS

L.C. Haderlie, T.S. Longley and P.J. Petersen[1]

Herbicides were injected through sprinkler irrigation systems at Aberdeen, Idaho over a three-year period to evaluate crop injury and weed control. Pre- and post-emergence herbicide applications were made in spring wheat (Triticum aestivum) and potatoes (Solanum tuberosum) by using a single sprinkler head per treatment. There were usually four (sometimes three) replications used. Weed and crop evaluations were made in a circular area between 10 - 25 ft from the sprinkler head. Metribuzin (4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one), (late emergence) was as effective in potatoes at 0.1 lb ai/A as at 0.38 lb/A with over 95% weed control. Single experiments with bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) postemergence in potatoes gave serious crop injury. Chloramben (3-amino-2,5-dichlorobenzoic acid) (2.7 lb ai/A) preemergence gave 98% or better control for common lambsquarters (Chenopodium album L.) and redroot pigweed (Amaranthus retroflexus L.). PP005 ((RS)-2[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate) at 0.13 lb ai/A + 1% crop oil concentrate postemergence gave 95, 78 and 73% control for witchgrass (Panicum capillare L.), green foxtail (Setaria viridis (L.) Beauv.) and volunteer grain, respectively. Doubling the rate of PP005 tended to improve control of green foxtail and volunteer grain. Postemergence applications of bromoxynil + MCPA at 0.38 + 0.38 ai/A in spring wheat were consistently effective on broadleaved weeds. A lower rate (0.25 + 0.25 lb ai/A) did not give adequate weed control. Low volatile esters or amine formulations of 2,4-D ((2,4-dichlorophenoxy)acetic acid) at 0.25 lb ai/A only gave 60% control of common lambsquarters and redroot pigweed. Sprinkler application of post- or pre-emergence herbicides can be as or more effective than ground or aerial spraying, depending on the herbicides.

[1]University of Idaho Research & Extension Center, Aberdeen, ID.

CHLORSULFURON FOR WEED CONTROL IN SAFFLOWER (Carthamus tinctorius)

R.L. Anderson[1]

Safflower (Carthamus tinctorius L.) is well adapted to the semi-arid regions of western U.S., but ineffective weed management systems have restricted successful safflower production and harvesting. A study was conducted to determine if a successful weed management system could be developed with presently available herbicides. Chlorsulfuron (2-chloro-N[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide) at 0.018 and 0.035 kg ai/ha was applied postemergence to safflower 15-20 cm in height, with trifluralin (α,α,α-trifluoro-2,6-dinitro-N-N-dipropyl-p-toliudine) or pronamide (3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide) applied previously as preplant incorporated treatments. The rates for

[1]USDA-ARS, Akron, CO.

trifluralin were 1.1 and 1.7 kg ai/ha while pronamide was applied at 0.8 and 1.1 kg ai/ha.

Safflower was planted in early May of both years, with chlorsulfuron applied in late June. Chlorsulfuron eliminated all broadleaf weeds, redroot pigweed (Amaranthus retroflexus L.), puncturevine (Tribulus terrestris L.) and common sunflower (Helianthus annuus L.), whether applied alone or sequentially after the preemergence herbicides (Table 1). Trifluralin, with or without chlorsulfuron, resulted in relatively weed-free safflower in both years. Pronamide, with or without chlorsulfuron, failed to completely control witchgrass (Panicum capillare L.) in one year, (Table 1), which reduced safflower grain yield 21-35%, compared to the weed-free safflower control (Table 2). The sequential treatment of trifluralin and chlorsulfuron and trifluralin applied alone resulted in grain yields similar to the weed-free control in both years. The chlorsulfuron-alone treatment was heavily infested with witchgrass in 1984, resulting in a significant yield loss. Chlorsulfuron phytotoxicity to safflower was not detected in any treatment in either year. Thus, potential exists for a postemergence application of chlorsulfuron to control broadleaf weeds in safflower grown in the Central Great Plains.

Table 1. Weed control by pronamide, trifluralin, and chlorsulfuron in 1983 and 1984.[a]

		1983			1984		
Treatment	Rate	Puncture vine	Redroot pigweed	Witchgrass	Common Sunflower	Redroot pigweed	Witchgrass
	(kg/ha)	---------	(plants/m²)	---------	---------	(plants/m²)	----------
Chlorsulfuron	0.035	0.3 b	0.0 b	2.3 ab	0.0 b	0.0 b	16.3 b
Pronamide	0.8	0.0 b	2.7 b	4.7 a	0.3 b	1.6 a	5.3 c
Trifluralin	1.1	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b	0.0 d
Chlorsulfuron + pronamide	0.035+ 0.8	0.0 b	0.0 b	0.7 b	0.0 b	0.0 b	4.3 c
Chlorsulfuron + trifluralin	0.035+ 1.1	0.0 b	0.3 b	0.0 b	0.0 b	0.0 b	0.3 d
Weed-infested control	-	2.3 a	6.0 a	2.3 ab	1.0 a	2.0 a	35.0 a

[a] Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

Table 2. Agronomic data of safflower treated with herbicides in 1983 and 1984[a].

		1983			1984		
Treatment	Rate	Grain yields	100-kernel weight	Germination	Grain yields	100-kernel weight	Germination
	(kg/ha)	(kg/ha)	(gm)	(%)	(kg/ha)	(gm)	(%)
Chlorsulfuron	0.035	1740 a	2.4 a	88 a	1230 b	2.9 a	87 a
Pronamide	0.8	1350 b	2.7 a	86 a	1420 b	2.8 a	85 a
Trifluralin	1.1	1810 a	2.4 a	84 a	2100 a	2.8 a	85 a
Chlorsulfuron + pronamide	0.035+ 0.8	1830 a	2.6 a	86 a	1500 b	2.8 a	85 a
Chlorsulfuron + trifluralin	0.035+ 1.1	1790 a	2.4 a	85 a	2370 a	2.8 a	87 a
Weed-infested control	-	960 b	2.5 a	80 a	490 c	2.6 a	84 a
Weed-free control	-	1720 a	2.3 a	87 a	2170 a	2.9 a	87 a

[a] Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

THE EFFECT OF PREPLANT INCORPORATED TRIALLATE ON SEVEN SPRING WHEAT CULTIVARS

V.R. Stewart and T.K. Keener[1]

The label instructions for the use of triallate (S-(2,3,3-tricholoallyl)diisopropylthiocarbamate) in spring wheat for western Montana requires application following seeding and double incorporation with a harrow. Because this method does not always provide effective wild oat (Avena fatua) control a study was designed to measure the effect of triallate applied preplant incorporated on seven spring wheat cultivars. The triallate was applied to a sandy loam soil then incorporated with a field cultivator consisting of sweeps, a rod and a harrow. Triallate applications were made using a "research-type" tractor mounted sprayer in 27 gpa to plots 10 feet by 14 feet. Spring wheat cultivars were seeded in randomized strips across treatments with a nursery seeder. The test was conducted under wild oat-free conditions.

The higher rates of triallate delayed the emergence of all cultivars by 1.5 to 2.0 days. Plant populations were reduced significantly as the rate of triallate was increased. There were significant differences in cultivar plant populations with Olaf, Owens and Len being the more tolerant cultivars. Heads per linear feet were reduced significantly with the higher rates of triallate. The number of heads per foot varied between cultivars with Borah and Newana showing the greatest reduction. Reduction in height was not significant because of triallate rates. There were significant differences found in yields among cultivars due to the rate of triallate. The yields from the plots tretaed with 2.0 lbs ai/A of triallate were significantly different from the other triallate treatments, and all treatments were significantly less in yield than the check. The highest yielding variety, Owens, was statistically significant from other cultivars. Test weights did not vary signifcantly because of the rate of triallate, however, the cultivar differences were apparent, as would be expected. Laboratory analysis of wheat samples indicate that protein levels increased as the level of triallate was increased.

[1]Montana Agricultural Experiment Station, Kalispell, MT.

SUPPRESSION OF PERSIAN DARNEL WITH GRANULAR TRIALLATE AND YIELD RESPONSE IN SPRING CEREAL GRAINS

James C. Adams[1]

Grasses are the predominant weed problem in Montana dryland cereal grain agriculture. Persian darnel (Lolium temulentum) infests over 60k hectares of spring cereal grains in central Montana, resulting in severe crop yield reductions. During periods of dry weather, joint infestations of Persian darnel and wild oats (Avena fatua) have, in some instances,

[1]Monsanto Company, Great Falls, MT.

resulted in zero grain yield of spring barley.

Recently, several grain producers reported that triallate, when used for wild oat control, also reduced Persian darnel populations. Based on this information, field trials were conducted by Monsanto personnel from 1982-84 to evaluate the efficacy of triallate on control of Persian darnel. Evaluations were made at nine locations where the granular formulation of triallate was applied and incorporated prior to seeding spring wheat or barley. At each location, the grassy weed population was a mixture of Persian darnel and wild oats.

At rates of 1.4 kg/ha and 1.68 kg/ha, preplant incorporated granular triallate provided 68% and 71% control of darnel, respectively. Corresponding control of wild oats at these rates was 78% and 84%. When crop response was measured, the 1.4 kg/ha and 1.68 kg/ha rates of triallate increased spring wheat yield 63% and 80%, respectively, compared to the untreated. As a result of this work, Monsanto has submitted a label addition to the EPA to include suppression of Persian darnel in spring wheat or barley with granular triallate.

Table 1. Triallate efficacy on Persian darnel and corresponding yield response in spring cereal grain.

Far-Go® 10G Rate (Kg ai/ha)	Percent Weed Control		Yield (bu/ha)	
	Wild Oats	Persian Darnel	Sp. Wheat	Barley
1.4	78.3	68.3	37.5	---
1.68	84.0	70.8	41.5	67.7
0.0	0.0	0.0	23.0	22.2

PPG-1013 POSTEMERGENCE IN SPRING WHEAT

Thomas M. Cheney, Fred R. Taylor and Joseph Deli[1]

Abstract. Broadleaf herbicides in small grains vary greatly as to activity and spectrum of weeds controlled. Contact herbicides are generally used early in the season for control of new emerging weeds. PPG-1013 fits into this type of usage as a low rate contact herbicide for control of broadleaves in small grains. Within this study, PPG-1013 was applied postemergence to spring wheat alone and in tank mix with low commercial rates of standard broadleaf herbicides. PPG-1013 was applied at two rates, 0.01 and 0.02 lb ai/A. The commerical standards used in this study were bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), 2,4-D ((2,4-dichlorophenoxy)acetic acid), MCPA ((4-chloro-2-methylphenoxy)acetic acid), and chlorsulfuron (2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl]benzenesulfonamide).

[1]PPG Industries, Inc., Pittsburgh, PA.

When comparing the two rates of PPG-1013 in tank mix with the standards, little difference in weed control of broadleaves was evident. Applications of the standard herbicides by themselves resulted in less crop phytotoxicity and less control of henbit than tank mix combinations with PPG-1013. By adding the commercial standards to PPG-1013, slightly better overall control of redroot pigweed and mustards was achieved when compared to treatments of PPG-1013 applied alone. When PPG-1013 is applied in tank mix with the commercial broadleaf herbicides at low rates of both, excellent control of redroot pigweed (Amaranthus retroflexus L.), mustards and henbit (Lamium amplexicaule L.) was achieved, while no appreciable increases in crop phytotoxicity were evident. PPG-1013 shows potential as a broad spectrum postemergence contact herbicide in small grains.

RESULTS OF THE 1984 EUP PROGRAM WITH AC 222,293 IN SMALL GRAINS

C.R. Amen, J.L. Johnson, S.R. Busse, P. Stryker, O. Bain and W.K. McNeil[1]

Abstract. AC 222,293 (methyl-6-(4-isopropyl-4-methyl-5-oxo-2-imidazolium-2yl)-m-toluate & methyl-2-(4-isopropyl-4-methyl-5-oxo-2-imidazolium-2-yl)-p-toluate), has been field tested in the United States since 1981 for wild oat (Avena fatua) control in wheat and barley. These studies have shown that AC 222,293 is most effective when applied at the 1-4 leaf stage of wild oat development. AC 222,293 also controls several important broadleaved weeds: wild mustard (Brassica kaber), tansy mustard (Descurainia pinnata), and field pennycress (Thalspi arvense), and stops the growth of wild buckwheat (Polygonum convolvulus), kochia (Kochia scoparia), Russian thistle (Salsola kali), and tartary buckwheat (Fagopyrum tataricum) to the point where they are noncompetitive.

Based on these findings, an Experimental Use Permit program was implemented in the North Central and Pacific Northwest Regions of the United States. Approximately 650 acres were treated on 42 sites under the EUP. AC 222,293 was applied alone and in combination with chlrosulfuron, bromoxynil, and the ester and amine formulations of 2,4-D and MCPA. AC 222,293 was applied at rates ranging from 420 to 700 g ai/ha. Applications were made at the 1-4 leaf stage of wild oat.

AC 222,293 at 420 g ai/ha, provided 92.5, 96.9 and 90.0% control of wild oat, wild mustard, and wild buckwheat, respectively, in the North Central Region (North Dakota, Minnesota, Montana, and South Dakota). Similar results were obtained in the Pacific Northwest.

AC 222,293 at 560 g ai/ha, provided 92.4, 96.1 and 90.8% control of wild oat, wild mustard, and wild buckwheat, respectively, for the North Central Region with similar results in the Pacific Northwest.

In addition, AC 222,293 at 420 to 560 g ai/ha, controlled tansy mustard, flixweed (Descurainia sophia), and field pennycress and stopped the growth of kochia, Russian thistle and common mallow (Malva neglecta).

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[1]American Cyanamid Company, Princeton, NJ.

Based on the results obtained from the Experimental Use Permit program in 1984, we plan to implement an expanded program in 1985. This program will target broadleaved weeds in addition to wild oats. Also, we will be evaluating additional tank-mix combinations including MCPA plus bromoxynil.

TYCOR: A SELECTIVE HERBICIDE FOR WINTER WHEAT

A.C. Scoggan[1]

Abstract. TYCOR, formerly known as SMY 1500, is a new selective herbicide being developed by Mobay Chemical Corporation for pre- or postemergence use in Winter Wheat. TYCOR has a broad spectrum of control, including most broadleaf weeds and certain grasses, especially Bromus spp. Research indicates that under certain conditions of use, selective control or economic suppression of jointed goatgrass (Aegilops cylindrica Host.) and cereal rye may also be obtained.

[1]Mobay Chemical Corp., Fresno, CA.

DEVELOPING WEED CONTROL SYSTEMS FOR CONIFER SEEDLINGS

Harry S. Agamalian[1]

The expansion of Christmas tree plantations in California has developed a need for field-grown bare root trees. Field seeding of Monterey pine (Pinus radiata) and Douglas Fir (Pseudotsugas menziesii) are grown for this market. The slow emergence and the long growing season make it essential that early and season long weed control be maintained during the growing period. For optimum cultural requirements a coarse texture soil with good drainage is preferred.

Methods and Procedures

These experiments were established with commercial nursery producers. The soil texture was a Greenfield sandy loam -- 56% sand, 23% silt, 21% clay and 0.7% O.M.

Following the seeding operations, preemergence herbicides were applied and sprinkler irrigation was used for seedling germination. Initial irrigation was one inch of water. Subsequent irrigation ranged from 2-3 inches of water up to tree seedling emergence. The experimental design was a complete randomized block with four replications. In addition to preemergence trials, post emergence applications were made when conifer seedlings were 5-6 inches tall.

[1]University of California - Cooperative Extension, Salinas, CA.

Data collected included weed control, tree stand counts, tree dry weights, and total marketable trees at harvest.

Results and Discussion

Initial experiments with the three year study included several herbicides that were discontinued because of poor conifer seedling tolerance or marginal weed control.

Several preemergence herbicides resulted in excellent conifer tolerance. These included prometryne (N,N'-bis(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine), bifenox (methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate), diphenamid (N,N-dimethyl- α-phenyl benzenacetamide) and oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene). Subsequent studies in the second and third year resulted in combinations of herbicides. The combinations of prometryne with bifenox, diphenamid, napropamide (N,N-diethyl-2-(1-naphthalenyloxy)propanamide) or oxyfluorfen resulted in increased weed control over single treatments while maintaining good tree selectivity.

Major weed species at these sites were little mallow (Malva parviflora), common groundsel (Senecio vulgaris), burclover (Medicago polymorpha), shepherdspurse (Capsella bursa-pastoris) and filaree (Erodium botrys) (Table 1).

Table 1. EFFICACY OF SEVERAL PREEMERGENCE HERBICIDES APPLIED TO MONTEREY PINE (Pinus radiata).

CONIFER SEED BED PREEMERGENCE
VARIETY: MONTEREY PINE (PINUS RADIATA)

		Weed Control			
TREATMENT	lb/A	cheese weed	common groundsel	filaree	burclover
BIFENOX	4	10.0	9.5	9.0	8.5
DIPHENAMID	4	7.0	7.5	7.5	8.0
NAPROPAMIDE	4	9.5	10.0	10.0	8.0
OXYFLUORFEN	1	10.0	9.5	8.5	7.5
PROMETRYN	1	8.0	9.8	9.0	9.0
CONTROL	0	0	0	0	0

Both burclover and filaree were the most difficult to control, but combinations of the herbicides did enhance weed control.

Conifer seedling vigor evaluations indicated the following herbicides to be safe. In decreasing order: prometryne, bifenox, dephenamid, napropamid and oxyfluorfen. Dried weight of trees at mid season indicated significant differences between single herbicide treatments of bifenox, napropamide, oxyfluorfen and prometryne over diphenamid and the hand weeded control. Comparisons of combinations of prometryne with bifenox, napropamide and oxyfluorfen were also significantly better than the hand weeded control (Table 2).

Table 2. TREE HARVEST EVALUATIONS ON MONTEREY PINE (Pinus radiata) WITH SEVERAL PREEMERGENCE HERBICIDES.

		MONTEREY PINE X TREE WEIGHT HARVESTED	
TREATMENT	LBS/A.	WT.(GM)	NO./3 FT ROW
GOAL	1	8.65 A	40.7 A
CAPORAL	2	8.80 A	35.2 B
MODOWN	4	8.07 A	36.7 B
GOAL + CAP.	1 + 2	8.06 A	40.0 A
GOAL + ENIDE	1 + 4	7.81 B	40.6 A
ENIDE + CAP.	4 + 2	7.77 B	37.0 B
ENIDE	4	7.55 B	44.5 A
WEEDY CONTROL	0	6.98 C	32.2 C

Data collected at harvest time indicated single herbicide treatments provided greater selectivity than combinations of herbicides. Although the combinations of prometryne and oxyfluorfen resulted in no significant differences than either herbicide alone.

Post emergence applications of bifenox, oxyfluorfen and prometryne resulted in effective season long weed control. All three herbicides exhibited post emergence weed control and possess residual capability. Oxyfluorfen applied to Monterey pine and Douglas fir resulted in some phytotoxicity (Table 2). Monterey pine was more sensitive than Douglas fir. These treatments at 1 lb/A resulted in shoot damage, subsequently causing a 20-30% loss of marketable Monterey pine. Douglas fir trees treated at the same dosage were more tolerant, resulting in a 1-2% loss of marketable trees.

Conclusions

The data generated from these experiments conducted over a three year period indicated that several preemergence herbicides can be safely applied. Prometryne demonstrated good selectivity to Monterey pine and Douglas fir at the 1-2 lb/A active. Combinations of prometryne with bifenox (2-4 lb/A); diphenamid (4 lb/A); or oxyfluorfen (0.5-1 lb/A) will enhance broadleaf weed control and still maintain excellent seedling selectivity.

Post emergence applications of prometryne (1-2 lb/A) and bifenox (2-4 lb/A) when the trees were 8-10" tall resulted in acceptable tree tolerance. To obtain season long weed control for Monterey pine and Douglas fir seedlings, a preemergence application of several herbicides may be used, followed by post emergence applications of prometryne or bifenox.

Table 3. THE EFFECTS OF PAST EMERGENCE HERBICIDES ON SEEDLING CONIFERS

CONIFER BED

POST EMERGENCE, SEEDLINGS 8 - 10" TALL

TREATMENT	LB/A	PHYTOTOXCITY MONTEREY PINE	PHYTOTOXCITY DOUGLAS FIR
BIFENOX	4	0	0
OXYFLUORFEN	1	4.5	1
PROMETRYN	2	0	0
CONTROL	0	0	0

SUSCEPTIBILITY OF EMORY OAK SPROUTS TO PICLORAM, TRICLOPYR, AND TEBUTHIURON

Howard L. Morton, Jimmy T. LaBaume and Del. W. Despain[1]

Abstract. Emory oak (Quercus emoryi Torr.) is being harvested in southern Arizona for fuelwood. This species reproduces by sprouting and regrowth, often creating a stand more dense than before the area was cleared. This study was conducted to determine the effectiveness of picloram (4-amino-3,5,6-trichloropicolinic acid), triclopyr ([(3,5,6-trichloro-2-pyridinyl) oxy]acetic acid), and tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]) for control of Emory oak sprouts.

The study area was harvested for fuelwood in late summer and fall of 1977. Slash was disposed of by the lop and scatter method and the area burned in the spring of 1979. All herbicide treatments were applied in March 1981. Broadcast applications of 10% pelleted potassium salt of picloram and 20% pelleted tebuthiuron were applied by hand at rates of 1.1, 2.2, and 4.5 kg/ha. Individual stump treatments of pelleted picloram and tebuthiuron were applied at rates of 0.5, 1.0 and 2.0 g/30 cm of sprout height. Broadcast sprays of the butoxyethyl ester of triclopyr were applied at rates of 1.1, 2.2 and 4.5 kg/ha in diesel oil-water carrier (1:7 v/v) at total volume of 94 L/ha, and individual plants were treated with sprays of the ester of triclopyr at concentrations of 227, 454 and 908 g/380 L in a diesel oil-water carrier (1:7 v/v). Sprays were applied to the foliage of Emory oak sprouts to the point of runoff. Mortalities of Emory oak plants were determined in September 1984 by counting living and dead plants on the treated plots.

Teburthiuron treatments were most effective for control of Emory oak with all broadcast treatments killing 100% of the treated plants and from

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[1]USDA-ARS, Tucson, AZ; Sul Ross Univ., Alpine, TX; and Univ. of Arizona, Tucson, AZ.

88 to 100% of the plants treated individually. Broadcast treatments of picloram killed from 16-28% of the Emory oak plants and from 48-80% of the plants treated individually. Broadcast spray treatments of triclopyr killed from 27-42% of the Emory oak plants and from 22-32% of the plants treated individually.

CONTROL OF JUNIPER IN NORTH-CENTRAL ARIZONA USING TEBUTHIURON, HEXAZINONE AND PICLORAM HERBICIDES

John H. Brock[1]

Abstract. Pelleted formulations of tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea), hexazinone (3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione) and picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) were applied in March 1981 on a clay upland range site in North-Central Arizona that had been reinfested with juniper following chaining approximately 20 years earlier. Herbicides were applied by surface broadcast, except hexazinone which was placed in a grid pattern, to plots 15 x 30 meters in size arranged in a randomized block design. Herbicide rates ranged from 0.25 to 4.0 kg/ha and were applied to 4 replicates. The objective of this study was to determine effective herbicide rates that could be used in an integrated brush management program where the treatment objectives might range from maximal brush control to brush suppression that would release fine fuels for later prescribed burning treatments. Canopy reduction was estimated at 7, 8, 18 and 30 months post treatment. Mortality was estimated at 18, 30 and 42 months after herbicide application. Canopy reduction ranged from 95-1 percent. Mortality ranged from approximately 90% on the 4.0 kg/ha tebuthiuron treatment to no mortality on plots receiving pilcoram formulated in 2% a.i. pellets. Herbicide rates, and herbicides that would provide high mortality levels and those that would suppress brush growth were identified.

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[1]Environ. Resources in Agric., Arizona State Univ., Tempe, AZ.

NITRO COMPOUNDS IN SPECIES OF *ASTRAGALUS* IN ARGENTINA

M.C. Williams and Edith Gomez-Sosa[1]

Abstract. Several species of *Astragalus* cause livestock losses in Argentina. The toxic principle in these species has not been isolated, but toxic signs observed in affected livestock are similar to those described for poisoning from nitro-bearing *Astragalus* in the western United States. A cooperative investigation between the Poisonous Plant Research Laboratory, Logan, Utah, and the Instituto de Botanica Darwinion, San

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[1]USDA-ARS, Logan, UT & Instituto de Botanica Darwinion, San Isidro, Argentina.

Isidro, Argentina, was conducted to determine the presence and type of nitro compound in species of Astragalus in Argentina.

Twenty-seven species of Astragalus were analyzed for nitro compounds. Twenty-four species, including those known to poison livestock, synthesized nitro compounds that hydrolyzed to highly toxic 3-nitro-1-propanol (3-NPOH). Nitro compounds in A. palenae hydrolyzed to both 3-NPOH and 3-nitropropionic acid (3-NPA). This is the first Astragalus species examined that contained both compounds.

The percentage of nitro-bearing Astragalus (89%) in Argentina was very high compared with the percentage of nitro-bearing species found in North America (52%) and the Old World (about 12%). Species in Argentina synthesize predominantly 3-NPOH whereas 3-NPA is more commonly found in species of Astragalus in North America and the Old World.

EFFECTS OF FIRE AND/OR ATRAZINE ON JAPANESE BROME AND WESTERN WHEATGRASS

Steven G. Whisenant[1]

Abstract. Spring burning significantly reduced both Japanese brome (Bromus japonicus) density and standing crop while increasing western wheatgrass (Agropyron smithii) tilelr density during the first growing season. However, during the second year following burning, Japanese brome tiller density returned to preburn levels and the apparent first-year benefits to western wheatgrass were lost. Preemergent applications of atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) (1.1 kg/ha) significantly reduced tiller densities of Japanese brome and western wheatgrass for the first year. The important consequences of these treatments are not determined during the first year. The treatment effects on Japanese brome population dynamics must be considered when long-term reductions are desired. This study indicated that Japanese brome seed bank reserves were sufficient to overcome the loss of a single year's crop. The reproductive capacity, seed bank, and competitive ability of Japanese brome will allow even a small number of plants to repopulate an area within two years. These data indicate that a single year's treatment will not result in more than one year of control. However, if the treatment has a carryover effect, such as with atrazine, control may be longer lasting.

Introduction

Japanese brome is an introduced winter-annual grass which has become abundant in many Great Plains mixed-grass communities. Gartner et al. (4) reported Japanese brome was more common on soils with a good mulch cover and less common on soils with less surface mulch. They further speculated that xeric microenvironments were less favorable for Japanese brome seed germination. Kirsch and Kruse (5) hypothesized that Japanese brome invaded much of the northern mixed-grass prairie as a result of reductions in fire frequency which increased the surface mulch; creating a more mesic microenvironment for seeds and seedlings.

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[1]Botany & Range Science Department, Brigham Young University, Provo, UT.

Bruning after seedling emergence is usually detrimental to annual plants (2, 9). Seeds are seldom damaged by grassland fires unless they are in the upper inflorescence (2, 7). As a result, most literature indicates burning during the dormant season seldom reduces subsequent populations of annual grasses (10). However, some exceptions are found; Evans and Young (3) reported a large percentage of downy brome (Bromus tectorum) seeds still in the inflorescence were destroyed by summer wildfires. This resulted in reduced downy brome populations for the next two years. They (11) reported less than 10 downy brome plants per m^2 in the first growing season following a summer wildfire. In the second growing season they found nearly 8,000 and over 16,000 per m^2 in the third season. This demonstrated a two- to three-generation reduction in downy brome populations.

Gartner et al. (4) stated that fall winter or spring burns were equally successful at reducing Japanese brome densities for at least two years and that prescribed burning has great potential as a range improvement practice on Japanese brome infested rangeland in western South Dakota. Whisenant et al. (8) reported little success in controlling annual grasses for more than one year with prescribed fire. Burning after seedling emergence killed Japanese brome in Texas for only one growing season (8). Seed immigration from other areas and/or recruitment from the seed bank allowed Japanese brome to regain preburn productivity by the second year.

Field observations in the Badlands National Park indicated that Japanese brome begins to flower in May or early June and the seeds are ripe by late June or July. As the seeds mature, the plants senesce and relatively few living plants are found by August. Japanese brome seeds are retained on dead and erect culms until fall and winter (1). Many seeds are dispersed between October and the following March. Some seed germination occurs in late fall; almost all of the current year's germination occurs by March and April.

The objectives of this research were to determine the influence of fire and/or atrazine on the density and standing crop of Japanese brome and western wheatgrass. Studying seed production and soil-seed reserves of Japanese brome was considered to be an important aspect of the long-term treatment response.

Study Area and Methods

This study was conducted on a mixed-grass prairie of the Badlands National Park in western South Dakota. Annual precipitation is approximately 38.4 cm, of which 30.3 cm (79%) falls during the growing season (April through September). Temperatures have an annual mean of 8.3°C in summer and drops to -29°C or lower in winter. The mean growing season is 126 days. Relative humidity has a wide diurnal variation; ranging from 45 to 85% during a typical summer day.

Western wheatgrass was the dominant perennial plant species and Japanese brome was the codominant on the study area. Western wheatgrass tiller densities were rather consistent; varying between 300 and 375 tillers per m^2 throughout the study period.

Thirty 5- by 5-m plots were established in a randomized complete block design with 3 replications and 10 treatments. Treatments applied are:

Untreated
Burned, April 1983
Burned, May 1983
Burned, April 1983 and 1984

Burned, May 1983 and 1984
Clipped, April 1983
Clipped, May 1983
Atrazine application (1.1 kg/ha), September 1983
Burned, April 1983 and atrazine application September 1983
Burned, April 1984

Tiller density was determined in April 1983 and July 1984 using five placements of an 0.10 m^2 quadrat placed on a permanently marked diagonal across each plot. Differences in tiller density among treatments were determined with analysis of covariance using the April density as the covariate. Standing crops were determined in August 1984 using five placements of an 0.10 m^2 quadrat in each plot. Differences in standing crops among treatments were determined with analysis of variance. Orthogonal comparisons were made on nine previously selected contrasts. Comparisons of tiller densities were made on the adjusted means obtained from analysis of covariance.

The number of developed seeds per spikelet and per plant were determined in July 1984. Seed production per m^2 was determined by multiplying seed production per plant times the number of plants per m^2.

The Japanese brome seed bank was determined by collecting the surface litter and the top 3 cm of soil in three 0.10 m^2 quadrats from each plot. Mature and filled seeds were counted in each of these collections. Treatment differences were determined with analysis of variance at the 5% level of significance. Mean separations, when necessary, were conducted using Student-Newman-Keul's test.

Results and Discussion

Japanese brome tiller density and standing crop were significantly ($P < 0.05$) reduced during the first year following either burning or atrazine application (Tables 1 and 2). However, during the second year, both tiller density and standing crop increased to preburn levels. Burning resulted in greater reductions in Japanese brome densities for at least two years following treatment than did clipping. This indicated that mortality resulted from the effects of heat rather than simply foliage removal. Atrazine applied as a preemergent herbicide significantly reduced Japanese brome tiller density and standing crop compared to the untreated plots (Tables 1 and 2).

Burning significantly increased western wheatgrass tiller density during the first growing season (Tables 1 and 2). However, during the second growing season, tiller density was reduced to untreated levels. Atrazine treatments significantly reduced western wheatgrass tiller density, at least for the first year after treatment. Western wheatgrass standing crop was not significantly affected by any of the treatments (Table 2).

Spring burning significantly reduced Japanese brome seed production during the first year after both the 1983 and 1984 burns (Table 3). Japanese brome seed production was still significantly reduced in the second season after burning (46,644 versus 94,212 per m^2 in the untreated plots). However, 46,444 seeds per m^2 is certainly sufficient to reestablish populations equivalent to untreated plots.

Spring burning dramatically reduced the surface seed bank during the first year after a fire (Table 3). The soil seed bank was not significantly affected during the first two years after a fire.

Table 1. Tiller density (per m^2) of Japanese brome and western wheatgrass in July 1984, after treating in 1983 and/or 1984. Badlands National Park, South Dakota[1].

Contrast	Japanese brome	Western wheatgrass
No treatment vs.	2,617	375
1983 burning treatments	2,028^{NS}	264^{NS}
No treatment vs.	2,617	375
1984 burning treatments	23**	507**
No treatment vs.		
double burning (1983	2,617	375
and 1984) treatments	580**	333^{NS}
1984 burning treatment vs.		
double burning (1983	23	507
and 1984) treatments	580**	333^{NS}
No treatment vs.	2,617	375
Atrazine treatment (Sept. 1983)	19**	95**
1983 clipping treatments vs.	3,250	297
1983 burning treatments	2,028*	264^{NS}
1983 burning treatments vs.	2,028	264
1984 burning treatments	23**	507**
April 1983 burning followed by		
Atrazine treatment vs.	19	95
Atrazine treatment	77^{NS}	302*
Atrazine treatment vs.	19	95
1984 burning treatment	23^{NS}	507**

[1] NS means the contrast is not significant; * means significant at the 5% error level; and ** means significant at the 1% error level. All analyses of contrasts are within a species.

Table 2. Standing crops (g/m^2) of Japanese brome and western wheatgrass in July 1984, after treating in 1983 and/or 1984. Badlands National Park, South Dakota[1].

Contrast	Japanese brome	Western wheatgrass
No treatment vs.	14.8	21.2
1983 burning treatments	19.9 NS	6.6 NS
No treatment vs.	14.8	21.2
1984 burning treatments	0.7*	22.4 NS
No treatment vs.		
double burning (1983	14.8	21.2
and 1984) treatments	4.7*	18.4 NS
1984 burning treatment vs.		
double burning (1983	0.7	22.4
and 1984) treatments	4.7 NS	18.4 NS
No treatment vs.	14.8	21.2
Atrazine treatment (Sept. 1983)	0.0*	7.7 NS
1983 clipping treatments vs.	24.7	13.0
1983 burning treatments	19.9 NS	6.6 NS
1983 burning treatments vs.	19.9	6.6
1984 burning treatments	0.7**	22.4 NS
April 1983 burning followed by		
Atrazine treatment vs.	1.5	17.4
Atrazine treatment	0.0 NS	7.7 NS
Atrazine treatment vs.	0.0	7.7
1984 burning treatment	0.7 NS	22.4 NS

[1] NS means the contrast is not significant; * means significant at the 5% error level; and ** means significant at the 1% error level. All analyses of contrasts are within a species.

Table 3. Selected features (per m^2) of Japanese brome population dynamics in July 1984 following burning and/or atrazine application[1].

	Burned April 1983	Burned April 1984	Atrazine September 1983	Unburned
Seedling density; April 1983	2,299a	--	2,412a	2,738a
Mature plants; August 1983	90b	--	2,287a	2,360a
Seed production; 1983	1,620b	--	69,258a	73,160a
Seedling density; April 1984	2,417a	2,381a	38b	2,287a
Mature plants; July 1984	2,028a	23b	19b	2,617a
Seed production; 1984	46,644b	368c	1,803c	94,212a
Surface seed bank; July 1984	11,775a	700b	10,897a	12,460a
Soil surface seed bank; July 1984	10,760a	11,512a	12,250a	11,852a

[1] Means within a single row, followed by the same lower-case letter, are not significantly ($P<0.05$) different according to Student-Newman-Keul's test.

Conclusions

Spring burning reduced Japanese brome density and standing crop for only one year. Western wheatgrass benefited from the Japanese brome reduction but was reduced to preburn levels in the following season. Pre-emergent applications of atrazine reduced density of both Japanese brome and western wheatgrass for at least the first year.

Carryover of Japanese brome seed in the seed bank was sufficient to establish populations similar to untreated plots in the next generation following a spring fire. Since many of the seeds germinating in the fall are from the previous year's seed crop (1), the loss of a single seed crop may not affect the next year's population. When combined with the relatively high seed bank, numbers common in annual grass communities (6) (Table 3), it is easy to understand the rapid recovery of the Japanese brome population following the loss of a single seed crop.

In contrast to the downy brome response observed by Evans and Young (3), no reductions in post-burned generations of Japanese brome were observed in this study. Some Japanese brome seeds are destroyed by spring burning but the seed bank appears to have sufficient reserves to renew the population in the next generation.

Downy brome grows in drier environments and may be limited by the availability of mesic micro-sites (3) common burned sites. In contrast, the Japanese brome in this study grew within an excellent stand of western wheatgrass which apparently created sufficiently mesic micro-sites for seed germination and establishment of seedlings.

Spring burning, in this study, only significantly affected the generation of annual plants being burned. Subsequent generations were not significantly affected. As a result, spring burning cannot be considered a suitable method of controlling Japanese brome in western wheatgrass communities. Atrazine may have a carryover influence on subsequent generations. Second year data on the atrazine treatments was not available at the time this report was prepared.

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ECONOMIC LEAFY SPURGE (*Euphorbia esula* L.) CONTROL AND FORAGE PRODUCTION IN PASTURE AND RANGELAND

Rodney G. Lym and Calvin G. Messersmith[1]

An experiment to evaluate long term leafy spurge (*Euphorbia esula* L.) control and forage production was established at two sites in North Dakota in 1983. The treatments were selected based on previous research at North Dakota State University and included treatments that resulted in good leafy spurge control and/or high forage production. Herbicides were applied in August 1983 or July 1984 and economic return was estimated by converting forage production to animal unit days (A.U.D.) and then to pounds of beef at $0.60/lb minus the cost of the herbicide treatment.

Picloram (4-amino-3,5,6-trichloropicolinic acid) at 2.0 lb/A and dicamba (3,6-dichloro-o-anisic acid) at 8.0 lb/A provided the highest average leafy spurge control at 98 and 89%, respectively, as fall applications and 99 and 79%, respectively, as spring applications. Picloram + 2,4-D ((2,4-dichlorophenoxy)acetic acid) at 0.25 + 1.0 lb/A provided only 35% leafy spurge control when averaged over application site and date. However, previous research at North Dakota State University has shown that annual application of this treatment for 3-5 years will give 70 to 80% leafy spurge control and maximum forage production (Proc. W.S.W.S. 1984). The 2,4-D controlled leafy spurge topgrowth for only 2-3 months.

Fall applied 2,4-D at 2.0 lb/A provided an average gain of 24 A.U.D. and a net return of $2/A compared to the control. Fall applied picloram at 2.0 lb/A and dicamba at 8.0 lb/A resulted in a gain of 29 and 21 A.U.D., respectively, compared to the control but were uneconomical treatments after one year because of the high initial cost. Much leafy spurge topgrowth remained and forage production was unaffected by spring applied treatments when harvested 1 month after application. Herbicides that provided good leafy spurge control generally were not cost effective and the least expensive annual treatments gave low leafy spurge control the first year of the study.

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[1]Agronomy Department, North Dakota State University, Fargo, ND.

EFFECTIVENESS OF TRICLOPYR FOR THE CONTROL OF LEAFY SPURGE

J.M. Krall and E.I. Hackett[1]

A trial was established in Elko County, Nevada to evaluate triclopyr for the control of leafy spurge in a grass pasture. Sequential applications were made May 22, 1981 during the early bloom stage, June 29, 1981 during the seed formation stage and July 12, 1982 during the late bloom stage of leafy spurge. All treatments were made using a 4-nozzle backpack sprayer which delivered 22 gallons of spray volume/A. Each treatment was replicated 3 times in a randomized complete block design. Individual plot areas were 6' x 30'.

Visual observations of percent shoot control on each treatment were made September 10, 1981, August 13, 1982, July 14, 1983 and September 8, 1984. Assessment of effectiveness of treatment was measured by control of leafy spurge regrowth. No damage to the pasture grasses was observed in any of the treatments. All treatments caused leafy spurge foliage to die back. Two applications of 3.0 lb ai/A applied during the bloom stage of leafy spurge for two consecutive years provided 90% control that has continued through the end of the fourth growing season. Triclopyr at lower rates and repeated applications showed promise the initial year of treatment, but not in subsequent years.

Leafy spurge regrowth following treatment of triclopyr

Herbicide	Rate (lb. ai/A)	Leafy spurge regrowth control (%) 1981	1982	1983	1984
Triclopyr	0.25 1/ 2/ 3/	28	25	10	0
Triclopyr	0.37 1/ 2/ 3/	38	30	15	0
Triclopyr	0.50 1/ 2/ 3/	43	40	45	40
Triclopyr	3.00 1/ 2/ 3/	60	85	90	90

1/ applied May 22, 1981 during early bloom stage of leafy spurge
2/ applied June 29, 1981 during seed formation of leafy spurge
3/ applied July 12, 1982 during late bloom stage of leafy spurge

[1]Range, Wildlife and Forestry Division, University of Nevada, Reno, NV.

EVALUATION OF HERBICIDES FOR LEAFY SPURGE CONTROL ON RANGE LAND IN NEVADA

E.I. Hackett, J.M. Krall and J.H. Marion[1]

A 1977 pubescent wheatgrass seeding in Northeast Nevada failed due to leafy spurge invasion at the time of establishment. Three trials were established on this seeding to test control of leafy spurge by: (1) experimental herbicides (2) tank mixtures and (3) rope wick with picloram. The trial site was 6200 feet in elevation in the 16 inch precipitation zone. The experimental herbicides and the rope wick applications were applied July 12, 1982 during the late bloom stage of leafy spurge. The tank mix applications of herbicide were applied August 13, 1982 during the fully developed seed stage of leafy spurge. Spray treatments were made using a 4 nozzle back-pack sprayer which delivered 22 gallons of spray volume/A. Each treatment was replicated 4 times in a randomized complete-block design. Individual plot areas were 6 ft x 30 ft. The rope wick applications were made with a pistachio rope wick with one person on each end.

Visual observations were made on top growth control July 13, 1983 and August 8, 1984. Herbicides providing 80% or more control of top growth of both seedlings and mature leafy spurge plants were: (1) picloram 22K at 2 lb ai/A, (2) picloram 2K pellets at 2 lb ai/A and (3) a 33% solution of XRM-4665, with 2 passes of the rope wick applicator. Top growth control in excess of 80% was also observed on mature leafy spurge plants sprayed with SC-0545 at 3 lbs ae/A, SC-0545 at 4.5 lb ae/A, glyphosate at 3.0 ae/A and glyphosate at 4.5 lb ae/A. However, these herbicides damaged the grasses and by July 17, 1983, leafy spurge seedlings completely dominated the treated plots. A followup spraying of the plots with 2,4-D on September 13, 1983 resulted in no additional seedling or mature leafy spurge control.

Treatment	Rate (lb/A)	Leafy Spurge Shoot Control: Shoot Control Percent 1983	1984	Grass Damage	Carryover Seedling Control
Tank mixes 1/					
Triclopyr + 2,4-D LV	1.0 + 2.0 ai	0	0	None	Good
Triclopyr + picloram 22K	1.0 + 0.5 ai	17	20	None	Good
2,4-D LV + picloram 22K	2.0 + 0.5 ai	17	67	None	Good
Picloram 2K pellets	2.0 ai	93	90	Slight	Excellent
No treatment	--	0	0	--	--
Experimental herbicide 2/					
SC-0545	3.00 ae	77	83	Severe	Poor
SC-0545	4.50 ae	87	90	Severe	Poor
SC-0224	3.00 ae	77	90	Severe	Poor
SC-0224	4.50 ae	90	87	Severe	Poor
Glyphosate	3.00 ae	87	90	Severe	Poor
Glyphosate	4.50 ae	90	90	Severe	Poor
HOE-00661	1.00 ai	0	10	Severe	Poor
HOE-00661	1.25 ai	13	10	Severe	Poor
HOE-0066	1.50 ai	0	10	Severe	Poor
No treatment	--	0	0	--	--
Rope wick 3/					
XRM-4665	10% 1 pass	13	20	--	--
XRM-4665	10% 2 passes	43	47	--	--
XRM-4665	33% 1 pass	63	67	--	--
XRM-4665	33% 2 passes	77	80	--	--
Picloram 22K	0.25 ai	0	13	--	--
Picloram 22K	0.50 ai	7	20	--	--
Picloram 22K	1.00 ai	37	43	--	--
Picloram 22K	2.00 ai	83	87	--	--
No treatment	--	0	0	--	--

1/ applied August 13, 1982 during seed maturity of leafy spurge
2/ applied July 12, 1982 during the late bloom of leafy spurge
3/ applied July 12, 1982 during the late bloom of leafy spurge

[1]Range, Wildlife & Forestry Div., University of Nevada, Reno, NV.

GRASS CONTROL WITH POSTEMERGENCE GRASS HERBICIDES AND CONTACT HERBICIDES

C.E. Bell and C. Kemp[1]

Abstract. The selective postemergence grass herbicides control grasses, but they are relatively slow in activity. Even though the mode of action is not precisely known, it is apparent that these herbicides affect meristematic tissue before leaf tissue. Therefore, it should be possible to decrease the time from application to death by using the grass herbicide to kill the meristems and a contact herbicide a few days later to kill the leaves. It may also be possible to decrease the required dosage of the grass herbicide.

Two experiments were conducted to test this hypothesis. Four postemergence grass herbicides; sethoxydim (2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one), fluazifop-butyl (butyl 2-[4-[5-(trifluromethyl-2-pyridyl]oxy)phenoxy]propionate), PP005 (butyl(R)-2[4-[5-trifluoromethyl)-2-pyridyl]oxy)phenoxy]propionate), and DPX-Y6202 (2-[4-[(6-chloro-2-quinoxalinyl)oxy]-phenoxy]propionic acid, ethyl ether)) were evaluated against four grasses; Mexican sprangletop (Leptochloa uninervia (Persl.) Hitchc. & Chase), junglerice (Echinochloa colonum(L.) Link), prairie cupgrass (Eriochloa contracta Hitchc.), and Italian ryegrass (Lolium multiflorum Lam.) in combination with diquat (6,7-dihydrodipyrido-[1,2-a:2',1'-c]pyrazinediium ion).

Some results support the hypothesis, while other results are not conclusive. In experiment 1, the combination of fluazifop-butyl with diquat, applied a few days after, was numerically but not significantly better than fluazifop-butyl applied alone at the two highest rates (.2 and .3 lbs a.i./A) for control of ryegrass. At significantly better than fluazifop-butyl applied alone or with diquat applied on the same day.

In the second experiment, the combination of any grass herbicide with diquat killed mature junglerice after 15 days. No grass herbicide applied alone killed junglerice. There was a significant difference between control of prairie cupgrass with the combination compared to the grass herbicides applied alone. However, the combination did not perform better than the grass herbicides alone for control of Mexican sprangletop.

Introduction

The ability of the postemergence grass herbicides to control grasses without injury to non-grass plants is well established. This ability has resulted in considerable testing of these products and widespread use commercially.

Although the mode of action of these herbicides is not completely understood, some details are known. According to Asare-Boamah and Fletcher (1), sethoxydim inhibited growth, chlorophyll accumulation and respiratory activity, while it also increased sugar and anthocyanin levels in corn seedlings. Gealy and Slife (2) reported that sethoxydim inhibited corn growth before it affected photosynthesis. They suggested that sethoxydim was initially translocated to the base of the stem where the chemical

[1]Cooperative Extension, University of California, El Centro, CA.

disrupted cell division and later had an effect on photosynthesis in the leaves. Their results and speculation on the activity of these herbicides support observations by the author in numerous field trials, where it is apparent that meristematic tissue is affected before leaves.

On an applied basis, this delay in the death of leaf tissue, which can be from 2-4 weeks, poses two problems. One concern is whether the rate of herbicide is adequate to kill the target weed, since the applicator will not know for quite some time. The other problem is a desire for crop producers to see dead weeds immediately so they are sure they have been successful. It has been observed by the author in 3 field trials of these herbicides that application of a contact herbicide, a few days after the grass herbicide, greatly increased the rate of kill compared to previous experience. Therefore, a hypothesis was developed that these herbicides could be used to kill the meristems of the grasses followed by a subsequent treatment with a contact herbicide to destroy the leaves, resulting in dead plants shortly after treatment. It was also felt that this hypothesis offered the possibility of using reduced rates of the grass herbicides.

Materials and Methods

Two experiments were conducted to test the hypothesis.

Experiment 1 consisted of fluazifop-butyl applied to annual ryegrass (Lolium multiflorum Lam.) at 5 rates (.025, .05, .1, .2, and .3 lbs ai/A) the same rates followed by .25 lb ai/A of diquat 3 days later, fluazifop-butyl at .2 and .3 lbs ai/A plus diquat at .25 lbs ai/A on the same day, diquat alone at .25 and .5 lbs ai/A and an untreated control. The ryegrass was planted on 60" beds on November 1, 1984 and irrigated with a drip system. Plot size was 1 bed by 25', with 4 replications in a randomized complete block design. Herbicide applications were all made with a CO_2 pressured sprayer using an 8003E flat fan nozzle at 30 gallon per acre (GPA) total volume. The Italian ryegrass was 4-6 inches tall with 3-4 tillers at time of treatment. All treatments using fluazifop-butyl included 1 quart/A of oil surfactant. The first application was made on December 17, 1984 with the subsequent diquat application on December 20, 1984. Visual evaluations were made on January 3, January 14, and February 7, 1985.

Experiment 2 was established in a weedy area of an alfalfa field to compare 4 postemergence grass herbicides in combination with a contact herbicide. The 4 grass herbicides were sethoxydim, fluazifop-butyl, PP005, and DPX-Y6202. These were all applied at .25 and .5 lbs ai/A on September 18, 1984. Plot size was 4' x 12' with 4 replications in a randomized complete block design. On September 21, 1984, diquat was applied in a 5' swath across each plot at .375 lbs ai/A. A 2' x 12' strip was left untreated by the grass herbicides between each plot, however 5' of this strip was treated with the diquat. Application was made with a CO_2 pressured sprayer using 8004 nozzles at 40 psi at 40 GPA. All grass herbicide treatments included 1 quart per acre of oil surfactant. Weeds present at time of treatment were; Mexican sprangletop and prairie cupgrass. They were all mature and beginning to flower. The experiment was evaluated on September 24, October 3, October 12 and November 9, 1984.

Results and Discussion

In the case of experiment 1 the results support the hypothesis that a contact herbicide can improve the activity of the grass herbicide. As can be seen from the data compiled in Table 1, the only treatment able to provide complete control the ryegrass was the combination treatment of fluazifop-butyl at .2 or .3 lb ai/A with diquat at .25 lb ai/A. At the first evaluation date (January 3), the most effective treatments were either diquat alone or those including diquat. As time progressed, the effects of the diquat wore off. By the time of the last evaluation, the most effective treatments were those including .2 or .3 lbs ai/A of fluazifop-butyl. In all cases, the combination treatment of fluazifop-butyl with diquat when the diquat was applied 3 days after the fluazifop-butyl, performed better than the fluazifop-butyl alone. For example, fluazifop-butyl at .1 lb ai/A plus diquat at .25 lb ai/A at 3 days was significantly better than fluazifop-butyl at .1 lb ai/A plus .25 lb ai/A diquat applied on the same day or .1 lb ai/A of fluazifop-butyl applied alone.

TABLE 1.
Results of Experiment 1.

Treatment	Date Applied	Rate (lbs.ai/A)	Italian Ryegrass Control* Jan. 3	Jan. 14	Feb. 7
1.fluazifop	Dec. 17	.025	1.0f	1.0h	.5ef
2.fluazifop	Dec. 17	.05	2.5de	2.8g	1.8e
3.fluazifop	Dec. 17	.1	2.0e	3.3g	5.3c
4.fluazifop	Dec. 17	.2	3.5d	5.3f	9.3ab
5.fluazifop	Dec. 17	.3	3.5d	6.3ef	9.8ab
6.fluazifop	Dec. 17	.025			
+ diquat	Dec. 20	.25	7.8ab	7.0de	3.5d
7.fluazifop	Dec. 17	.05			
+ diquat	Dec. 20	.25	7.8ab	7.5cde	5.3c
8.fluazifop	Dec. 17	.1			
+ diquat	Dec. 20	.25	7.8ab	9.0ab	8.3b
9.fluazifop	Dec. 17	.2			
+ diquat	Dec. 20	.25	8.0ab	8.8abc	10.0a
10.fluazifop	Dec. 17	.3			
+ diquat	Dec. 20	.25	8.8a	9.8a	10.0a
11.diquat	Dec. 20	.25	6.3c	3.0g	4.0cd
12.diquat	Dec. 20	.5	7.3bc	5.3f	5.0cd
13.fluazifop	Dec. 17	.1			
+ diquat	Dec. 17	.25	7.3bc	7.0de	5.3c
14.fluazifop	Dec. 17	.2			
+ diquat	Dec. 17	.25	7.0bc	8.0bcd	8.5ab
15.untreated control			0.0g	0.0h	0.0f

*10 = all plants dead, 0 = no control
numbers in each column followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Experiment 2 supported the hypothesis in some cases and not in others. As with experiment 1, the overspray of diquat improved the initial control of the grasses, but did not always provide a greater degree of final control. This was particularly true of Mexican sprangletop. In the case of Mexican sprangletop, the only herbicide to kill this weed (Table 2) at these rates, was DPX-Y6202, the other herbicides only slowed growth and injured some tissue. With regard to junglerice (Table 4), the combination of a grass herbicide with diquat succeeded in killing the grass 15 days after the first treatment. The application of a grass herbicide applied alone did not kill junglerice, which is consistent with previously observed activity of these herbicides when applied alone to mature junglerice. Diquat alone applied to junglerice caused considerable injury, but did not kill any plants. Prairie cupgrass control was enhanced by the addition of diquat, as illustrated in Table 3, although no treatment was sufficient to kill the weed.

TABLE 2.
Results of experiment 2., mexican sprangletop control

Treatment	Rate	Evaluation* Sept. 24	Oct. 3	Oct. 12	Nov. 9
1. sethoxydim	.25	1.3	4.3	3.3	2.3
+ diquat	.38	7.3	8.0	6.0	2.3
2. sethoxydim	.5	1.5	5.0	3.3	0.5
+ diquat	.38	7.3	8.5	5.8	0.5
3. fluazifop	.25	1.3	4.5	3.3	0.5
+ diquat	.38	6.8	8.3	5.0	0.0
4. fluazifop	.5	1.3	4.3	4.0	1.3
+ diquat	.38	6.8	7.8	4.8	1.3
5. PP005	.25	1.5	3.8	4.5	0.0
+ diquat	.38	6.8	7.8	5.5	0.0
6. PP005	.5	1.5	5.0	4.3	5.0
+ diquat	.38	7.3	8.5	7.3	4.3
7. DPX-Y6202	.25	0.5	4.8	6.5	7.8
+ diquat	.38	7.5	8.5	7.8	8.3
8. DPX-Y6202	.5	1.0	5.8	8.3	8.8
+ diquat	.38	8.0	9.0	9.3	9.3
9. untreated control		0.0	0.0	0.0	0.0
+ diquat		7.0	5.8	2.3	0.0

* 10 = all weeds dead, 0 = no control

Summary

It is difficult to conclude from these data that the hypothesis is valid or that it is not. There appears to be significant differences between how the weeds react to the combination of a grass herbicide and diquat. In most cases (e.g., Italian ryegrass, junglerice, prairie cupgrass), the combination resulted in better control than the grass herbicide alone at the same rate. It is also apparent that some grasses are more sensitive to diquat than others. Mature junglerice is nearly killed by .38 lb ai/A of diquat, whereas Mixican sprangletop is only moderately and temporarily injured. Further work is needed to elucidate the parameters of the hypothesis; which weeds are sensitive to the combination and what is the proper timing for greatest benefit.

TABLE 3.
Results of experiment 2., prairie cupgrass control

Treatment	Rate	Evaluation* Sept. 24	Oct. 3	Oct. 12
1. sethoxydim	.25	4.0	7.0	5.0
+ diquat	.38	7.7	8.8	8.3
2. sethoxydim	.5	4.3	7.7	7.5
+ diquat	.38	7.3	9.0	9.0
3. fluazifop	.25	3.0	6.8	5.7
+ diquat	.38	8.5	8.3	8.3
4. fluazifop	.5	3.5	7.8	4.0
+ diquat	.38	7.3	8.8	7.8
5. PP005	.25	3.3	7.0	5.0
+ diquat	.38	7.8	7.7	8.3
6. PP005	.5	4.3	8.0	5.5
+ diquat	.38	7.8	8.3	9.0
7. DPX-Y6202	.25	3.3	6.3	7.3
+ diquat	.38	7.3	8.5	8.3
8. DPX-Y6202	.5	4.8	8.0	8.0
+ diquat	.38	7.5	9.0	8.5
9. untreated control		0.0	0.0	0.0
+ diquat		7.3	7.5	4.0

* 10 = all weeds dead, 0 = no control

TABLE 4.
Results of experiment 2., junglerice control

Treatment	Rate	Evaluation* Sept. 24	Oct. 3	Oct. 12
1. sethoxydim	.25	3.5	5.8	6.0
+ diquat	.38	8.7	10.0	10.0
2. sethoxydim	.5	4.0	6.0	6.5
+ diquat	.38	8.8	10.0	10.0
3. fluazifop	.25	3.0	5.3	5.0
+ diquat	.38	8.8	10.0	10.0
4. fluazifop	.5	2.0	5.5	5.7
+ diquat	.38	8.7	9.8	10.0
5. PP005	.25	2.5	5.3	5.0
+ diquat	.38	8.8	10.0	10.0
6. PP005	.5	3.0	5.3	6.5
+ diquat	.38	8.8	10.0	10.0
7. DPX-Y6202	.25	2.8	5.8	6.8
+ diquat	.38	8.3	10.0	10.0
8. DPX-Y6202	.5	3.3	7.3	8.0
+ diquat	.38	9.0	10.0	10.0
9. untreated control		0.0	0.0	0.0
+ diquat		8.5	8.8	6.8

* 10 = all weeds dead, 0 = no control

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RESPONSE OF YOUNG GRAPES TO DORMANT CONTACT APPLICATIONS WITH OXYFLUORFEN

J.T. Schlesselman[1]

Oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene) has been registered for use in dormant established grapevines for several years. However, the label prohibits its use on dormant young grapes which are not trellised or staked. The reasoning to this restriction was insufficient data supporting the safety of oxyfluorfen being applied directly to the dormant buds. This safety was of definite concern considering the substantial contact preperties of oxyfluorfen. Fifteen research studies were conducted in 12 grape varieties between 1981-1984. The primary objective in establishing these trials was to determine the response of young grapes to dormant contact applications with various rates of oxyfluorfen. This also included the effect to grapes depending on stage of bud dormancy at time of application.

Other considerations in these trials were to determine the activity of oxyfluorfen to grapes based on spray volume and the addition of a surfactant.

Materials and Methods

Initial trials conducted in 1981 included a wide rate change of oxyfluorfen (0.03, 0.125, 0.5, 2.0 and 8.0 lb ai/A). The application of oxyfluorfen to grape buds at various stages of dormancy was accomplished by means of a pump-type atomizer to individual buds at a spray volume equivalent to 100 GPA. One replication of each rate consisted of spraying 4 individual buds along a cane. This was replicated 4 times throughout the vineyard. In 3 timing trials, buds were sprayed when dormant (1/7/81), when they were beginning to swell (2/12/81) and when buds were pushing (3/9/81). The other 3 trials involved treating the buds at just one stage; when grape buds were in the semi-dormant stage (2/6/81).

The remaining trials, conducted during 1982-1984, consisted of applying oxyfluorfen (at 1.0, 2.0, and 4.0 lb ai/A) directly over the young grapevines. Generally the plots were 5 vines each with 4 replications. Applications were made using a hand-held spray boom with flat-fan nozzles (8004) pressurized with carbon dioxide.

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[1]Rohm and Haas Company, Reedley, CA.

Results and Discussion

Evaluations from bud spraying trials conducted in 1981 showed a significant initial response by the grapes from oxyfluorfen applications made to semi-dormant buds (beginning to swell). Table 1 shows the response of Chardonnay, Pinot Noir and Gamay Beaujolias grapes when applications were made on 2/6/81. Bud-break occurred on about 3/10/81. The evaluation taken on 3/27/81 showed all rates of oxyfluorfen adversely affecting the young shoots of the 3 varieties. Symptoms were generally overall stunting (vigor reduction) with some slight curling or distortion of the first few leaves. By 4 weeks after the first evaluation (6 weeks after bud-break) all grapes had recovered to where there were no significant differences between the treated and untreated grapes. There was, however, a more lasting effect with the higher rates of oxyfluorfen in the Chardonnay grapes.

Table 1. Response of 3 grape varieties to dormant contact applications with oxyfluorfen.

		% Vigor Reduction					
		Chardonnay		Pinot Noir		Gamay Beaujolias	
Herbicide	Lb ai/A	7 wks	11 wks	7 wks	11 wks	7 wks	11 wks
Oxyfluorfen	0.03	10b	0a	4b	1a	8b	0a
Oxyfluorfen	0.125	16b	0a	9c	0a	9bc	0a
Oxyfluorfen	0.5	30c	15b	11c	0a	14cd	0a
Oxyfluorfen	2.0	35c	20b	24d	0a	20d	0a
Oxyfluorfen	8.0	53d	25b	45e	6ab	30e	7a
Control	0.0	0a	6ab	0a	5ab	0a	2a

Treated 2/6/81, Triton AG-98 added at 0.25%.
Spray Volume: 100 GPA
Evaluated: 3/27/81, 4/22/81.

Application timing, with regard to bud dormancy, has a definite effect on the response of grapes to oxyfluorfen. The closer the grapes are to bud-break at application, the greater the response to oxyfluorfen. Table 2 shows the results from one of the timing trials when oxyfluorfen was applied to Thompson Seedless grapes at various stages of bud dormancy. It is apparent there is a greater degree of initial vigor reduction (stunting) with the grapes treated just prior to bud-break than when the buds were dormant. However, after another 4 weeks, the grapes had fully recovered including the grapes treated while buds were pushing.

The larger field trials conducted during 1982-1983 support earlier findings regarding oxyfluorfen applied over dormant grapes: There is a short-term response by the grapes to dormant contact applications with oxyfluorfen. Results from a trial conducted in Gewurztraminer grapes are shown in Table 3. Recovery from effects of the oxyfluorfen application is complete as indicated by the cane weights taken at the end of the season. The plots were relatively weed-free, so there was no weed competition influence on the cane weights.

Table 2. Activity of oxyfluorfen on Thompson Seedless grapes when applied to buds at various stages of dormancy.

Herbicide	Lb ai/A	% Vigor Reduction Evaluated: 4/1/81 #1	#2	#3	Evaluated: 4/29/81 #1	#2	#3
Oxyfluorfen	0.03	--	1a	8bc	--	0a	0a
Oxyfluorfen	0.125	2a	2a	10b-d	0a	0a	0a
Oxyfluorfen	0.5	3a	3ab	28e	1ab	5a-c	4a-c
Oxyfluorfen	2.0	8ba	13cd	33e	6a-c	5a-c	6a-c
Oxyfluorfen	8.0	16d	28e	48f	5bc	10bc	15bc
Control	0/0	0a	0a	0a	6a-c	2ab	10bc

#1 - Treated: 1/7/81 (buds dormant)
#2 - Treated: 2/12/81 (buds beginning to swell)
#3 - Treated: 3/9/81 (buds pushing)
Spray Volume: 100 GPA

Table 3. Response of Gewurztraminer grapes to dormant contact applications with oxyfluorfen.

Herbicide	Lb ai/A	% Vigor Reduction 2 Mos.	6 Mos.	Cane Weights (grams) 11 Mos.
Oxyfluorfen	1.0	25b	12a	242a
Oxyfluorfen	2.0	26bc	5a	380a
Oxyfluorfen	4.0	39c	15a	200a
Control	0.0	5a	19a	151a

Treated: 2/9/81, Triton AG-98 added at 0.25%.
Spray Volume: 50 GPA.
Evaluated: 4/7/82, 8/5/82, 1/6/83.
Plots relatively weed-free.

The research conducted during 1984 dealt primarily with the effect of oxyfluorfen applied over dormant young grapes based on spray gallonage and the addition of a surfactant (Triton AG-98 at ¼%). Table 4 shows there was no difference in response of Chenin Blanc grapes to dormant contact applications with oxyfluorfen whether or not a surfactant was added, or whether spray volume was 50 GPA or 10 GPA. As in the past, the initial grape response to oxyfluorfen is rate dependent and is temporary.

Conclusions

Oxyfluorfen can be safely applied to young grapes, provided the buds are dormant at time of application. Any adverse effect by the grapes to dormant applications with oxyfluorfen is temporary and will not affect the overall seasonal growth. Different spray volumes or the addition of a surfactant will not affect the response of grapes to dormant contact applications with oxyfluorfen.

Table 4. Effect of oxyfluorfen applied over dormant young Chenin Blanc grapes based on spray gallonage and the addition of a surfactant.

Herbicide	Lb ai/A	GPA	% Vigor Reduction 2½ Mos.	5 Mos.	9 Mos.
Oxyfluorfen	1.0	50	9a	4a	1a
Oxyfluorfen	2.0	50	17a-c	5a	1a
Oxyfluorfen	4.0	50	36c	4a	0a
Oxyfluorfen + AG-98 @ ¼%	1.0	50	9a	4a	0a
Oxyfluorfen + AG-98 @ ¼%	2.0	50	15ab	3a	0a
Oxyfluorfen + AG-98 @ ¼%	4.0	50	32bc	3a	0a
Oxyfluorfen	1.0	10	5a	2a	0a
Oxyfluorfen	2.0	10	9a	4a	0a
Oxyfluorfen	4.0	10	29bc	4a	0a
Control	0.0	--	3a	3a	0a

Treated: 1/27/84.
Evaluated: 4/16/84, 6/26/84, 10/30/84.

CONTROL OF BUTTERCUP OXALIS IN ARTICHOKES WITH OXYFLUORFEN

R.C. Hildreth and H. Agamalian[1]

Introduction

Weed control in many crops has been shown to increase yield and crop quality by the reduction of competition for light, nutrients and water. In some instances, weed control can provide added benefits such as reduced insect, disease or pest pressure, frost suppression or improved water drainage. Artichoke growers regularly practice weed control with mechanical cultivation and/or herbicides to reduce weed competition, to facilitate baiting for control of a pest vole (Microtis California) and probably most important, to improve water drainage during the winter rain season.

Artichokes (Cynara scolymus L.) require regular rains or irrigation for maximum growth and yield, but cannot tolerate excessive soil moisture. To avoid plant damage during the winter rain season, California artichoke growers establish drainage ditches between the rows to carry off excess water. These ditches must be kept free of weeds over the 4-5 month winter season. Buttercup oxalis (Oxalis pes-caprae L.) is a major problem weed in artichokes.

[1]Rohm and Haas Co., Danville, CA., & Univ. of Cal. Coop. Ext. Salinas, CA.

Buttercup oxalis is a perennial weed which propogates from numerous small bulbs produced on a deep root stock. Mechanical cultivation, while temporarily eliminating vegetative growth, contributes to the weed problem by redistributing the bulbs throughout the soil and by transporting the bulbs from field to field on equipment. An effective herbicide would appear to offer the only practical means of controlling or at least suppressing this weed.

Methods

Trials conducted by Rohm and Haas Company and the Monterey County Farm Advisor during 1982, 1983, and 1984 evaluated the potential of oxyfluorfen (1-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) for control of buttercup oxalis.

Oxyfluorfen was applied both preemergence and postemergence to the oxalis in winter drainage ditches in established artichoke fields with a history of heavy oxalis populations.

Oxyfluorfen rates of 0.25 to 4.0 lb ai/A were applied in 50 gallons of water per acre using a CO_2 backpack sprayer. Applications were made between October and January at various stages of oxalis development. Postemergence applications were made at early flowering (25%), mid flowering (50%) and late flowering (75%) stages of oxalis. Both single and multiple postemergence applications were evaluated. All applications were made as directed sprays with minimum exposure to artichoke foliage.

Results and Discussion

When applied preemergence to oxalis, oxyfluorfen provided initial control in direct relation to rates of 0.5 lb ai/A (50-55% control), 1.0 lb ai/A (70-81% control), 2.0 lbs ai/A (85-90% control) and 4.0 lb ai/A (100% control) (Tables 1 and 2). Although providing excellent oxalis control, the high rate of 4.0 lbs ai/A is considered too costly for weed control in artichokes. A rate of 2.0 lb ai/A is more cost effective and provides good initial oxalis control. However, late emerging oxalis did become established before the end of the rain season thus shortening the effectiveness of the winter drainage ditch.

TABLE 1

Preemergence Control of Buttercup Oxalis
With Oxyfluorfen - 1983

Watsonville, CA

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control Observation Date 11-15	12-20	3-10	% Artichoke Phytotoxicity 11-15	Total Artichoke Harvested Per 4 Replicate
	1	0	0	0	0	0	98
10-20-83 Preemergence	2	0.5	52	62	50	0	103
	3	1.0	78	81	78	11	111
	4	2.0	82	85	81	20	105
	5	4.0	92	100	100	21	99

TABLE 2

Preemergence Control of Buttercup Oxalis in Artichokes
With Oxyfluorfen - 1983

Jarris Ranch - Salinas, CA

Trial 1

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control Observation Date 12-7	1-27	2-14	3-14
10-25-83	1	None (control)	0	0	0	0
Preemergence	2	0.5	50	0	0	0
	3	1.0	75	10	0	0
	4	2.0	90	20	10	0

Trial 2

10-25-85	1	None (control)	0	0	0	0
Preemergence	2	0.5	55	10	0	0
	3	1.0	70	40	0	0
	4	2.0	90	60	10	0

Pedzzini Ranch - Castroville, CA

Trial 3

10-26-83	1	None (control)	0	0	0	0
Preemergence	2	0.5	20	10	0	0
	3	1.0	40	20	10	0
	4	2.0	60	40	20	10

Single postemergence applications of oxyfluorfen provided effective control of oxalis dependent on rate and timing of application. When applied to oxalis in the prebloom stage, oxyfluorfen provided initial control ratings of 0.25 lb ai/A (70-80% control), 0.5 lb ai/A (40-90% control), 1.0 lb ai/A (40-100% control) and 2.0 lb ai/A (85-90% control) (Tables 3 and 4). However, incomplete postemergence control resulted in some regrowth of oxalis during the term of the experiments.

Because single applications of the lower rates of oxyfluorfen (0.25-1.0 lb ai/A) did not always provide adequate control of oxalis, it was postulated that two applications might provide more complete and/or longer control. Two applications of oxyfluorfen applied postemergence to oxalis at various stages of oxalis development, e.g. early flowering, mid flowering and late flowering, did provide more adequate and season-long control. Good results were obtained in all cases where the rate of two applications combined reached 2.0 lbs ai/A or more. It also appears best to apply a higher rate first, e.g. 1.0 lb ai/A (Tables 5 and 6).

Although crop injury will result from direct spray contact of artichoke leaves with oxyfluorfen, injury from postdirected sprays is minimal and is limited to lower mature leaves contacted directly. Slight injury from oxyfluorfen does not have an adverse effect on artichoke yields (Tables 1 and 3).

Control or suppression of oxalis with oxyfluorfen appears to have a beneficial effect on artichoke yields with rates of 0.5, 1.0 and 2.0 lbs ai/A showing yield increases over the weedy check (Tables 1 and 3). This is probably due to reduced weed competition.

Conclusions

Single applications of oxyfluorfen at 1.0 to 2.0 lbs ai/A emergence will provide acceptable control/suppression of oxalis when applied pre-emergence or postemergence over winter drainage ditches in artichokes.

Two postemergence applications of oxyfluorfen totaling about 2.0 lbs ai/A will provide better oxalis control/suppression than single postemergence applications at comparable rates.

Injury to artichokes from directed applications of oxyfluorfen is minimal and has no affect on yield.

Oxyfluorfen should be registered for use in established artichokes for buttercup oxalis control.

TABLE 3

Postemergence Control of Buttercup Oxalis
in Artichokes With Oxyfluorfen - 1982 and 1983

Castroville, CA

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control	Total Artichoke Harvested Per 4 Replicate
12-23-81 Postemergence	1	0	0	54
	2	0.25	70	60
	3	0.5	90	81
	4	1.0	100	101
11-20-82 Postemergence	1	0	0	69
	2	0.25	80	80
	3	0.5	95	107
	4	1.0	100	123

TABLE 4

Postemergence Control of Buttercup Oxalis
in Artichokes With Oxyfluorfen - 1983

Sea Mist Farms - Castroville, CA

Trial 1

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control Observation Date 12-7	1-27	2-14	3-14
	1	None (control)	0	0	0	0
11-3-83 Early Postemergence	2	0.5	50	30	10	0
	3	1.0	60	40	20	0
	4	2.0	75	50	30	15
12-8-83 Early Flowering	5	0.5		70	70	60
	6	1.0		85	80	70
	7	2.0		90	90	80
1-5-84 Mid Flowering	8	0.5				40
	9	1.0				60
	10	2.0				80

Trial 2

	1	None (control)	0	0	0	0
11-13-83 Postemergence	2	0.5	50	25	10	0
	3	1.0	70	60	40	20
	4	2.0	85	80	60	40
12-8-83 Early Flowering	5	0.5		20	20	15
	6	1.0		40	40	40
	7	2.0		60	60	60
1-25-84 Late Flowering	8	0.5				40
	9	1.0				60
	10	2.0				75

Table 4 (cont'd.)

Trial 3

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control Observation Date 12-7	1-27	2-14	3-14
	1	None (control)	0	0	0	0
11-13-83	2	0.5	70	70	50	30
Postemergence	3	1.0	80	80	70	40
	4	2.0	85	85	75	50
1-5-84	5	0.5		50	50	40
Mid Flowering	6	1.0		65	70	60
	7	2.0		80	85	80
1-25-84	8	0.5				40
Late Flowering	9	1.0				50
	10	2.0				60

TABLE 5

Two Postemergence Applications of Oxyfluorfen for Buttercup Oxalis Control in Artichokes - 1983
Pedzzini Ranch - Castroville, CA

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control Observation Data 2-14	3-14
	1	None (control)	0	0
12-8-83 Early Flowering	2	0.5 + 0.5	70	70
	3	0.5 + 1.0	80	80
	4	0.5 + 2.0	95	95
1-5-84 Mid Flowering	5	1.0 + 0.5	85	80
	6	1.0 + 1.0	95	100
	7	1.0 + 2.0	100	100
		Jarris Ranch - Salinas, CA		
		Trial 1		
	1	None (control)	0	0
12-8-83 Early Flowering	2	0.5 + 0.5	70	70
	3	0.5 + 1.0	85	80
	4	0.5 + 2.0	100	95
1-25-84 Late Flowering	5	1.0 + 0.5	95	95
	6	1.0 + 1.0	100	100
	7	1.0 + 2.0	100	100
		Trial 2		
	1	None (control)	0	0
1-5-84 Mid Flowering	2	0.5 + 0.5	70	70
	3	0.5 + 1.0	85	80
	4	0.5 + 2.0	95	90
1-25-84 Late Flowering	5	1.0 + 0.5	80	95
	6	1.0 + 1.0	95	100
	7	1.0 + 2.0	100	100

Table 4 (cont'd.)

Trial 3

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control Observation Date 12-7	1-27	2-14	3-14
	1	None (control)	0	0	0	0
11-13-83	2	0.5	70	70	50	30
Postemergence	3	1.0	80	80	70	40
	4	2.0	85	85	75	50
1-5-84	5	0.5		50	50	40
Mid Flowering	6	1.0		65	70	60
	7	2.0		80	85	80
1-25-84	8	0.5				40
Late Flowering	9	1.0				50
	10	2.0				60

TABLE 6

Two Postemergence Applications of Oxyfluorfen for Buttercup Oxalis Control in Artichokes - 1983
Sea Mist Farms - Castroville, CA

Trial 1

Application Date and Oxalis Stage	Treatment Number	Oxyfluorfen Rate (lbs. A.I./A)	% Oxalis Control Observation Data 2-14	3-14
	1	None (control)	0	0
12-8-83 Early Flowering	2	0.5 + 0.5	65	65
	3	0.5 + 1.0	80	80
	4	0.5 + 2.0	95	90
1-5-84 Mid Flowering	5	1.0 + 0.5	80	85
	6	1.0 + 1.0	95	95
	7	1.0 + 2.0	100	100

Trial 2

	1	None (control)	0	0
12-8-83 Early Flowering	2	0.5 + 0.5	30	30
	3	0.5 + 1.0	60	60
	4	0.5 + 2.0	85	80
1-25-84 Late Flowering	5	1.0 + 0.5	40	45
	6	1.0 + 1.0	75	80
	7	1.0 + 2.0	90	95

Trial 3

	1	None (control)	0	0
1-5-84 Mid Flowering	2	0.5 + 0.5	75	75
	3	0.5 + 1.0	70	80
	4	0.5 + 2.0	85	85
1-25-84 Late Flowering	5	1.0 + 0.5	75	80
	6	1.0 + 1.0	90	90
	7	1.0 + 2.0	100	100

PENDIMETHALIN AND OXYFLUORFEN FOR SELECTIVE WEED CONTROL IN SEEDED ONIONS

W. Powell Anderson and Gary Hoxworth[1]

Abstract. Oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) is labeled for selective weed control in seeded onions as a postemergence treatment to onions in the 2-true-leaf or later stage of growth at dosages of 0.12 to 0.25 lb/A; repeat treatments may be made but not to exceed 0.5 lb/A per season.

Research with oxyfluorfen in southcentral New Mexico has shown that by the time fall-seeded and spring-seeded onions are in the 2-true-leaf stage the weeds are too large to be adequately controlled by oxyfluorfen at labeled dosages or by as much as 4 times the maximum allowable dosage. Results of this research have shown that fall-seeded and spring-seeded onions can be safely treated in the 1-true-leaf stage with oxyfluorfen at dosages as high as 1.0 lb/A (and up to 2.0 lb/A in spring-seeded onions) and, with respect to effective weed control, this is a preferred time of application, rather than the 2-true-leaf stage. Oxyfluorfen induces a typical spotted necrosis of contacted onion leaf tissue and this necrosis may cause the first-true-leaf to be pinched and fall over, but growth of later emerging leaves is unaffected.

Applied postemergence, oxyfluorfen has not adequately controlled common lambsquarter (Chenopodium album L.) and prostrate knotweed (Polygonum aviculare L.) and, when present, these two weed species must be controlled by other means.

Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzeneamine), applied preplant to the surface of preformed seedbeds at a dosage of 1.0 lb/A and soil incorporated about 1-inch deep, provided excellent selective control of common lambsquarter and prostrate knotweed as well as other susceptible weeds, in spring-seeded onions. It has also been safely used preplant in fall-seeded onions, with some control of London rocket (Sisymbrium irio L.), annual sowthistle (Sonchus oleraceus L.) and flixweed (Descurainia sophia (L.) Wats.), but populations of these weed species emerged later and were potential problem weeds. In fall-seeded onions, preplant pendimethalin reduced onion stands an estimated 10 percent, but this reduction was not expressed in subsequent onion bulb yields.

When applied October 31, 1983 to fall-seeded onions in the flag stage, oxyfluorfen appeared to kill the onions at dosages of 0.125 to 1.0 lb/A, and these treated areas remained bare of onions until about March 1, 1984 when onion seedlings began to appear first in land treated to 0.125 and 0.25 lb/A and later in that treated at 0.5 and 1.0 lb/A. Although onion stands were reduced, these onion seedlings eventually matured and bulbs were harvested (Table 3). At this stage of onion growth (flag stage), oxyfluorfen was applied preemergence or very early postemergence to the weeds and excellent season-long weed control was obtained, without the need for additional control measures. In spite of the apparent death of the onions prior to March 1, the experimental area was irrigated as needed.

Two complete experiments were lost to common lambsquarter and prostrate knotweed infestations in spring-seeded onions in which preplant pendimethalin had not been applied and postemergence applications of

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[1]Crop & Soil Science Dept., New Mexico State Univ., Las Cruces, NM.

Table 1. Yields of two varieties of fall-seeded onions treated preplant with pendimethalin and two postemergence applications of oxyfluorfen.

Treatment (lb ai/A)	Number of onion bulbs per plot, Variety A	Number of onion bulbs per plot, Variety B	Harvested marketable onions, Percent, Variety A	Harvested marketable onions, Percent, Variety B	Harvested marketable onions, 50-lb bags/A, Variety A	Harvested marketable onions, 50-lb bags/A, Variety B
Pendimethalin, preplant						
1.0	294	276	68	74	366	416
Pendimethalin, preplant plus two applications of each dosage of oxyfluorfen postemergence.						
Oxyfluorfen, postemergence						
0.125	277	263	76	78	464	567
0.25	280	273	76	81	498	639
0.33	314	280	74	75	478	550
0.50	288	243	77	82	518	642
0.75	276	262	78	73	544	683
1.00	254	255	76	81	544	662
Handweeded control	401	322	70	77	570	668

Onion varieties: A = Early New Mexico Yellow Grano.
B = NuMex BR1.

First application of oxyfluorfen December 9, 1983, to onions in 1.5-true-leaf stage; second application March 20, 1984. All herbicide-treated plots were handweeded twice during the season. The handweeded control plots were weeded more often, as needed.

Onions harvested June 12, 1984, and yield data are the average of four replications. Each harvested plot was one 40-inch bed 20 feet long, with 4 rows of onions per bed per variety. Onions were grown on raised beds furrow irrigated.

Table 2. Time required for two persons to make first hoeing of emerged weeds in fall-seeded onions treated with pendimethalin preplant and oxyfluorfen postemergence to onions in 1.5-leaf stage. Hoeing date, February 27, 1984.

Treatment (lb ai/A)	Ten (minutes) for two men to hoe each plot — Replication 1	2	3	4	Av.	Projected time for two men to hoe one acre (hours)
Pendimethalin, preplant (Applied October 10, 1983)						
1.0	2.2	2.7	1.6	2.3	2.2	6.0
Pendimethalin, preplant plus/oxyfluorfen postemergence December 9, 1983, to onions in 1.5-leaf stage.						
Oxyfluorfen, postemergence (Applied December 9, 1983)						
0.125	2.4	2.3	1.7	2.1	2.1	5.7
0.25	4.7	1.7	1.5	---	2.6	7.1
0.33	1.8	1.8	0.9	2.0	1.6	4.4
0.50	2.6	1.8	1.1	1.0	1.6	4.4
0.75	2.1	0.6	0.9	1.5	1.3	3.5
1.00	1.0	1.0	0.8	1.6	1.1	3.0

Principal weeds present were flixweed, London rocket, and a few annual sowthistles. These onions are of the same experiment for which yields are recorded in Table 1 of this paper. Handweeded control were included in the experiment and hoed weed-free periodically as needed, but hoeing times were not recorded.

various dosages of oxyfluorfen were made at several stages of onion growth. The oxyfluorfen treatments failed to control these weed species. The weed infestations soon became so dense that the experiments were disked out.

In spring-seeded onions, oxyfluorfen has been safely applied to onions in the loop-to-flag, 1-to-1.5-true-leaf, and 2-to-2.5-true-leaf stages at dosages as high as 2 lb/A, without onion injury other than the typical leaf spotting. Season-long weed control in spring-seeded onions has been obtained with pendimethalin applied preplant at 1.0 lb/A followed by 2.0 lb/A of oxyfluorfen applied to onions in the 1.5-leaf stage. Lower dosages of oxyfluorfen have also provided excellent weed control when used early postemergence with a preplant application of pendimethalin.

Procedure

Pendimethalin was applied preplant to the surface of pre-formed seedbeds and soil incorporated about 1-inch deep using a power-tiller/bedshaper. Oxyfluorfen was applied postemergence in the equivalent of 30 gal/A water using a bicycle-type small-plot sprayer and a spray-boom with

Table 3. Yields of two varieties of fall-seeded onions trated with two postemergence applications of oxyfluorfen at four dosages and three growth-stages.

Oxyfluorfen dosages (lb ai/A)	Number of onion bulbs per plot		Harvested marketable onions			
			Percent		50-lb bags/A	
	Variety		Variety		Variety	
	A	B	A	B	A	B
Onions in flag stage						
0.125	140	96	79	89	334	328
0.25	68	37	84	93	225	153
0.50	35	19	93	81	170	106
1.00	11	2	91	80	67	20
Handweeded	375	333	71	77	553	651
Onions in flag to 1-leaf stage						
0.125	396	424	60	66	409	559
0.25	471	332	64	76	487	620
0.50	501	340	62	78	516	692
1.00	421	322	67	84	542	697
Handweeded	485	406	64	74	562	766
Onions in 1.3 to 2-leaf stage						
0.125	426	399	65	77	524	683
0.25	344	393	68	82	542	704
0.50	243	346	69	75	567	704
1.00	378	348	69	80	565	747
Handweeded	403	307	78	83	660	821

Onion varieties: A = Early New Mexico Yellow Grano.
B = NuMex BR1.

Onion flag stage: Oxyfluorfen applied October 31, 1983, and March 20, 1984.

Onion flag to 1-leaf stage: Oxyfluorfen applied November 11, 1983, and March 20, 1984.

Onion 1.3 to 2-leaf stage: Oxyfluorfen applied December 9, 1983, and March 20, 1984.

Onions harvested June 12, 1984, and yield data are the average of three replications. Each harvested plot was one 40-inch bed 20 feet long, with 4 rows of onions per bed per variety. Onions were grown on raised beds and watered by furrow irrigation.

TeeJet 8004 nozzle tips; spray pressure was 30 psi. The basic plot size was four 40-inch beds (13.3 ft) wide by 25. Later, each plot was shortened to 20 ft long by hoeing a 2.5 ft portion off the ends of each plot, and this area was used as a work alley. Two adjacent beds in each plots were seeded to one onion variety and the other two beds to a second variety. Four rows of onions were seeded on each bed using a tractor-mounted seeder. The onions were watered by furrow irrigation. At time of harvest, the center two beds of each plot, one bed of each variety, were topped, counted and bagged by hand, then weighed, graded by machine, and marketable onions weighed. This procedure and plot size was the same for the fall- and spring-seeded onions. Fall-seeded onion varieties were Early New Mexico Yellow Grano and NuMex BR1. The spring-seeded onion varieties were Yellow Sweet Spanish and Ben Sheman.

Table 4. Yields of two varieties spring-seeded onions treated preplant with pendimethalin and postemergence with oxyfluorfen at three dosages to onions in 2-leaf stage.

Oxyfluorfen dosages (lb ai/A)	Number of onion bulbs per plot		Harvested marketable onions			
			Percent		50-lb bags/A	
	Variety		Variety		Variety	
	A	B	A	B	A	B
Pendimethalin, preplant						
1.0	56	46	67	62	193	158
Pendimethalin, preplant plus one postemergence application of oxyfluorfen to onions in 2-true-leaf stage.						
Oxyfluorfen, postemergence						
0.25	91	104	73	76	351	359
0.50	102	111	78	81	411	405
1.0	98	106	71	79	377	371
Handweeded	86	111	52	78	273	368

Onion varieties: A = Yellow Sweet Spanish.
B = Ben Sheman.

Onions seeded February 14, 1984; 1st furrow irrigation, February 16, 1984.

Pendimethalin applied to surface of preformed beds and soil incorporated about 1-inch deep with power-tiller/bedshaper on February 14, 1984.

Oxyfluorfen applied April 30, 1984, in equivalent of 33 gal water per acre.

Onions harvested July 25, 1984, and yield data represent the average of three replications. Each harvested plot was one 40-inch bed 20 feet long, with 4 rows of onions per bed per variety. Onions grown on raised beds and furrow irrigated.

Table 5. Yields of two varieties spring-seeded onions treated preplant with pendimethalin and postemergence with oxyfluorfen at four dosages and three stages of onion growth.

Oxyfluorfen dosages (lb ai/A)	Number of onion bulbs per plot		Harvested marketable onions			
			Percent		50-lb bags/A	
	Variety		Variety		Variety	
	A	B	A	B	A	B
Pendimethalin, preplant (Applied February 14)						
1.0	33	52	38	42	121	141
Pendimethalin, preplant plus one postemergence application of oxyfluorfen.						
Oxyfluorfen, postemergence						
Onions in loop-to-flag stage (Applied March 23)						
0.3	66	95	76	75	308	334
0.6	93	99	81	77	411	348
1.2	97	108	76	73	403	388
2.4	111	115	79	88	440	414
Onions in 1- to 1.5-leaf stage (Applied April 17)						
0.25	125	119	76	68	506	420
0.50	128	97	77	72	483	351
1.00	137	111	71	72	558	388
2.00	165	126	74	78	592	495
Onions in 2- to 2.5-leaf stage (Applied May 4)						
0.25	113	101	67	65	394	334
0.50	135	117	77	74	532	411
1.00	133	115	73	67	492	414
2.00	182	118	81	69	765	403
Handweeded	116	136	63	55	403	368

Onion varieties: A = Yellow Sweet Spanish.
B = Ben Sheman.

Onions seeded February 14, 1984; 1st furrow irrigation February 16, 1984.

Pendimethalin applied to surface of preformed beds and soil incorporated about 1-inch deep with power-tiller/bedshaper. Oxyfluorfen applied as broadcast spray in equivalent of 33 gal water per acre.

Onions harvested July 25, 1984, and yield data represents average of three replications. Each harvested plot was one 40-inch bed 20 feet long, with 4 rows of onions per bed per variety. Onions were grown on raised beds and furrow irrigated.

VEGETATION MANAGEMENT SYSTEMS - A NEW TOOL UTILIZING GLYPHOSATE IN TREE AND VINE CENTERS

E.E. Sieckert, J.W. Budzynski, and B.H. Wells[1]

A Vegetation Management System (VMS) is a new program which utilizes glyphosate (N-[phosphonomethyl]glycine) for reduced mowing or disking in orchard and vineyard centers. It employs Low Rate Technology (LRT) by decreasing carrier volume to 3-15, thus allowing rates of 0.19-0.38 lb ae/A. VMS can be applied for frost protection, for spring/summer annual weed control, or preharvest. This system can manage weed growth after mowing to a desired maintenance level by removing existing weeds or suppressing vegetation to a desired height. Tall annual weeds growing on orchard or vineyard centers produces a cooler orchard, thus increasing the chances for frost injury. Glyphosate at 0.38 lbs ae/A on light, moderate soil types can be utilized to control vegetation and improve frost protection. Where soils are heavy and some vegetation is required to provide access with light vehicles or prevent erosion, a 0.19 lbs ae/A rate has shown promise in providing suppression of the vegetation. During the spring/summer months weed populations change as day length and temperature increases. Results in 1983-84 have shown that glyphosate applied at 0.38 lbs ae/A to control such weeds as: Chenopodium album, Echinochloa crusgalli, Amaranthus retroflexus, Digitaria sanguinalis, and other species. Vegetative suppression at 0.19 to 0.38 lbs ae/A can maintain a 4-6 inch height up to forty days without destroying desireable vegetative cover provided by the normal weed populations. Mowings may be reduced by fifty percent or more under either system. Preparation for harvest in almond or walnut orchards requires a clean, smooth orchard surface for harvest. Research in 1983-84 has shown that 0.38 lbs ae/A after the last mowing will provide control or existing vegetation and a clean harvest. VMS offers a choice in management of weeds in orchards and vineyards, providing control or suprpession of the weeds according to the needs of the grower.

[1]Monsanto Agricultural Products Co., Sacramento and Fresno, CA.

CINMETHYLIN (SD 95481) FOR USE IN VEGETABLE, VINE, TREE AND ORNAMENTAL CROPS

J.W. May and J.R. Goss[1]

Abstract. Cinmethylin (proposed common name for SD 95481) (7-oxabicyclo-(2.2.1)heptane,1-methyl-4-(1-methylethyl)-2-(2-methylphenylmethoxy),-exo-) is a cineole herbicide which is being introduced in 1985 under an Experimental Use Permit on soybeans, cotton and peanuts. Numerous tests in Western states since 1981 have indicated that cinmethylin is useful for the control of annual grasses in a variety of horticultural crops including cucurbits, beans, peans, Irish potatoes, sweet potatoes, cole crops, tomatoes, peppers, vines, tree crops and turf.

[1]Shell Development Company, Modesto, CA.

Cinmethylin performs best as a preemergence soil-applied treatment, and has little, if any, post-emergence activity. Under extended dry periods or with row irrigation, cinmethylin requires shallow surface incorporation for activation. The compound is most effective against weedy annual grasses requiring either tank mixtures or sequential treatments with other herbicides for wide spectrum weed control.

WSWS Business Meeting
March 14, 1985

The meeting was called to order at 7:30 a.m. by President Stan Heathman. He thanked Elanco for hosting the breakfast.

The Research Committee report was presented by Ralph Whitesides for Chuck Stanger. Bart Brinkman is chairman-elect for 1986. Project leaders for 1986 are as follow:

		Chairman	Chairman-elect
Section 1	Perennial Herbacious Weeds	Galen Schroeder	Don Thill
Section 2	Herbaceous Weeds Range and Forest	Mark Ferrel	Celestine Lacey
Section 3	Undesireable Woody Plants	Bruce Kelpsas	Nelroy Jackson
Section 4	Weeds in Horticultural Crops	Ron Brenchley	Carl Buchholz
Section 5	Weeds in Agronomic Crops	Steve Miller	
Section 6	Aquatic Ditchbank and Non-crop Weeds	David Spencer	
Section 7	Chemical and Physiological Studies	Phil Peterson	Fred Ryan

The 1985 Research Progress Report was published (350 copies) containing 220 individual reports by 118 authors.

The Treasurer's Report was presented by LaMar Anderson. Finances for WSWS are sound and solvent.

WSWS Financial Statement
March 6, 1984 - March 8, 1985

Income

Registration, Spokane Meeting		
178 X $30.00	$5,340	
Preregistration, 159 X $25	3,975	$9,315.00
Graduate Student, 52		
Guests, 3		
Dues, members not attending annual meetings (95)		475.00
Extra luncheon tickets (16 X $10)		160.00
1984 Research Progress Report sales		3,580.00
1984 Proceedings sales		4,342.50
Sale of back issues of publications		486.32
Payment of outstanding invoices from 1983		27.00

(cont.)

Income (cont.)	
Advance order payments	204.00
Coffee Break donations	950.00
Refund	4.91
Total 1984-85 fiscal year income	$19,544.73
Expenditures	
1984 Annual Meeting incidental expenses	$1,269.25
1985 Annual Meeting incidental expenses	583.70
Luncheon, 1984 Annual Meeting	3,946.05
Guest Speaker expenses	470.00
Graduate Student room subsidy	690.00
Graduate Student Paper awards	225.00
Business Manager honorarium	500.00
CAST dues	600.00
1984 Research Progress Report publication costs	2,205.80
1984 Proceedings publication costs	4,290.07
Postage	812.45
Newsletters, publication costs	218.85
Office supplies	646.83
Refunds	63.50
1985 Program, printing costs	576.58
Total 1984-85 fiscal year expenditures	$17,098.08
1984-85 operation profits	2,446.65
Interest on checking	318.55
Interest on savings	1,180.96
Actual total increase during 1984-85	$3,946.16
Assets	
Savings certificates	$25,500.00
Checking	9,783.55
Cash on hand	50.00
	$35,333.55

The Finance Committee report was given by Sheldon Blank. An audit of finances showed excellent records and he congratulated LaMar Anderson. There is a 1-2/3 year operating budget in reserve. Their recommendations were to 1) increase awards to graduate students, 2) continue financial aid to graduate students, 3) consider aid for graduate students for 1989 for trip to Hawaii. Sheldon moved acceptance of the Treasurer's Report. The motion carried.

The WSSA Report was given by Clyde Elmore. He reported on the recently concluded WSSA meeting in Seattle, WA. Of the 2100 total members of the WSSA, 620 are western members. The announcement was made that the 1986 meeting will be held in Houston, TX; 1987 in St. Louis, MO and 1988 in Boston, MA or San Diego, CA. As to the financial situation of the WSSA, at present there is a reserve nearly two times the annual operating budget. The past copule of years, the Society has been going in the red about $1000

per year. This is due primarily to an increase in publishing costs for the WSSA journal and a concurrent lack of publications to sell to make money. In 1985, four new monographs will be published and sold, and this should substantially improve the financial status of the WSSA. 1985 officers are: Jim Riggelman - President; Jean Dawson - President-Elect; Orvin Burnside - Vice President; Lloyd Wax - Secretary; and Henry Wilson - Treasurer.

Clyde announced that there will be an increase in reprint charges for 1985. The new directory of weed scientists will come out soon.

The Resolutions Committee Report was given by Steve Dewey. A single resolution was presented:

Resolution

WHEREAS, the facilities and arrangements for the 1985 annual meeting of the Western Society of Weed Science are of excellent quality, and

WHEREAS, the program for this meeting was well organized, timely and of excellent quality;

THEREFORE, BE IT RESOLVED that the membership of the Western Society of Weed Science in conference assembled expresses its sincere appreciation to Co-chairmen Ralph Spilsbury and Alan Dunlap, and members of the 1985 Local Arrangements Committee; to the management and staff of the Phoenix Hilton Hotel; to Chairman Harvey Tripple and members of the 1985 Program Committee; and to the 1985 Project Chairmen.

The motion was moved, seconded and carried.

The Nomination Committee Report was given by Harvey Tripple. New officers for 1986 are: Harvey Tripple, President; John O. Evans, President-elect; Sheldon Blank, Secretary; Ralph E. Whitesides, Chairman Research Section; Bart Brinkman, Chairman-elect Research; Phillip D. Olson, Chairman Education and Regulatory Section; and Robert Callihan, Chairman-elect of Education and Regulatory Section.

The Site Selection report was given by Paul Ogg for Don Burgoyne. Any suggestions for the site for 1990 should be given to Paul Ogg. Sites for future meetings are as follow:

1986 - Town and Country, San Diego, CA. March 18-20, Nelroy Jackson, Chairman of Local arrangements.
1987 - Red Lion Inn, Boise, ID. March 10-12.
1988 - Centre Plaza Holiday Inn, Fresno, CA. March 8-10.
1989 - Honolulu, Hawaii, March 13-17.

The Student Paper Contest was reviewed and winners presented by Clyde Elmore. Third place was D.C. Burkhart, Montana State University; advisor, Pete Faye. Second place was Stott Howard, Washington State University; advisor, Ralph Whitesides. First place was Jesse Richardson, Washington State University; advisor Larry Morrow.

Stan Heathman passed responsibility to the new President, Harvey Tripple. The business meeting was adjourned at 8.50 am.

Respectfully submitted,
Lloyd C. Haderlie

The following Fellow member was elected and awarded at the Phoenix meeting.

Jack Warren
Fellow, Western Society of Weed Science

After six and a half years in the U.S. Air Force as a meteorologist, he earned a B.S. degree in Agronomy at the University of California at Davis in 1948. He was employed immediately as a field research specialist in Northern California for Dow; research was conducted on use of herbicides in crops, range, forests and rights-of-way, as well as on insecticides and miticides, nitrogen conservers and soil fumigants. A 17-acre research farm was established near Sacramento in 1957 and was enlarged to a 160-acre Research Station near Davis, CA in 1962 under his direction. He transferred to the Field Development position in 1964 and has included work on picloram and several other herbicides, drift control and further development of soil fumigants for weed and other pest control since. He and his wife, Margaret, have six sons and presently reside in Sacramento. Positions in WSWS include Chairman of Range and Forestry Sections at different times, member and Chairman of the Resolutions Committee and President-elect (1980-81). He was awarded the Weed Warrior of 1975 by the Washington State Weed Conference and received an award from Idaho Weed Control Association in 1979 for conservation of Idaho Plant Resources.

He is currently involved with Regional Technical Research and Development for the Dow Chemical Co., with responsibility for herbicide development in the Western United States.

FELLOWS OF WSWS

Robert B. Balcom, 1968
*Walter S. Ball, 1968
Alden S. Crafts, 1968
F.L. Timmons, 1968
D.C. Tingey, 1968
Lambert C. Erickson, 1969
*Jesse M. Hodgsen, 1969
Lee M. Burge, 1970
Bruce Thornton, 1970
Virgil H. Freed, 1971
W.A. Harvey, 1971
*H. Fred Arle, 1972
Boysie E. Day, 1972
Harold P. Alley, 1973
K.C. Hamilton, 1973
William R. Furtick, 1974
*Oliver A. Leonard, 1974
Richard A. Fosse, 1975
Clarence I. Seeley, 1975
Arnold P. Appleby, 1976
J. LaMar Anderson, 1977
Arthur H. Lange, 1977
David E. Bayer, 1978
Kenneth W. Dunster, 1978
Louis A. Jensen, 1979
Gary A. Lee, 1979
W.L. Anliker, 1980
P. Eugene Heikes, 1981
J. Wayne Whitworth, 1981
Bert L. Bohmont, 1982
Lowell S. Jordan, 1982
Richard D. Comes, 1983
Clyde L. Elmore, 1983
Larry C. Burrill, 1984
Jack Warren, 1985

*Deceased

HONORARY MEMBERS OF WSWS

*Dick Beeler, 1976
Dale H. Bohmont, 1978
R. Phillip Upchurch, 1982
Virgil H. Freed, 1983
Warren C. Shaw, 1984

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*Deceased

Membership List of the Western Society of Weed Science, June 1, 1985

Mohamed Abidi
Department of Agronomy
Kansas State University
Manhattan, KS 66506

Edward B. Adams
WSU Cooperative Extension
N 222 Havana
Spokane, WA 99202

James C. Adams
Monsanto Company
1201 10th Ave. S., Suite 206
Great Falls, MT 59405

Norton Addy
Plant Genetics, Inc.
146 Gold Creek Circle
Folsom, CA 95630

Harry S. Agamalian
California Extension Service
118 Wilgart Way
Salinas, CA 93901

Jack Aldridge
Nor-Am Chemical Company
P.O. Box 4291
Fresno, CA 93744

Donald G. Alexander
Washington State Dept. Agr.
406 General Adm. Bldg. AX-41
Olympia, WA 98504

Harold P. Alley
Dow Chemical USA
1121 Reynolds
Laramie, WY 82070

J. LaMar Anderson
Plant Science Department
Utah State Univ., UMC 48
Logan, UT 84322

James E. Anderson
Mobay
2224 27th Ave. Ct.
Greeley, CO 80631

Lars W. J. Anderson
USDA/ARS Aquatic Weed Lab
Univ. Calif, Botany Dept.
Davis, CA 95616

Monte D. Anderson
American Hoechst Corporation
South 11611 Keeney Road
Spokane, WA 99204

Randy L. Anderson
USDA/ARS
P.O. Box K
Akron, CO 80720

W. Powell Anderson
Crop & Soil Sciences Dept.
New Mexico State University
Las Cruces, NM 88003

W. L. Anliker
Ciba-Geigy Corporation
811 S.E. 97th Ave.
Vancouver, WA 98664

Arnold P. Appleby
Crop Science Department
Oregon State University
Corvallis, OR 97331

Thomas F. Armstrong
Monsanto Company
800 N. Lindbergh Blvd, C35C
St. Louis, MO 63167

Richard N. Arnold
Agr. Science Center
P.O. Box 1018
Farmington, NM 87499

Stan Ashby
Arizona Agrochemical Company
P.O. Box 21537
Phoenix, AZ 85036

Floyd M. Ashton
Botany Department 0900
University of California
Davis, CA 95616

Alvin A. Baber
DuPont Company
673 Rosecrans Street
San Diego, CA 92106

Richard W. Bagley
MAAG Agrochemicals R&D
P.O. Box X
Vero Beach, FL 32961-3023

Richard B. Bahme
AgriDevelopment Company
3 Fleetwood Court
Orinda, CA 94563

Oakford G. Bain
American Cyanamid Company
8920 Stynbrook
Boise, ID 83704

John L. Baker
Fremont County Weed Control
County Court House, Basement
Lander, WY 82520

Robert B. Balcom
4720 44th St., N.W.
Washington, D.C. 20000

Larry D. Barnes
American Cyanamid Company
8413 Elkridge Ave.
Lubbock, TX 79423

Sam N. Bartee
Bartee Agr. Consultants, Inc.
427 S. Parker
Olathe, KS 66061

Connie Bartelma
Rohm & Haas Company
P.O. Box 5553
Mesa, AZ 85201

Loretta M. Bartel-Ortiz
Velsicol Chemical Corp.
341 E. Ohio Street
Chicago, IL 60611

Paul G. Bartels
Dept. of Plant Sciences
University of Arizona
Tucson, AZ 85721

Brooks Bauer
Zoecon Corporation
20592 Ayers Avenue
Escalon, CA 95320

K. George Beck
Plant, Soil & Entomol. Science
University of Idaho
Moscow, ID 83843

Carl Bell
Univ. Calif. Coop. Extension
Court House, 939 Main
El Centro, CA 92243

Wayne S. Belles
Zoecon Corporation
1240 Joyce Road
Moscow, ID 83843

Russell F. Bellina
E.I. du Pont de Nemours & Co.
Barley Mill Plaza
Walker's Mill 3-116
Wilmington, DE 19898

Warren E. Bendixen
Univ. Calif. Coop. Extension
624 West Foster Road
Santa Maria, CA 93455

E. Ray Bigler
Chemonics Industries
P.O. Box 21537
Phoenix, AZ 85036

Bruce Bilbrey
Arizona Agrochemical Co.
22039 N. 86th Avenue
Peoria, AZ 85345

Sheldon Blank
Monsanto Company
3805 S. Dennis
Kennewick, WA 99337

Bert L. Bohmont
127 Shepardson Bldg.
Colorado State University
Fort Collins, CO 80523

E. J. Bowles
Licensed P.C.A.
3979 North Drexel Avenue
Fresno, CA 93726

Dale W. Bohmont
Park Tower
280 Island Avenue
Reno, NV 89507

Russell Boyce
DuPont
5600 N. 69th Pl.
Scottsdale, AZ 85253

Jeff Boydston
BASF
P.O. Box 997
Yuma, AZ 85364

Dick Bray
Arizona Agrochemical Company
P.O. Box 21537
Phoenix, AZ 85036

Ronald G. Brenchley
Mobay Chemical Corporation
Rt #1, Box 31
Ashton, ID 83420

Hugh C. Bringhurst, Jr.
Salt Lake County
1814 West 6020 South
Salt Lake City, UT 84118

Bart Brinkman
Velsicol Chemical Corporation
5130 2nd Ave. S.E.
Salem, OR 97302

John H. Brock
Division of Agriculture
Arizona State University
Tempe, AZ 85283

David L. Bruce
Stauffer Chemical Company
5785 Encina Rd., Apt. 104
Goleta, CA 93117

Carl Buchholz
Ciba Geigy Corporation
674 Oberlin Road
Middletown, PA 17057

Henry Buckwalter, Jr.
ICI Americas Inc.
117 Wild River Lane
Folsom, CA 95630

Lee Burge
1625 California Avenue
Reno, NV 89507

Donald L. Burgoyne
17075 Oak Leaf Drive
Morgan Hill, CA 95037

Al Burkhalter
Monsanto Company
800 N. Lindbergh Blvd.
St. Louis, MO 63167

Dan Burkhart
Johnson Hall, Plant Science
Montana State University
Bozeman, MT 59717

Stephen T. Burningham
Utah Dept. of Agriculture
350 North Redwood Road
Salt Lake City, UT 84106

Ronald J. Burr
Rhone-Poulenc Inc.
13446 Waldo Hills Dr, S.E.
Sublimity, OR 97385

Larry C. Burrill
IPPC, Gilmore Annex
Oregon State University
Corvallis, OR 97331

Steven Busse
American Cyanamid
1502 19th St. South
Moorhead, MN 56560

J. Hugh B. Butler
Ministry of Agric. & Fish.
P.O. Box 24
Lincoln, NEW ZEALAND

John L. Callahan
Calgene
1201 Marina Circle
Davis, CA 95616

Janice A. Bojanowski
Velsicol Chemical Corporation
341 E. Ohio
Chicago, IL 60611

John E. Boutwell
U.S. Bureau of Reclamation
P.O. Box 25007, D-1522
Denver, CO 80225

Steven Bowe
Velsicol Chemical Corporation
Shandon Star Rt, Geneseo Rd.
Paso Robles, CA 93446

Robert H. Callihan
Plant,Soil & Entomol. Science
University of Idaho
Moscow, ID 83843

Thomas Camp
Campco Chemical Div.
5033 N. 66th Ave.
Glendale, AZ 85301

James Campbell
American Cyanamid
One Cyanamid Place
Wayne, NJ 07110

Henry Carrasco
Agr. Production Consultants
506 Santa Paula Drive
Salinas, CA 93901

Vanelle Carrithers
Dow Chemical Company
Rt. 1, Box 1313
Davis, CA 95616

Charles W. Carter
BASF Corporation
1796 Margo Drive
Concord, CA 94519

John J. Cato
Walla Walla County Weed Board
314 W. Main St.
Walla Walla, WA 99362

Carl L. Cauffman
Big Horn County Weed Control
355 East 5th
Lovell, WY 82431

Earl Chamberlain
Ciba-Geigy Corporation
2900 Westown Parkway, Suite G
West Des Maines, IA 50265

Ming Chan
Mobay Chemical Corporation
Box 4913
Kansas City, MO 64120

Thomas H. Chemens
Stauffer Chemical Company
3601 Christmas Tree
Bakersfield, CA 93306

Tom Cheney
PPG Industries
517 East C Street
Moscow, ID 83843

Jon Chernichy
University of Arizona
4201 East Broadway
Phoenix, AZ 85040

William J. Chism
Botany & Plant Science Dept.
University of California
Riverside, CA 92521

M. Dale Christensen
Ciba Geigy Corporation
1951 Chateau Ct.
Walnut Creek, CA 94598

Dean Christie
ICI Americas, Inc.
945 E. 108th Avenue
Northglenn, CO 80233

M. Brent Chugg
Del Monte Corporation
P.O. Box 59
Franklin, ID 83237

David Lee Coble
Plant & Soil Science Dept.
Montana State University
Bozeman, MT 59715

Donald R. Colbert
American Cyanamid Company
2133 Jackson Street
Lodi, CA 95240

Floyd O. Colbert
Lilly Research Labs
7521 W. California Avenue
Fresno, CA 93706

Robert W. Colby
Dow Chemical USA
Rt. 1, Box 1313
Davis, CA 95616

J. Wayne Cole
Univ. Idaho Extension Service
P.O. Box 427
Preston, ID 83263

Ron Collins
Consulting Entomologist
Route 2, Box 344
Hillsboro, OR 97123

Dale R. Comer
Nor-Am Chemical Company
135 W. Walnut Avenue
Visalia, CA 93277

Richard D. Comes
USDA/ARS
P.O. Box 30
Prosser, WA 99350

Fred Corbus
4633 N. 42nd Place
Phoenix, AZ 85018

Deborah K. Cowan
Union Carbide Agr. Products
2310 'D' Street
Sacramento, CA 95816

James Pete Cox
3M Company
661 Douglas Avenue
San Marcos, CA 92069

Garvin Crabtree
Horticulture Department
Oregon State University
Corvallis, OR 97331

Roe D. Crabtree
P.O. Box 3434
Spokane, WA 99220

A. S. Crafts
Botany Department
University of California
Davis, CA 95616

Gary Cramer
BASF Corporation
3303 E. River Road
Tucson, AZ 85718

Will Crites
Shell Development Company
649 Teak Ct.
Walnut Creek, CA 94598

Ron P. Crockett
Monsanto Company
E.12929 Sprague
Spokane, WA 99216

David W. Cudney
Univ. California Coop. Exten.
Batchelor Hall, U.C. Riverside
Riverside, CA 92521

William S. Curran
Dept. Agronomy & Soils
Washington State University
Pullman, WA 99164-6420

Alan Dalrymple
University of Wyoming
811 South 10th
Laramie, WY 82070

Lee C. Darlington
BASF Corporation
4609 Englewood Avenue
Yakima, WA 98908

Edwin A. Davis
USDA Forest Hydrology
8022 E. Whitton Avenue
Scottsdale, AZ 85251

Jason C. Davison
Cooperative Extension Service
569 Court Street
Elko, NV 89801

Jean H. Dawson
USDA, IAREC
P.O. Box 30
Prosser, WA 99350

Boysie E. Day
University of California
43 Western Drive
Richmond, CA 94801

Nathan Dechortez
USDA, Botany Department
University of California
Davis, CA 95616

Howard Deer
Extension Pesticide Specialist
Utah State University, UMC 46
Logan, UT 84322

Bud Deerkop
Rt. 1, Box 181
Potlach, ID 83855

Brian D. Deeter
Union Carbide Agr. Products
2155 S. 14th Avenue #17
Yuma, AZ 85364

Donald L. DeLay
Nor-Am Chemical Company
35462 Road 150
Visalia, CA 93291

Dan Devlin
Washington State University
A18 Valley Crest
Pullman, WA 99163

Steven A. Dewey
Plant Science Department
Utah State University, UMC 48
Logan, UT 84322

George Dickerson
13525 Durant N.E.
Albuquerque, NM 88001

J. W. DiVall
Stauffer Chemical Company
10250 Regency Circle, Suite 102
Omaha, NE 68114-3782

Joseph E. Dorr
Ciba-Geigy Corporation
925 N. Grand Avenue
Covina, CA 91724-2091

Chuck Doty
ICI Americas
P.O. Box 208
Goldsboro, NC 27530

Robert Downard
Plant Science Department
Utah State University, UMC 48
Logan, UT 84322

Brian Drew
Crop Development Center, Rm 316
University of Saskatchewan
Saskatoon, Saskatchewan
CANADA S7N OWO

Robert G. Duncan
Velsicol Chemical Corporation
3223 South Loop 289,Suite 324
Lubbock, TX 79423

Don Dunham
Fremont County Weed Control
County Courthouse, Basement
Lander, WY 82520

Allen Dunlap
Arizona Agrochemical Company
P.O. Box 21537
Phoenix, AZ 85036

Robert Dunlap
Union Carbide Agr. Products Co
3239 Vartikian Avenue
Fresno, CA 93710

Ken W. Dunster
Union Carbide Ag Products Co.
P.O. Box 2188
Fremont, CA 94536

Donal P. Dwyer
Nor-Am Agr. Products
266 S. Monroe
Fresno, CA 93726

Jack Edmondson
Eli-Lilly & Company
P.O. Box 3008
Omaha, NE 68103

Matthew Ehlhardt
American Hoechst Corporation
29 Violet Lane
Ione, CA 93640

Clyde Elmore
Botany Department
University of California
Davis, CA 95616

Lambert C. Erickson
University of Idaho
842 East 7th Street
Moscow, ID 83843

John O. Evans
Plant Science Department
Utah State University, UMC 48
Logan, UT 84322

Stuart Evans
Chemomics
734 E. South Pacific Drive
Phoenix, AZ 80521

Peter Fay
Plant & Soil Science Dept.
Montana State University
Bozeman, MT 59717

Gary Fellows
Plant & Soil Science Dept.
Montana State University
Bozeman, MT 59717

John Fennell
DuPont, Walker's Mill #3-116
Barley Mill Plaza
Wilmington, DE 19898

Steve A Fennimore
ICI Americas Inc.
498 N. Mariposa Avenue
Visalia, CA 93277

J. Scott Ferguson
Ciba-Geigy
1338 W. Juanita
Mesa, AZ 85202

Mary P. Ferguson
IR-4 Program
University of California
Davis, CA 95615

Mark A. Ferrell
Plant Science Division
Box 3354, University Station
University of Wyoming
Laramie, WY 82071

Duane Flom
Plant, Soil & Entomol. Sci.
University of Idaho
Moscow, ID 83843

R. A. Fosse
Union Carbide Ag Products
10144 E. French Camp Road
Manteca, CA 95336

John Foster
Velsicol Chemical Corporation
2809 Redwing Road
Fort Collins, CO 80526

Rodney Frack
Stauffer Chemical Company
2522 Marjorie Drive
Hays, KS 67601

Ron J. Frank, Suite 302
Shell Development Company
10330 Regency Parkway Dr.
Omaha, NE 68114

R. Ron Frazier
Nalco Chemical Company
1124 W. Escalon
Fresno, CA 93711

Virgil H. Freed
Agricultural Chemistry Dept.
Oregon State University
Corvallis, OR 97331

James S. Freeman
Cascade County
521 1st Avenue N.W.
Great Falls, MT 59404

Chris Furgueron
American Cyanamid Company
P.O. Box 669035
Marietta, GA 30066

C. W. Gaddis, Mgr.
Magna Corporation
Route 7, Box 425
Bakersfield, CA 93311

J. M. Gaggero
Zoecon Corporation
8276 Canyon Oak Drive
Citrus Heights, CA 95610

Dean Gaiser
Plant, Soil & Entomol. Sci.
University of Idaho
Moscow, ID 83843

Alvin F. Gale
Plant Science Division
University of Wyoming
Laramie, WY 82071

Charles J. Galley, Jr.
American Cyanamid Corporation
One Cyanamid Place
Wayne, NJ 07470

John Gallagher
Union Carbide Ag Products Co.
P.O. Box 12014
Research Triangle Park, NC
27709

Allen Gardner
Cache County Weed Control
P.O. Box C
Logan, UT 84321

Leland Gardner
Jefferson County Weed Control
Courthouse, Room 34
Rigby, ID 83442

Don R. Gargano
Pennwalt Corporation
51 Anne Marie
Hollister, CA 95023

David Gealy, USDA/ARS
215 Johnson Hall, Agronomy
Washington State University
Pullman, WA 99164

Jay Gehrett
Velsicol Chemical Company
Rt.3, Box 27, Whitney Road
Walla Walla, WA 99362

Frank De Gennaro
DuPont, Stine-Haskell
Box 30, Elkton Road
Newark, DE 19711

Pat Gentry
BASF
P.O. Box 128
Corte Madera, CA 94925

Richard D. Gibson
Arizona Coop Extension Serv.
820 E. Cottonwood Lane Bldg C
Casa Grande, AZ 85222

Jess Gilbert
Nevada Dept. Transportation
P.O. Box 930
Reno, NV 89504

Susie Going
Bannock County Weed Control
5500 South 5th
Pocatello, ID 83204

James C. Graham
Monsanto Company, C3SC
800 N. Lindbergh Blvd
St. Louis, MO 63167

K. A. Gregg
K.A. Gregg Company
P.O. Box 292
Upland, CA 91786

Mary Griffin
Velsicol Chemical Corporation
341 East Ohio Street
Chicago, IL 60611

Mark Grubbs
Arizona Agrochemical Company
P.O. Box 21537
Phoenix, AZ 85036

Robert Gunnell
Plant Science Department
Utah State University, UMC 48
Logan, UT 84322

Keith Haagenson
Great Western Sugar, ARC
11939 Sugarmill Road
Longmont, CO 80501

Tip Haagsma
Dow Chemical Canada Inc.
Modeland Road
Sarnia, Ontario CANADA

Irving Hackett
University of Nevada
Box 443
Elko, NV 89801

Lloyd Haderlie
Univ. Idaho Res & Ext Center
Box AA
Aberdeen, ID 83210

Delane M. Hall
Power County Weed Control
P.O. Box 121
American Falls, ID 83211

Donald H. Hall
Brea Agricultural Services
1336 W. Fremont Street
Stockton, CA 95201

K. C. Hamilton
Plant Sciences Department
University of Arizona
Tucson, AZ 85721

Jack V. Handly
Dow Chemical Company
P.O. Box 240
Geneseo, IL 61254

Charles A. Hanson
Field Agr. Chem. & Tech Serv.
P.O. Box 9303
Whittier, CA 90608

Ronald H. Hanson
Union Carbide Agr Products
8172 Pollard Avenue
Fair Oaks, CA 95628

Michael Hargrave
Grigsby Bros.
21 W. Stuart Avenue
Redlands, CA 92374

Mike Harrell
Agri Growth Research, Inc.
Route 1, Box 33
Hollandale, MN 56045

Jonathan J. Hart
Botany Department
University of California
Davis, CA 95616

W. A. Harvey
University of California
14 Parkside Drive
Davis, CA 95616

Hans Hayden
Mid Crystal Farms
Arbon, ID 83212

Louis C. Hearn
ICI Americas
P.O. Box 3959
Visalia, CA 93278

Stanley Heathman
Plant Sciences Department
University of Arizona
Tucson, AZ 85721

Eugene Heikes
Colorado State University
716 Garfield
Fort Collins, CO 80524

David Hein
University of Wyoming
2256 N. 15th
Laramie, WY 82070

Charles Heinzman
Monsanto Company
800 N. Lindbergh Blvd.
St. Louis, MO 63167

Stu Helffrich
S. Helffrich & Assoc.
16 W. Medlock
Phoenix, AZ 85013

Ole T. Helgerson
Oregon Coop Extension
1301 Maple Grove Drive
Medford, OR 97501

Ray C. Henning
Chevron Chemical Company
5910 N. Monroe
Fresno, CA 93711

Ann Henson
DuPont Company
926 Yucca Court
Longmont, CO 80501

Homer M. Hepworth
CIMMYT
Londres 40, Apdo 6-641
06600 Mex. D.F. MEXICO

R. C. Hildreth
Rohm & Haas Company
1031 White Gate Road
Danville, CA 94526

James E. Hill
Agronomy & Range Sci. Dept.
University of California
Davis, CA 95616

Kenneth R. Hill
Nevada Coop. Extension Service
P.O. Box 231
Tonopah, NV 89049

Larry K. Hiller
Hort. & LA Department
Washington State University
Pullman, WA 99164-6414

George F. Hittle
Wyoming Dept. of Agriculture
P.O. Box 5001
Cheyenne, WY 82003

Mary Ellen Hogan
Weed Research Lab
Colorado State University
Fort Collins, CO 80523

E. B. Hollingsworth
USDA, Retired
Box 919
Leland, MS 38756

Jay A. Holmdal
Rohm & Haas Company
Indpendence Mall West
Philadelphia, PA 19105

Jodie S. Holt
Botany & Plant Science Dept.
University of California
Riverside, CA 92521

Michael Horak
Botany & Plant Science Dept.
University of California
Riverside, CA 92521

Robert Hornford
University of Saskatchewan
236-510 Prairie Ave.
Saskatoon, Saskatchewan
CANADA S7N OWO

Harry S. Howard III
AccuTech Associeates
805 N. 7th Avenue, #150
Bozeman, MT 59715

Stott Howard
Agronomy & Soils Department
Washington State University
Pullman, WA 99164-6420

Clair W. Hull
Franklin County Weed Control
P.O. Box 427
Preston, ID 83263

Neil Humburg
6615 Evers Blvd
Cheyenne, WY 82009

Wesley A. Humphrey
Univ. Calif. Coop. Extension
1000 S. Harbor Blvd.
Anaheim, CA 92805

William A. Iselin
Iselin & Assoc.
4520 S. Juniper
Tempe, AZ 85282

Nelroy Jackson
Monsanto Comapny
24551 Raymond Way, Suite 285
El Toro, CA 92630

Larry S. Jeffery
Agronomy & Horticulture Dept.
Brigham Young University
Provo, UT 84602

Max Jehle
Rohm & Haas Company
5909 Charman Street
Bakersfield, CA 93309

Arthur O. Jensen
American Cyanamid Company
106 Las Vegas Road
Orinda, CA 94563

James I. Jessen
Stauffer Chemical Company
Box 1383
Glendive, MT 59330

Thomas N. Johnsen, Jr.
USDA/ARS
2000 E. Allen Road
Tucson, AZ 85711

Douglas L. Johnson
Cascade County Weed Control
521 1st Avenue NW
Great Falls, MT 59404-2885

Glen D. Johnson
ICI Americas
1937 E. Jeanine Drive
Tempe, AZ 85284

Janelle Johnson
American Cyanamid Company
541 Pierce Street
Twin Falls, ID 83301

William B. Johnson
W.M.J. & Son, Inc.
1384 Highland Road
Walla Walla, WA 99362

Ivan B. Jones
USU Extension Agent
160 North Main
Nephi, UT 84648

Carl E. Joplin
Mobay Chemical
Rt. 7, Box 7165-D
Nampa, ID 83651

Lowell S. Jordan
Botany & Plant Sciences Dept.
University of California
Riverside, CA 92521

Larry K. Justesen
Carbon County Weed & Pest Dist.
P.O. Box 1126
Rawlins, WY 82301

David S. Justice
Arizona Agrochemical Company
P.O. Box 21537
Phoeniz, AZ 85036

J. Phillip Keathley
J. Phillip Keathley, Inc.
25330 S. Ruess Road
Ripon, CA 95366

Paul E. Keeley
USDA Cotton Research Station
17053 Shafter Avenue
Shafter, CA 93263

Harold M. Kempen
Univ. Calif. Coop. Ext. Serv.
P.O. Box 2509
Bakersfield, CA 93303

Steven L. Kimball
Monsanto Company
800 North Lindbergh Blvd.
St. Louis, MO 63167

Jim Klauzer
Rohm & Haas Company
P.O. Box 7154
Boise, ID 83701

Ron Knapp
CIMMYT
Londres 40, APTDO 6-641
Delg, Cuahtemoc, Mexico DF
06600 MEXICO

Don E. Koehler
California Dept. Food & Agr.
1220 N Street, Room A-400
Sacramento, CA 95814

Don L. Kosteff
Fremont County Weed Control
County Courthouse, Basement
Lander, WY 82520

James M, Krall
University of Wyoming
Route #1, Box 374
Torrington, WY 82240

Ron Kukas
FMC
1128 W. Evergreen
Visalia, CA 93277

Celestine Lacey
Plant & Soil Science Dept.
Montana State University
Bozeman, MT 59715

Fred N. Lamming
Fremont County Weed Control
County Courthouse
Lander, WY 82520

Lawrence W. Lass
University of Idaho
913 W. Palouse Rv. Dr, #35
Moscow, ID 83843

Tom Lauridson
USDA-ARS
1005 Skyline Drive
Fort Collins, CO 80523

Jerry D. Lavoy
Union Carbide Agr. Products Co.
P.O. Box 12014
Res. Triangle Park, NC 27709

Gary A. Lee
Plant, Soil & Entomol. Sci. Dept
University of Idaho
Moscow, ID 83843

Philip W. Leino
Univ. Idaho Res. Center
P.O. Box AA
Aberdeen, ID 83210

Joan Lish
Plant, Soil & Entomol. Sci. Dept
University of Idaho
Moscow, ID 83843

Kerry Locke
Route 3, Box 356
Rupert, ID 83350

Allan J. Luke
Union Carbide Agr. Products
1447 N. 1180 East
Idaho Falls, ID 83402

Earl E. Lukkes
Big Horn Weed & Pest Dist.
355 East 5th
Lovell, WY 82431

Rodney G. Lym
Agronomy Dept, P.O. Box 5051
North Dakota State University
Fargo, ND 58105

Frederick W. Marmor
DuPont Company
47 Burgan
Clovis, CA 93612

R. J. Marrese
American Hoechst
St. 202/206 North
Somerville, NJ 08876

Ernest R. Marshall
Union Carbide Agr. Products Co.
P.O. Box 3650
Salinas, CA 93912

Duane A. Martin
Plant Science Division
University of Wyoming
Laramie, WY 82070

Phil Martinelli
Nevada Department of Agriculture
P.O. Box 11100
Reno, NV 89511

Manny Martinez
Zoecon Corporation
11816 Sunburst Avenue
Yuma, AZ 85364

Hamid Mashhadi
Plant Science Department
Utah State University, UMC 48
Logan, UT 84322

Garry D. Massey
3M Company
653 E. Dovewood
Fresno, CA 93710

Bruce Maxwell
Forest Science Department
Oregon State University
Corvallis, OR 97331

John W. May
Shell Development Company
P.O. Box 4248
Modesto, CA 95352

Terry W. Mayberry
Nor-Am Chemical
Rt. 1, Box 218
Pendleton, OR 97801

Paul Mayland
American Hoechst Corporation
2962 Southgate Drive
Fargo, ND 58103

F. Wayne McBride
Keecide Chemical
2528 Tallent
Modesto, CA 95335

Tom McCaffrey
Stauffer Chemical Company
644 St. Ives Ct.
Walnut Creek, CA 94598

Scott McCalley
PPG Industries
2580 Andler Road
Placerville, CA 95667

Hugh McEachen
South Columbia Basin Irr. Dist.
P.O. Box 96
Mesa, WA 99343

W. B. McHenry
Botany Department
University of California
Davis, DA 95616

James R. McKinley
Union Carbide Agr. Products
424 Aero View
Yakima, WA 98908

Ken McMartin
Dow Chemical
913 Kehl Circle
Bellevue, NE 68005

Wayne McNeil
American Cyanamid
P.O. Box 400
Princeton, NJ 08540

Robert B. McReynolds
Marion County Extension
3180 Center Street NE
Salem, OR 97301

Deborah J. Meier
Stauffer Chemical Company
P.O. Box 760
Mt. View, CA 94042

Charles Melton
Rhone-Poulenc Inc.
1247 W. Millbrae Avenue
Fresno, CA 93711

Mari Mengel
University of Idaho
2316 Wallen Road
Moscow, ID 83843

Robert M. Menges
USDA/ARS
P.O. Box 267
Weslaco, TX 78596

Robert Merz
Monsanto Company
800 N. Lindbergh Blvd.
St. Louis, MO 63167

Raymond W. Meyer
Route 1, Box 754
Pullman, WA 99163

Robert J. Meyer
Weed Control Mgt, Inc.
156 Pasatiempo Drive
Bakersfield, CA 93305

Reao H. Mickelson
Caribou County Weed Control
159 South Main
Soda Springs, ID 83276

Stephen Miller
Plant Science Division
University of Wyoming
Laramie, WY 82071

Larry W. Mitich
Botany Department
University of California
Davis, CA 95616

Allen Mooney
Campbell County Weed & Pest
Box 191
Gillette, WY 82716

George R. Moore
Stauffer Chemical Company
Westport, CT 06881

Alice H. Morgan
Dow Chemical USA
P.O. Box 1706
Midland, MI 48640

Gaylin F. Morgan
Morgan & Assoc.
146 E. Milwaukie
Jefferson, WI 53549

Don W. Morishita
Plant, Soil & Entomol. Sci Dept
University of Idaho
Moscow, ID 83843

Sud Morishita
Bonneville County Weed Control
605 N. Capital
Idaho Falls, ID 83402

Larry A. Morrow
NW 2010 Friel
Pullman, WA 99163

Howard L. Morton
USDA/ARS
2000 E. Allen Road
Tucson, AZ 85719

Barbra Mullin
Montana Dept. of Agriculture
6th & Roberts, Ag/Livestock Bld
Helena, MT 59620

W. R. Mullison
Dow Chemical
1412 North Parkway
Midland, MI 48640

Glen A. Mundt
Transbas Inc.
P.O. Box 957
Billings, MT 59103

Tom Neidlinger
Rohm & Haas Company
13016 NE Pacific Court
Portland, OR 97230

W. Richard Neilson
PPG Industries, Inc.
2852 Viejas View Place
Alpine, CA 92001-9535

Jim Nelson
Plant & Soils Department
Montana State University
Bozeman, MT 59715

Marlyn J. Nelson
Bingham County Weed Control
P.O. Box 583
Blackfoot, ID 83221

Michael Newton
Department of Forest Science
Oregon State University
Corvallis, OR 97331

Fred L. Nibling, Jr.
U.S. Bureau of Reclamation
P.O. Box 25007 Attn: D-1522
Denver, CO 80225

Scott Nield
Lincoln County Weed & Pest
P.O. Box 117
Afton, WY 83110

Richard S. Nielsen
American Cyanamid Company
2727 W. Bluff Ave, #108
Fresno, CA 93711

Scott Nisson
Plant & Soil Science Dept.
Montans State University
Bozeman, MT 59715

Wesley O. Noel
Velsicol Chemical Corporation
P.O. Box 3852
Bozeman, MT 59772

Robert F. Norris
Botany Department
University of California
Davis, CA 95616

Francis Edward Northam
Plant, Soil & Entomol. Sci.
University of Idaho
Moscow, ID 83843

Alex G. Ogg, Jr.
USDA-ARS, 215 Johnson Hall
Washington State University
Pullman, WA 99164

Paul J. Ogg
American Cyanamid Company
3619 Mountain View
Longmont, CO 80501

Ron Oliver
BASF
1208 W. Shaw
Fresno, CA 93711

Ben Oller
Mobay Chemical Corporation
1900 N. Gateway Blvd, Suite 152
Fresno, CA 93727

H. Christian Olsen
Union Carbide Agr. Products
1833 7th Avenue South
Fargo, ND 58103

Phillip D. Olson
American Hoechst Corporation
E 2655 Prairie Avenue
Post Falls, ID 83854

Deborah R. Orcutt
Botany & Plant Sciences Dept.
University of California
Riverside, CA 92521

Gregory L. Orr
Plant Pathology & Weed Science
Colorado State University
Fort Collins, CO 80523

Jack P. Orr
Univ. California Coop. Ext.
4145 Branch Center Road
Sacramento, CA 95827

John E. Orr
ICI Americas
2018 Coloma Way
Boise, ID 83712

Joe L. Pafford
Lilly Research Laboratories
3131 S. Vaughn Way, Suite 111
Aurora, CO 80014

Harlan K. Palm
DuPont Company, Suite 300
7401 W. Mansfield Avenue
Denver, CO 80235

Robert Parker
Wash State Univ. IAREC
P.O. Box 30
Prosser, WA 99350

Robert R. Parsons
Park County Weed & Pest Control
P.O. Box 626
Powell, WY 82435

Dwight V. Peabody
NW Wash. Res. & Ext. Unit
3340 Martin Road
Mt. Vernon, WA 98273

John O. Pearson
BASF Corporation
406 Arbours
Savoy, IL 61874

Glenn Pecor
Solano Irr. Dist.
508 Elmira Road
Vacaville, CA 95688

Phil J. Petersen
DuPont Company
2366 Rolling Hills Drive
Clarkston, WA 99403

Nick Poletika
Stauffer Chemical Company
P.O. Box 248
Orange Cove, CA 93646

Emmanuel Moterang Pomela
Plant, Soil & Entomol. Science
University of Idaho
Moscow, ID 83843

Paula P. Pretzer
Shell Chemical
2490 Yowell Ct. #47
Yuma, AZ 85364

C. L. Prochnow
Stauffer Chemical Company
11509 N.E. 3rd Avenue
Vancouver, WA 98685

Doug Prosch
Velsicol Chemical Corporation
P.O. Box 507
Woodstock, IL 60098

L. Joe Purchase
American Cyanamid Company
18947 E. Mercer Drive
Aurora, CO 80013

J. Robert Pust
USDA
Rt. 1, Box 40
Pullman, WA 99163

Alan R. Putnam
105 Pesticide Research Center
Michigan State University
East Lansing, MI 48824

Mickey Qualls
Stauffer Chemical Company
372 Dodson Road
Ephrata, WA 98823

Janet Rademacher
University of Arizona
2047 East 5th Street
Tucson, AZ 85719

William H. Rademacher
University of Arizona
2047 East 5th Street
Tucson, AZ 85719

Steven R. Radosevich
Forest Science Department
Oregon State University
Corvallis, OR 97331-5704

Dan W. Ragsdale
Zoecon Corporation
P.O. Box 10975
Palo Alto, CA 94202-0859

Pat Rardon
DuPont Company, Stine Lab
Box 30
Newark, DE 19711

Dennis Rasmusson
Monsanto Chemical Company
900 N. Broadway
Minot, ND 58701

Thomas A. Reeve
USU Extension Aervice
Courthouse
Manti, UT 84642

Roy Reichenback
Converse County Weed Dist.
P.O. Box 728
Douglas, WY 82633

Howard Rhoads
962 West Street
San Luis Obispo, CA 93401

Jesse Richardson
Agronomy & Soils Department
Washington State University
Pullman, WA 99164-6420

Richard S. Riddle
Stauffer Chemical Company
3729 Oak Ridge Drive
Yuba City, CA 95991

Riggleman, James D.
DuPont Agchem, Walker's Mill
Barley Mill Plaza
Wilmington, DE 19898

Randal Ristau
Colorado State University
27939 Road 21
Rocky Ford, CO 81067

Don E. Robinson
Lilly Research Laboratories
7521 West California Avenue
Fresno, CA 93706

Robert R. Robinson
ICI Americas, Inc.
6900 E. Camelback, Suite 700
Scottsdale, AZ 85251

Benjamin P. Rodriquez
Stauffer Chemical Company
P.O. Box 248
Orange Cove, CA 93646

Jack Root
Zoecon Corporation
3260 N. Hayden Road, #209
Scottsdale, AZ 85251

Ed Rose
Stauffer Chemical Company
12150 East Kings Canyon Road
Sanger, CA 93657

Claude Ross
FMC Corporation
4343 Redbirt Ct.
Loveland, CO 80537

Tomie Runyan
ICI Americas Inc.
232 Kimberly Drive
Lubbock, TX 79403

Travis T. Rushing
DuPont Company
2180 Sand Hill Rd, Suite 240
Menlo Park, CA 94025

Louis Russo
Zoecon Corporation
1610 W. Sierra Avenue
Fresno, CA 93711

Frederick J. Ryan
USDA/ARS Aquatic Weeds
Botany Department
University of California
Davis, CA 95616

Donald J. Ryrych
Oregon State Univ.-CBARC
P.O. Box 370
Pendleton, OR 97801

Doug Ryerson
Monsanto Company
1768 Pomerelle Drive
Twin Falls, ID 83301

James E. Saxton
Bear Lake County Weed Control
P.O. Box 218
Paris, ID 83261

Ron Sbragia
Dow Chemical Company
2800 Mitchell Drive
Walnut Creek, CA 94598

Mark Scaife
AGI Nursery
6527 W. Phelps Rd.
Glendale, AZ 85306

John T. Schlesselman
Rohm & Haas Company
726 E. Kip Patrick Drive
Reedley, CA 93654

David A. Schmer
Farmland Industries
5625 "O" Street, Suite #9
Lincoln, NE 68510

Jerry Schmierer
Univ. California Coop. Ext.
Memorial Bldg.
Susanville, CA 96130

R. A. Schnackenbery
Agri-Turf Supplies, Inc.
P.O. Box 4248
Santa Barbara, CA 93140

Galen L. Schroeder
Velsicol Chemical Corporation
1233 4th Street North
Fargo, ND 58102

Tim W. Schultz
Agronomy & Soils Department
Washington State University
Pullman, WA 99164-6420

Thomas K. Schwartz, Suite 460
Union Carbide Agr. Products
26 West Dry Creek Circle
Littleton, CO 80120

Richard A. Schwartzbeck
Farmland Industries
P.O. Box 7305
Kansas City, MO 64116

Edward E. Schweizer
USDA/Crops Research Laboratory
Colorado State University
Fort Collins, CO 80523

Allen C. Scoggan, Suite 152
Mobay Chemical Corporation
1900 North Gateway Blvd
Fresno, CA 93727

Clarence Seely
University of Idaho
430 Lewis
Moscow, ID 83843

Nancy T. Sego
4707 West Northern
Glendale, AZ 85301

George Senechal
Cooperative Extension Service
P.O. Box 270
Meeker, CO 81641

Warren C. Shaw
ARS, USDA
1907 Edgewater Parkway
Silver Springs, MD 20903

David A. Shields
BASF Wyandotte Corporation
P.O. Box 758
Dinuba, CA 93618

Thomas H. Shrader
U.S. Bureau of Reclamation
P.O. Drawer P
El Paso, TX 79952

Edwin E. Sieckert
Monsanto Company
601 University Ave, Suite 266
Sacramento, CA 95825

H. G. Simkover
Shell Development Company
6690 Amador Plaza Rd, #101
Dublin, CA 94568

Ralph Simnacher
Sweetwater County Weed Control
Box 173
Farson, WY 82932

Lonnie C. Sloan
DuPont Company
2751 W. Palo Alto
Fresno, CA 95711

Darryl E. Smika
USDA Central Great Plains Sta.
P.O. Box K
Akron, CO 80720

Christian Smith
Stauffer Chemical Company
18851 Barnhart Avenue
Cupertino, CA 95014

Fred A. Smith
American Cyanamid Company
1232 W. Palo Verde Drive
Phoenix, AZ 85013

Leslie W. Sonder
California Dept. Food & Agric.
1220 'N' Street, Rm A 357
Sacramento, CA 95814

Ronald E. Sosebee
Dept. Range & Wildlife Mgt.
Texas Tech University
Lubbock, TX 79409

David F. Spencer
USDA/ARS Aquatic Weed Res Lab
Botany Dept, Univ. California
Davis, CA 95616

David Spratling
Agronomy & Soils Department
Washington State University
Pullman, WA 99163

Ralph D. Spilsbury
Wilbur-Ellis Company
P.O. Box 699
Glendale, AZ 85311

Leonard Stach
Velsicol Chemical Corporation
330 E. Grand
Chicago, IL 60611

Phillip Stahlman
Plant Science Div, Box 3354
University of Wyoming
Laramie, WY 82071

Gil Stallknecht
Montana State University
Rt. 1, Box 131
Huntley, MT 59037

Charles E. Stanger
Malheur Exp. Station, OSU
Rt. 1, Box 620
Ontario, OR 97914

Sam Stedman
Univ. Arizona Ext. Service
820 E. Cottonwood Lane
Casa Grande, AZ 85222

Vern R. Stewart
N.W. Agr. Res. Center
4570 Montana 35
Kalispell, MT 59901

Dan Stiffler
American Cyanamid Company
7614 S. Humboldt
Littleton, CO 80122

Edwin K. Stilwell
Stilwell Consulting
8708 Bray Vista Way
Elk Grove, CA 95624

Loyd L. Stitt
Field Seed Mgt.
1085 Johnson Place
Reno, NV 89509

Randall K. Stocker
Imperial Irrigation District
4151 Highway 86
Brawley, CA 92227

Richard Stoltz
American Cyanamid Company
3587 Bluff Street
Norco, CA 91760

Roger Storey
Wilbur-Ellis Company
Box 699
Glendale, AZ 85311

Dean L. Stubblefield
Nelson Research
1215 Sand Key
Corona Del Mar, CA 92625

Robert E. Stubblefield
Texas Tech University
Dept. Range & Wildlife Mgt.
Lubbock, TX 79414

Larry Summers
Botany & Plant Science Dept.
University of California
Riverside, CA 92521

Dean G. Swan
Agronomy Dept, 173 Jsn. Hall
Washington State University
Pullman, WA 99164-6412

Mark G. Sybouts
Velsicol Chemical Corporation
2152 Jason Way
Modesto, CA 95350

Hisayoshi Tanda
Idemitsu Kosan Company, Ltd.
50 Rockefeller Plaza
New York, NY 10020

Fred R. Taylor
PPG Industries, Inc.
One PPG Place - 34E
Pittsburgh, PA 15272

Fred E. Temby
Pennwalt Corp, Fresno Res Sta.
6830 N. Chateau Fresno
Fresno, CA 93711

Carlyle R. Tennis
U.S.Bureau of Reclamation
2800 Cottage Way
Sacramento, CA 95825

Donn C. Thill
Plant, Soil & Entomol. Science
University of Idaho
Moscow, ID 83843

Lafayette Thompson, Jr.
Editor, WSSA Newsletter
1142 E. Maynard Rd.
Cary, NC 27511

W. T. Thomson
Monterey Chemical Company
Box 5317
Fresno, CA 93755

Bruce Thornton
1507 Peterson
Fort Collins, CO 80521

Tom Threewitt
Ciba-Geigy Corporation
RR 1
Larned, KS 67550

Joan S. Thullen
U.S. Bureau of Reclamation
P.O. Box 25007, D-1522
Denver, CO 80225

Robert J. Thullen
USDA, Cotton Research Station
17053 Shafter Avenue
Shafter, CA 93263

Jeff Tichota
Velsicol Chemical Corporation
P.O. Box 70
Tea, SD 57064

Barry Tickes
Univ. Arizona Extension Serv
1047 4th Avenue
Yuma, AZ 85364

Thomas Tillett
Rhom & Haas Company
1520 E. Shaw Ave, Suite 119
Fresno, CA 93710

F. L. Timmons
1047 North Caribe
Tucson, AZ 85710

D. C. Tingey
653 East 400 North
Logan, UT 84321

James M. Torell
Plant Scienc Dept. UMC 48
Utah State University
Logan, UT 84322

Dan Toya
Stauffer Chemical Company
1061 West Broadway
Moses Lake, WA 98837

Harvey D. Tripple
Monsanto Agr Products Compa
Meridian Office Building
9785 Maroon Circle, Suite 1
Englewood, CO 80112

Stuart W. Turner
Stuart W. Turner & Company
P.O. Box 10539
Bainbridge Island, WA 981

Library
Union Carbide Agr. Products
P.O. Box 12014
Res. Triangle Park, NC 277

R. Phillip Upchurch
College of Agriculture
University of Arizona
Tucson, AZ 85721

Kai Umeda
American Cyanamid Company
11404 S. Ki Road
Phoenix, AZ 85044

Bernal E. Valverde
323 Crop Science Department
Oregon State University
Corvallis, OR 97331

Lee Van Deren
Union Carbide Agr. Products Co.
P.O. Box 850
Carpinteria, CA 93013

J. R. van Diepen
PBI/Gordon Corporation
P.O. Box 4090
Kansas City, MO 64101

Ron Vargas
Univ. California Extension Serv
128 Madera Avenue
Madera, CA 93637

Tim C. Vargas
Stauffer Chemical Company
Rt. 1, Box 1066
Jerome, ID 83338

Ronald E. Vore
Box 306
Beulah, WY 82712

George H. Waibel
Union Carbide Agr. Products Co.
5050 E. Bannock Street
Phoenix, AX 85044

Ted R. Warfield
FMC Corporation
P.O. Box 208
Fort Calhoun, NE 68023

Lloyd C. Warner
Lilly Research Laboratories
130 Palmer Drive
Fort Collins, CO 80525

Roderick W. Warner
DuPont Company
502 Mountain View Drive
Bozeman, MT 59715

Jim Warnock
Western Farm Service
Rt. 2, Box 1228
Walla Walla, WA 99362

G. F. Warren
1130 Cherry Lane
W. Lafayette, IN 47906

L. E. Warren
Dow Chemical Company
Rt 1, Box 1313
Davis, CA 95616

B. Kelley Washburn
American Cyanamid Company
925 Cole Road
Meadow Vista, CA 95722

Steve Watkins
ICI Americas Inc.
2210 Lorie Lane
Yuma, AZ 85365

Robert P. Watwood
65 Paseo Hermoso
Salinas, CA 93908

Barbara H. Wells
Monsanto Company
723 E. Locust, Suite 120
Fresno, CA 93710

Drew Wenner
American Hoechst Corporation
Rt. 3, Box 266-A
Moscow, TN 38057

Steve Whisenant
Botany & Range Sci, 401 WIDB
Brigham Young University
Provo, UT 84602

Louis Whitendale
ICI Americas, Inc.
498 North Mariposa Ave.
Visalia, CA 93277

Ralph E. Whitesides
Agronomy & Soils Department
Washington State University
Pullman, WA 99164-6420

Tom Whitson
131 Crop Science Bldg.
Oregon State Univ. Ext. Serv.
Corvallis, OR 97331

Duke C. Wiley
BASF
125 E. Keystone
Woodland, CA 95695

Roger W. Willemsen
Rhone Poulenc, Inc.
P.O. Box 5416
Fresno, CA 93755

Ray D. William
Extension, Horticulture Dept.
Oregon State University
Corvallis, OR 97331

M. Coburn Williams
USDA, Biology Department
Utah State University, UMC 45
Logan, UT 84322

Michael Willis
American Cyanamid Company
1790 B Bayland Lane
Yardley, PA 19067

Linda L. Willitts
ICI Americas, Inc.
104 Prospector Court
Folsom, CA 95630

C. Barry Wingfield
Selco
650 'O' Street
Greeley, CO 80631

Sandra Wingfield
Agrisan Pest Management
P.O. Box 323
Eaton, CO 80615

Winn Winkyaw
Salt River Project
P.O. Box 1980
Phoenix, AZ 85001

Lawrence E. Wittsell
Shell Development Company
P.O. Box 4248
Modesto, CA 95352

Jeanette Wrysinski
Univ. Calif. Rice Exp. Station
P.O. Box 306
Biggs, CA 95917

Eleanor Yeatmen
Botany Department
University of California
Davis, CA 95616

Samuel P. Yenne
Plant, Soil & Entomol. Science
University of Idaho
Moscow, ID 83843

Frank Young
USDA/ARS, 215 Johnson Hall
Washington State University
Pullman, WA 99164

Ken Yelle
Agri Search
11955 Blake Road
Galt, CA 95632

David L. Zamora
University of Idaho
P.O. Box 3712
Moscow, ID 83843

Robert L. Zimdahl
Weed Research Lab
Colorado State University
Fort Collins, CO 80523

Richard K. Zollinger
Department of Agronomy
Michigan State University
East Lansing, MI 48823