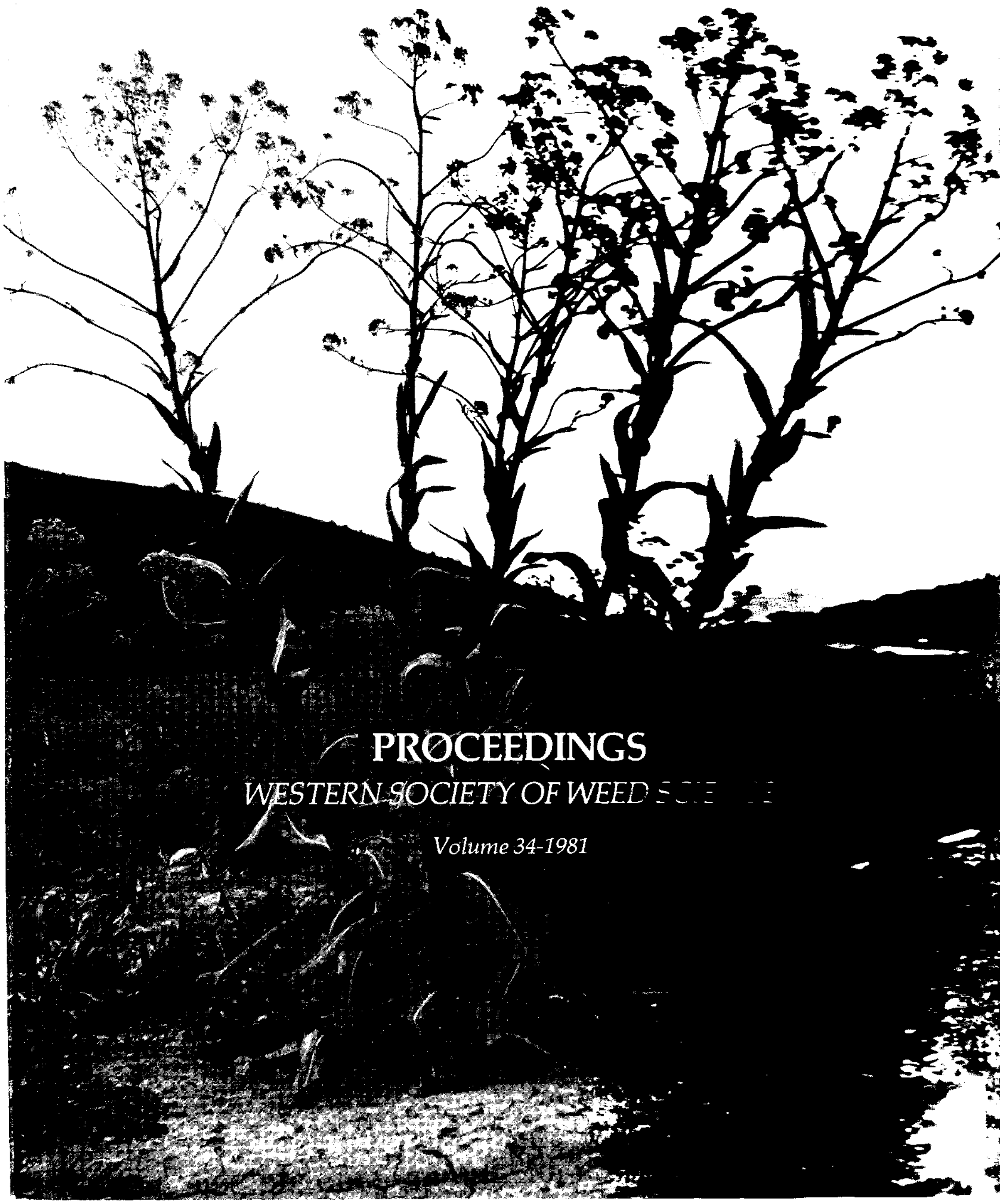
ISSN: 0091-4487



PROCEEDINGS

WESTERN SOCIETY OF WEED SCIENCE

Volume 34-1981

1981

PROCEEDINGS

OF

THE WESTERN SOCIETY OF WEED SCIENCE

VOLUME 34

PAPERS PRESENTED AT THE ANNUAL MEETING

MARCH 17, 18, 19, 1981

SAN DIEGO HILTON

SAN DIEGO, CALIFORNIA

PROGRAM AND TABLE OF CONTENTS

PRESIDENTIAL ADDRESS

THE CHALLENGES FOR WEED SCIENTISTS

L. E. Warren[1]

Good morning, members and guests of the Western Society of Weed Science. I appreciate having the honor and privilege of serving as your President this last year. It has been a pleasure because of the willingness of members to accept role of leadership in the Society when called upon to do so.

First, a little Society business. We had over 300 registered for our 1980 meeting in Salt Lake City last year, including 40 graduate students. This shows continual growth; we expect even more at this meeting. LaMar Anderson reports that the total paid membership is now 417.

Our financial position is good, according to LaMar Anderson. We have operating funds to last us over a year. Alex Ogg, your Program Chairman, his committee, and the several project chairmen have developed good programs that encourage exchanging recent information in several different subject areas.

I would like to encourage more members to become active in the Society's business and to help chart its path in the 1980's. Production of food, fiber and energy will become increasingly important and our Society and its members can contribute greatly to constructive solutions.

That introduces the subject I will address this morning: What can we as agricultural scientists do to restore the progress of food and fiber production?

We in U.S. agriculture can feel satisfied with the accomplishments of our science in developing new techniques, tools, varieties and systems, and of the procedure in adopting these advancements for a dramatic increase in production of crops and animal products. U.S. agriculture is credited with supplying $154 billion return to some 3 million farmers or companies in farming in 1980. This expands to at least $300 to $500 billion or more value from supporting and associated businesses. It is the largest business in the U.S., and the most important. Life would be much less rewarding for most of us without such a success story. In addition, $40 billion of agricultural exports helps relieve suffering abroad and improves our balance of trade.

Dr. Ted Holmsen, in a recent article in Down to Earth magazine, showed that there were several-fold increases in yields of several large acreage crops, such as small grains, soybeans, etc. during the last 50 years (3). Weed control, especially with herbicides, has contributed immeasurably to this success. We have seen reports of or observed the losses caused by weeds in crops or rangelands. Dr. John Abernathy, Texas Agricultural Experiment Station (1), has computed that herbicides in crops have saved the U.S. farmer $12.9 billion in 1976. Our citizens benefit, mostly unknowingly, at the marketplace in having the most economical and safest foods in the world. Improvement of cultural practices, such as minimum or nontillage programs, are made more feasible by the use of herbicides. Weed and brush control in forests and on roadsides and rights-of-way offer even more savings or are essential practices. More progress will be made with additional research and chemical activity.

---

[1]The Dow Chemical Company, Davis, CA

These are great accomplishments, but progress has slowed. It is evident that present improvements in farming practices are based on research that developed several years ago. It usually takes 8 to 10 years for a new practice, crop variety or pesticide to be generally accepted, and local variation may take even longer. Dr. Glenn Pound, University of Wisconsin (4), and several others, have objected to the reduced funding for research in agriculture and predicted seriously reduced gains in production. Holmsen (3) shows a leveling of yields for several large acreage crops in the last few years which reflects reduced research results.

As some of you are keenly aware, funds for research, teaching and extension in agriculture are dwindling at state and federal levels. In the last 15 years funds for federal and state agricultural research and extension have actually decreased in relation to inflation and sometimes even actual dollars while the non-producing programs of social welfare and government regulation have expanded enormously. Our reduced research and extension efforts will certainly be reflected in reduced gains in production or efficiency--at a time when the world population is expanding to an estimated 6 billion by the year 2000. Developments from industry are retarded unnecessarily by excessive requirements for registration of pesticides and other excessive governmental regulation--even at some state levels. Harsh criticism of pesticides, agriculture and business by certain groups is magnified greatly by self-serving media which leads to more demands by a concerned but uninformed public for more controls. By all standards, our food supply is the safest in the world. The encouragement of basic and applied research and programs to inform the potential users have made the great progress of the past possible. We must remove some of the shackles from the sources of innovation which are research in both government and industry laboratories.

I'm certain that opportunities for further improvements in crop, animal and forest production abound. Serious losses of crops and animals are still suffered from many pests, including weeds. Dr. Robertson (5) in 1981 reported a 45% loss of potential yield to pests at a time when 500 million people are suffereing from serious malnutrition and another 1.5 billion are inadequately fed. He estimated about 1/3 of the loss is to direct crop pests and the rest in handling and storage. For various reasons--partly economic and historic, but mostly governmental interference or stifling regulations locally and abroad--pesticides and progressive practices are not being adopted by the countries where the need is greatest. Our technology can be exported only partially because of limitations in accepting new ways or inability to pay the price for the products, whether they are pesticides, fertilizers or equipment.

We, in the advanced countries, must then be able to produce more food and fiber to allow sufficient exports to relieve the extensive suffering abroad. Development of other goods in underdeveloped countries may make an equitable exchange possible. It is essential that increased production of food, fiber and energy in this country be encouraged.

Robertson (5) and others have suggested that development of more arable land is limited; indeed highways, homes, shopping centers and commercial buildings are taking up some of the better land. So much better use of the land we have in production is necessary. Higher producing varieties and improved cultural practices can be developed to enhance yields, and new. systems to handle, preserve, store and process products could save tremendous quantities of food that are lost now. In addition, Holmsen (3) indicates that a combination of genetic alterations and chemical stimulants for greater efficiency could provide another long step upward in yields.

Much of this reduction has resulted from the politicizing of federal and state activities and programs. The technicalities of laws or regulations and excessive concern for certain minor elements of the environment have diverted large amounts of time, funds and scientific thoughts to satisfying demands of new rules. Protection of the environment is important; we and our descendants have to live here and it must be "safe". However, a member of the World Health Organization from an underdeveloped country listened to a U.S. representative explain our extensive programs by the EPA to ensure a food supply safe from pesticides; he commented, "In our country, we just need more food;" and that the benefits from pesticides would be most welcome.

The inordinate concern in the U.S. with the legal aspects of pesticide use in agricultural production is a definite burden on food and fiber production. We need to encourage much more support for agriculture. This has been lacking even in the USDA. There may be a more favorable political atmosphere now to support the productive segments of our society and it seems like an opportune time to make changes.

Other adverse influences on food production include a number of organizations that purport to have a concern for the health and welfare of different groups and the general consuming public. Hazard data on pesticides is greatly exaggerated with little effort made to explain the perspective and benefits. The media selects the spectacular parts, even if untrue or out of perspective, and carries along these opinions and emotions to the general public.

Dealing with opposing groups has some aspects that are not readily observable or understood. Names are misleading, such as the Campaign for Economic Democracy sponsored by Tom Hayden and Jane Fonda. Their position is definitely anti-business. Opposition to pesticides or agriculture may actually reflect a basic anti-business or anti-technology objective which is stated in manuals of some of the organizations. Their objective is not to relieve health hazards or to help the consumers, but to obstruct and harass business. And only a few committeed subverters can greatly change public opinion.

R. H. Dean (2) and others warn that we must recognize the characteristics and objectives of these groups. They are intelligent, articulate and dedicated and hardly susceptible to being "educated" by the purveyours or supporters of poisons or pollutors. I think we have to bypass, neutralize or expose the falsehoods, half-truths and innuendos propounded by these groups, and attempt to persuade regulators, legislators, teachers, doctors and the rest of the public of the truths in each case. Since pesticides have more research on safety and environmental effect than any other products on the market, it is well to challenge these anti-pesticide groups to improve the health of other sufferers. Some 350,000 people will die early from cigarettes in 1981; 10-15 million people are alcoholics with untold misery for family and employer; 27,000 people will die from drunken drivers. Drug problems are horrendous!

Several groups, such as CAST and the Council for Environmental Balance, several producer associations at the national level and in the states, such as National Association of Wheat Growers (6), Citizens for Food and Fiber, Women for Agriculture, etc., have become active in support of agriculture. I think there is progress. I was in Eureka-Arcata last week to speak to several classes about safety of pesticides. A group there defeated an anti-herbicide initiative last year. They are preparing to continue the battle. Citizens for Food and Shelter in Oregon defeated a proposed initiative in Oregon and in 20 individual counties for the same purpose. It will be helpful to support and work with these groups. They are quite effective.

So, what can we as weed scientists do? Certainly more than develop better weed control practices! Some suggestions:

1. Urge federal and state legislators to encourage production of value rather than dubious and wastful programs;
2. Urge more funding for agricultural research at federal and state levels;
3. Urge more funding for extension and higher education in agriculture;
4. Request more funding for range weeds and management practices to control noxious and invading weeds;
5. Encourage cooperative projects between pest and crop disciplines at universities and USDA and between industry research and development and government or university;
6. Urge relief from restrictive pesticide registration and regulation;
7. Attempt to counter anti-pesticide and anti-agriculture actions at all levels;
8. Pressure the media to report facts in perspective on any problem;
9. Assist elementary through high schools in understanding agriculture and the need for and safety of pesticides;
10. Continue your progress in research, education and extension in spite of the limited funds.

Each of you should be ready to voice your desires for increased support from your state and federal legislators and administrators for the needed research and conservation. This investment in improved production will untimately help reduce the inflation spiral--a contribution to the supply side of economics which is badly needed. The outlook for us is bright and we can help lift the living standard of millions abroad.

Literature Cited

1. Board, W. L. 1978. Weed scientist says herbicides prevent $12.9 billion loss to American agriculture. Delta Farm Press (quotes of J. Abernathy).

2. Dean, R. H. 1980. Excepts from speech, as quoted in "Editor's Forum". Crops and Soils. October, pp 5-7.

3. Holmsen, T. W. 1980. The need for chemicals to alleviate environmental stress in crop plants--A new technology. Down to Earth 37 (1): Dow Chemical Company, Midland, MI.

4. Pound, G. S. 1980. Historical development of U.S. agricultural research. quoted in "Editor's Forum", Crops and Soils, October, pp 5-7.

5. Robertson, A. 1981. Global perspectives on the impact of environmental legislation. World of Agricultural Aviation 8(2):

6. Williams, M. 1981. Panels producer members work to ensure better balance in pesticide debate. The Wheat Grower 4(1):

INTEGRATED WEED MANAGEMENT SYSTEMS TECHNOLOGY FOR THE FUTURE

W. C. Shaw[1]

It took the people of the world from the dawn of time until 1830 to reach a population of 1 billion. By 1960 we reached 3 billion, and by 1980 we had a population of 4.5 billion. It is estimated that by the year 2000 there will be 7 billion people in the world. That means that within the next 30 years we must produce as much food as we have produced since the beginning of history. Can we feed this many people? Yes, but expanded research to develop improved technology will be required to meet the challenge.

Although our best weed management technology has been used effectively, weeds continue to cause annual losses of about 10 percent in agricultural production (crops, livestock, forests, and aquatic resources). In 1980, this loss amounted to about $12 billion in the United States. Farmers spend about $3.6 billion each year for chemical weed control and about $2.6 billion for cultural, ecological, and biological methods of control. Thus, the losses and the costs of control total about $18.2 billion annually (14).

The mission of agricultural research is to develop the technology needed to assure an adequate supply of nutritious food, high-quality feed and fiber, and a quality environment. No mission is of greater importance to the general public. Those of us who contribute to this mission are both fortunate and privileged! We are not going to accomplish this mission unless we increase agricultural yields. You know, of course, that these yields have begun to level off globally. Even the most elementary analysis will show that we will not increase agricultural yields without effective integrated weed management systems (IWMS) that utilize the best combination of principles, practices, technologies, and strategies.

Integrated pest management (IPM) is an approach in which principles, practices, methods, materials, and strategies are chosen to control pests while minimizing undesirable results. IWMS are used as a part of pest management strategies. IWMS require several levels of integration to deal with the diversity of weed problems. These include: 1) the integration of several procedures to control a single weed, 2) the integration of many methods against a complex of weeds infesting a single commodity, 3) the integration of many methods against a complex of weeds and other pests attacking a group of commodities, 4) the integration of weed management technology with other pest management systems, and 5) the integration of weed and other pest management systems into agroecosystems on farms, areas, and regions (32) (Figure 1).

Effective IWMS must be an integral part of the overall management of a farm, a ranch, or a forest. A thorough understanding of these complex operations can be accomplished by the systems approach. This approach takes into full account the need to increase agricultural production and to determine economic losses, risks to human health and safety, quality of the environment, energy requirements, and potential damage to those organisms that we do not want to adversely affect.

IPM is one of today's "in phrases." Most of the scientific disciplines that include the study of pests, with some justification, claim to have developed the concept. Some view IPM as a systems approach that

---

[1]National Research Program Leader, Crop Sciences Staff, National Program Staff, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture, Belsville, MD 20705.

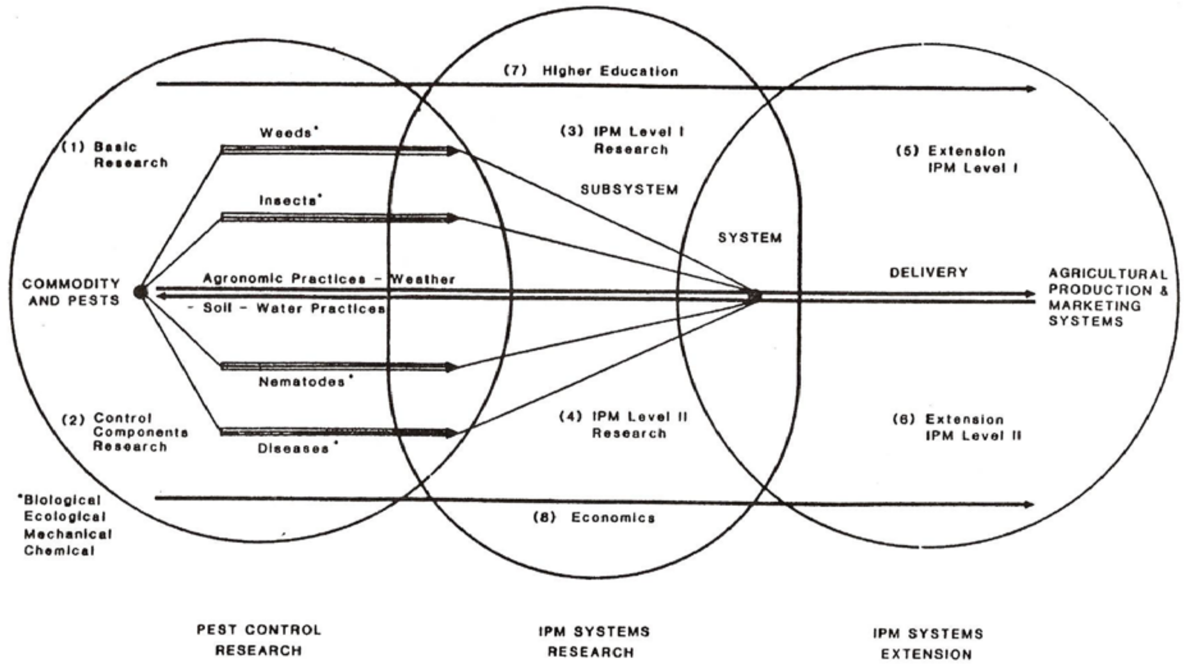


Figure 1. Interrelationships among basic research, control components research, IPM systems research Levels I and II, IPM systems extension Levels I and II, and higher education in IPM.

will aid in improving agricultural production, while others view it as a means of protecting the environment from the excessive use of pesticides. Regardless of individual points of view or the views of various disciplines, IPM is a term that fires the emotions like soil conservation did during the droughts and windstorms of the 1930's.

Some of our senior leaders in the disciplines that study pests say that "Pest management is not new; we've been managing pests for years." This is probably the most accurate translation of history. However, we are in a new era of IPM. The methods of IPM can best fit together with the systems approach. Highly desirable control components that have been developed from basic research include the use of selective pesticides; diseases, predators, and parasites that attack pests; and the development of multiple-pest-resistant crop varieties and livestock breeds. Such systems also include ecological, biological, cultural, chemical, and mechanical practices for controlling weeds in crops, habitat management, protection of wildlife, attractants that divert and entrap pests, and repellents.

What do weed scientists mean when they encourage farmers to use IWMS? To me, it means emphasizing a directed agroecosystem approach for the management and control of weed populations. The IWMS approach includes the use of multiple-pest-resistant, high-yielding, well-adapted varieties that resist weed competition; precision placement of fertilizer to give the crop a differential advantage in competing with weeds; and timing the fertilizer application for maximum stimulation of the crop and minimum stimulation of the weed population. IWMS include preplanting seedbed tillage, effective seedbed preparation, and seeding methods that enhance crop growth and minimize weed growth; optimum plant populations per acre, including close spacing in the row and close spacing between the rows to optimize crop growth and minimize weed growth; and the use of crops that form a canopy for shading as early in the growing season as possible to discourage weed growth. IWMS also include the use of judicious irrigation practices; timely and appropriate cultivations; sound crop rotations; crop diversifications; field sanitation; hervesting methods that do not spread weed seeds; use of biological agents such as insects and pathogens; and effective chemical methods. For the IWMS directed agroecosystem approach to be most effective, preventive weed control technologies must precede and accompany IWMS in order to reduce the recycling of weed seeds and other propagules in the agroecosystem (19).

I see IWMS as an integration of effective, dependable, and workable weed and crop management practices into crop and livestock production systems that can be used economically by producers. IWMS is a part of sound farm management. It is a tool in overall crop and livestock management rather than just weed control. I do not see IWMS or IPM as tools to regulate the use of biological agents or pesticides. Farmers would be immediately concerned about using IWMS or IPM to regulate the use of crop protection practices.

IWMS concepts are an important part of the educational programs conducted by extension specialists. When such programs result in more efficient and safe use of selective herbicides, a good job has been done. I believe the emphasis should be placed on local IWMS action programs. As weed scientists and leaders, we will provide research technology, formulate broad guidelines, and give other types of needed support. Action programs, however, must be developed and carried out locally to be workable.

Let's face it. If IWMS programs are technologically sound but uneconomical, farmers will not accept them. Extension specialists inform us that farmers are ready to use sound crop protection practices, and they are beginning to accept IWMS that show increased profits and fit into their farming systems.

I emphatically do not see IWMS replacing selective, safe, and efficient herbicides. Instead I see IWMS as a sound stratagem for encouraging the judicious use of herbicides along with other safe, effective and economical pest control components, methods, and strategies.

It is appropriate to ask, how can IWMA aid in solving some of the problems confronting agriculture? IWMS can aid in reducing the cost of agricultural production by increasing production efficiency and management effectiveness; in reducing high-cost labor, energy requirements, equipment needs, and losses caused by climatic stress; and in reducing the losses caused by weeds and lowering the cost of their control.

IWMS can aid in stabilizing the cost and efficiency of agricultural production against inflationary pressures created by the increased costs of weed control, failure of weed control practices, and progressively increasing regulatory constraints on weed control.

IWMS will require improved information, education, and technical assistance to improve grower decisions in choosing methods for use in controlling complexes of weeds affecting crop and livestock production systems. The farmer needs better knowledge concerning weed populations, their interaction with production practices in the environment, response to control technology, and ecological shifts to weeds that are more difficult to control.

IWMS can assist in attaining an enjoyable, high-quality environment that is not impaired by pests or pest control practices such as the non-judicious use of biological control organisms, excessive tillage, excessive herbicides, or other practices that damage the environment.

The objectives of IWMS are to: reduce losses caused by weeds, costs of control, energy, and labor requirements; reduce tillage and soil erosion caused by water and wind; assure an adequate supply of quality food, feed, and fiber--safeguarded against poisonous weed seeds and contaminants; improve environmental quality and reduce hazards to man; and maximize producer profits.

The costs, benefits, and risks of IWMS and the role of each component method of control in contributing to an adequate supply of food, feed, and fiber, and a quality environment are of wide public interest. The general public wants to know whether the technology used in IWMS is efficient, cost-effective, and safe. Thus, an objective of this paper is IWMS technology assessment--its costs, benefits, risks, and adequacy. The public is best served when science can reassure all of us that the technology used to provide our food supply is both effective and safe (25, 26, 28).

Ecology of Weeds

Many people apparently do not realize that the native vegetation in most areas of the United States was originally not very efficient as a source of food for humans, livestock, and wildlife. When native vegetation is disturbed or when cultivated fields are abandoned, the sequence within plant successions is well known. Weeds comprise an early stage of plant successions, one that terminates with the climax vegetation characteristic of the area. Plant successions are caused by powerful ecological forces and thus involve well-established ecological principles. This never-ending ecological pressure to change agricultural croplands back to native weeds, forages, shrubs, and trees means that IWMS are basic to efficient food production (Fig. 2).

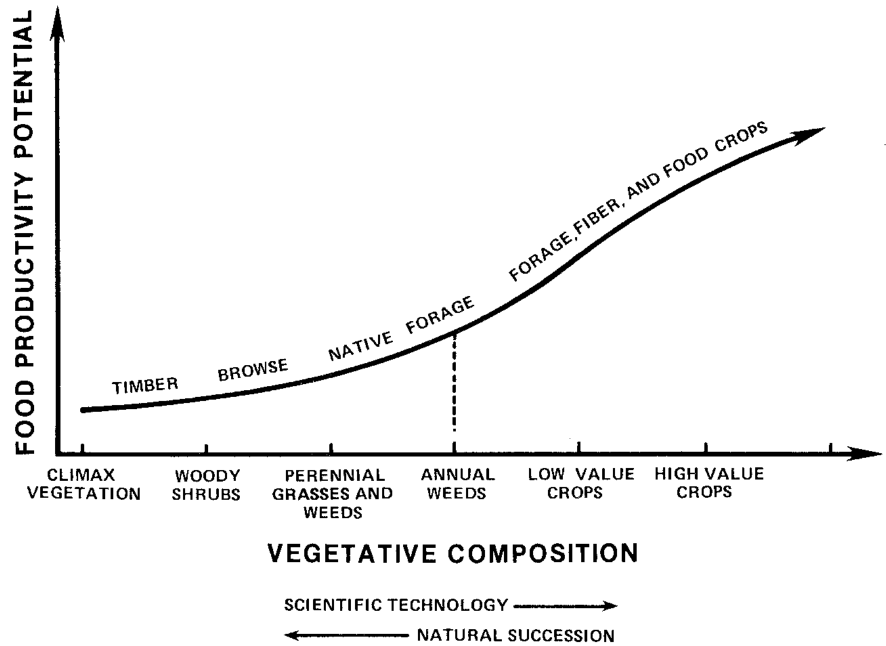


Figure 2. Relations of weed control to ecological principles.

Man's standard of living, and indeed his survival, depend upon his manipulation of the environment. The earth would support only about 20 million people if man did not practice agriculture. He must produce an ecological situation favorable to the production of food crops and livestock, to the protection of his natural resources, and to other environmental values. Weed management is a major environmental manipulation. It is necessary for the safe, efficient, and economical production of food crops and for the protection of our health and welfare. This technology does not merely benefit the general public, but is essential for the survival and continued development of civilization.

The public needs to understand the ecological situation in which agricultural commodities are produced. Crops and livestock compete in a complex environment that is shared by about 30,000 species of weeds, distributed throughout the world. More than 1,800 of these cause serious economic losses each year. Most cultivated crops are subjec to competition from about 200 weed species. Each year, 10 to 50 different species of weeds infest each of major food crops--these must be managed. Unlike insects, diseases, and nematodes, weeds will occur in every field every year at population threshold levels that will cause crop failure unless controlled (27).

Because there are many kinds of weeds with varying periods of germination and with highly divergent life cycles, they obviously cannot be managed by a single method. The management of diverse weed populations requires an integrated weed management systems approach that utilizes cultural, mechanical, biological, ecological, and chemical methods in a directed agroecosystem approach. The management of such diverse weed populations requires a broad spectrum of selective herbicides, mixtures of herbicides, and combination chemical treatments as key components of IWMS.

Advances in Technology for Use in IWMS

Advances in and cost of weed control technology are difficult to assess unless they are evaluated as a part of our total farm management production and protection technology which includes: genetically improved varieties; improved crop management practices; better plant and animal nutrition; improved farm equipment and mechanization practices; improved irrigation equipment, principles, and practices; and efficient control of diseases, insects, nematodes, parasites, and other pests. These production and protection practices have been integrated into high-yielding agroecosystems compatible with a quality environment. They have had far-reaching benefits (7, 19).

More than 90 percent of current weed control technology has been developed since 1940, and much of it since 1960. Cultural, ecological, and biological methods of weed control are used on more than 369 million acres of harvested crops each year. More than 157 million acres of intertilled row crops receive intensive tillage and cultural weed control at a cost of more than $10 per acre per year. Moderate cultural weed control is practiced on more than 212 million acres of drill crops at a cost of about $5 per acre per year. The intertilled row crops usually receive two to five seedbed preparation treatments, and from one to as many as seven cultivations in a single growing season. Cultural weed control practices are also used on more than one billion acres of hay, pasture, and rangelands, and on millions of acres of nonagricultural lands and aquatic sites (17, 20).

The use of insects to control Klamath weed, prickly pear cactus, and Lantana; the use of insects and fish to control several species of aquatic weeds; and the use of plant pathogens to control northern jointvetch in rice fields and strangler vine in citrus orchards are outstanding examples of biological control of weeds. These examples of success emphasize the need for expanded research to develop additional biological methods. They are highly cost-effective and aid in reducing total control costs. Interest is the use of biological agents to control weeds has grown rapidly in the last 20 years. Presently biological agents, primarily insects and plant pathogens, are being evaluated for control of 75-100 species of weeds by biological control specialists throughout the world. To date, substantial to complete control has been attained by the use of biological agents on 25-30 weed species in various problem situation. Natural enemies have been found for every plant studied thus far, but whether these can provide the levels of control required by today's standards remains open to question. Likewise, the role of biological control in integrated weed management systems and the extent to which it can help in controlling the world's 30,000 weeds remains to be seen.

Chemical weed control technology has progressed greatly during the past 20 years. In 1949, herbicides were used on 23 million acres of agricultural land; in 1952, on 30 million acres, in 1959, of 53 million acres;

in 1962, on 71 million acres; in 1965, on 120 million acres; and in 1973, on more than 200 million acres. The acreage treated with herbicides has about tripled in the past 15 years.

Herbicides in 1977 were used on about 250 million acres. The production and use of herbicides has grown at the rate of about 15 percent a year during the past 5 years. The domestic use of herbicides increased from 125 million pounds in 1963, to more than 645 million pounds in 1975. Currently, herbicides account for about 49 percent of the total pesticides used in the United States; and they represent about 62 percent of the value of total pesticide sales (1, 2, 9, 12).

Shifts to newer and more effective herbicides have increased average unit costs from about $0.94 per pound in 1963 to about $2.25 per pound in 1975. Both rate of usage and chemical costs per acre have increased primarily because of increased research, development, and production costs and shifts to herbicides that are applied to the soil as preplanting or preemergence treatments for weed control. Such treatments control a broader spectrum of weeds but usually require higher dosages (1, 2, 4, 5, 9, 12, 15, 17). Important progress has also been made in the development of efficient herbicide detection, screening, evaluation systems, and equipment. Use of these techniques has given impetus to the industrial discovery and development of new herbicides. In 1950, we had about 15 basic herbicides. Today we have more than 180 basic herbicides and about 6,000 formulated products.

New weed control techniques have improved the effectiveness and safe use of the herbicides. These approaches include versatile preplanting treatments; preemergence and other soil application and incorporation methods; granular formulation; low-pressure, low-gallonage application techniques; recirculating spray applicators, herbicide wipe-on applicators; and technology for improved distribution and deposit of sprays and low-drift formulations. Other significant advances were the development and use of cultural, ecological, bioenvironmental, and mechanical methods in an agroecosystems approach that included herbicide mixtures and crop-herbicide rotations. These are key component technologoies for use in IWMS.

Benefits of IWMS

The farm value of food and fiber produced in the United States was about $94 billion in 1976. Transporting, packaging, processing, distributing, and selling food added another $173 billion. This supply of wholesome food is amont the best bargains the American people buy. Our efficiency permits each farm worker to produce enough for 56 other persons. Only 5 percent of the population of the United States is engaged in agriculture. American families spend an average of only 17 percent of their income for food. This amount is less than that spent by families in any other nation. In the Soviet Union 39 percent of the population is engaged in agriculture and then spend 56 percent of their income for food (5).

The use of herbicides and associated chemical weed control technology has accounted for more than 10 percent of the total increase in farm output since 1940. This is an enormous benefit when compared to herbicide costs. Currently we have little excess production capacity. Any combination of factors that reduces our production by 10 percent would cause serious and untenable economic consequences. This knowledge alone explains why herbicides are so important to the production of food supplies (23, 24).

What are some of the positive and direct benefits derived from the use of herbicides as a part of IWMS? In 1939, the average yield of wheat in the United States was 14 bushels per acre. This year, the average yield will be about 31 bushels per acre. Better varieties and improved cultural practices; weed control; protection against diseases, insects, and nematodes; and harvesting practices account for the increase. However, during the past 20 years the use of 2,4-D to control weeds on an aggregated 460 million acres of wheat increased the yield of wheat about 2 billion bushels--enough to supply each American family with over a 6-year supply of bread. The total increase in farm income, during this period, from this single weed control practice was $3.25 billion. The bread is not only a bargain from the standpoint of cost, but it is also wholesome and nutritious (18).

The use of mechanical power has increased 30 percent and herbicides have increased seven-fold since 1950, while manual labor decreased 40 percent. Farming is becoming less physical and more mental (5). IWMS is at the forefront of these significant technological shifts.

In the past 30 years, wheat, rice, and potato yields in the United States have doubled and corn yields have tripled. IWMS is these crops have reduced labor requirements by 30 to 50 percent. In Japan, rice yields doubled between 1951 and 1961, while labor requirements for rice production were reduced 42 percent. Improvements in weed control accounted for 34 percent of the savings in labor.

The benefits of herbicides as a part of the IWMS can also be illustrated by determining the economic impact of banning their use. Banning the use of 2,4,5-T would increase cost to domestic users about $47 million per year, even if other chemical herbicides were not restricted. However, if other phenoxy herbicides were not available, costs would increase an estimated $157 million per year. In the short run, these additional costs would be borne by farmers, governmental units, and the recreational, industrial, and timber industries. However, in the long run, consumers would pay the bill (10).

Herbicides, as key components of IWMS, have greatly reduced the labor and equipment requirements in crop and livestock production. Production is also less dependent on manual labor. The yields and quality of crops have increased and losses caused by weeds have been reduced from 20 to about 10 percent. The chemical control of weeds that produce allergenic pollens greatly reduces human illness, and control of poisonous weeds prevents death of livestock and wildlife.

Herbicides when used in IWMS have many advantages: a) a wide array of herbicides is available to control most weeds at practical costs; b) herbicides act quickly and are effective against dense weed populations; c) reliable equipment is widely available to apply herbicides; d) herbicides permit the individual grower to protect his crops irrespective of any action taken by his neighbors; e) most herbicides are used selectively, and f) herbicides are dependable and essential to the effective use of IWMS (8).

Chemical weed control as a part of IWMS has contributed to economic stability in the United States through the creation of new occupations and a wide variety of employment opportunities at desirable pay levels. The use of herbicides is an effective and economic technique for the maintenance of airports, industrial sites, and rights-of-way. Effective and safe herbicides improve the maintenance of waterways, watersheds, and impounded waters for commercial, agricultural, and recreational uses. They also improve the safety of our highways by removing vegetation hazards, thereby improving visibility and reducing the number of accidents and deaths of humans and wildlife.

Benefits of Chemical Control on Crop Production Practices

Advances in chemical weed control technology have had far-reaching impacts on all phases of crop production, including the selection of crops and varieties, seedbed preparation, methods of seeding, and seeding rates. They have made possible a wide choice of row spacings, plant spacings in the row, and plant populations. They also influence fertilizer practices, including time of application and placement (7).

Tillage and cultivation techniques have been revolutionized. For many crops, chemical weed control as a part of IWMS now makes minimum tillage possible. Even zero tillage now seems feasible for a few crops on certain soil types. Weed control has had a major impact on irrigation practices, harvesting, seed-cleaning operations, and erosion control.

New herbicides used in IWMS have markedly increased the efficiency of fallow practices for weed control. The use of IWMS has greatly reduced tillage in some of the fallow-farming areas. The adoption of minimum tillage and chemical fallow practices greatly reduces wind erosion; improves moisture conservation; reduces sheet erosion; reduces energy requirements; improves fertilizer utilization; improves soil structure and drainage; and increases yield and quality of crops.

Chemical weed control has also improved the effectiveness of various practices directed to the control of diseases, nematodes, and insects. Herbicides have increased the effectiveness of pasture renovation techniques. They have also improved the productivity of pastures, rangelands, and forests. The use of farm water resources for irrigation, recreation, and the maintenance of reservoirs, drainage ditches, ditch banks, irrigation canals, and farm roadsides has been significantly improved by use of herbicides.

Crop production is on the threshold of a breakthrough in production efficiency because of the impact of chemical weed control. New practices have already established the necessity for a new research cycle in crop production that can result in new plateaus of crop yields, crop quality, and production and harvesting efficiency. These are the kinds of benefits that are difficult to assess in terms of dollar values! Perhaps it is simply best to state that modern farming as we know it could not be practiced without herbicides.

Benefits of IWMS in Agroecosystems

Our current strategies emphasize the development of improved technology for managing the agroecosystem for more effective weed control. We must recognize that weeds are a liability to the agroecosystem, the total farm, area, and region, and that all crops are subject to their competition. In the future we must give greater consideration to weed control problems on the total farm, area, or region as units rather than limiting control practices to weeds in a single crop in a single year. The use of IWMS in a directed agroecosystem approach offers new opportunities for improved farm management and environmental quality (13, 20).

In this approach, the interrelationships among weeds, diseases, namatodes, and insects, and the methods used to control them, must be understood. Crop production, as well as crop protection principles and practices, must be directed toward the control of weeds and other pests (16).

A 14-year (1964-1978) IWMS research program was conducted by Dr. Fred W. Slife, University of Illinois, and Dr. Loyd M. Wax, Agricultural Research (AR), Science and Education Administration (SEA), U.S. Department of Agriculture, at Urbana, Illinois. The evaluation of total farm weed control practices clearly indicated the advantages of this approach to weed management[2]. Chemical weed control significantly increased yields, reduced weed seeds in soils, reduced tillage, improved harvesting efficiency, reduced labor requirements, and dramatically increased net farm profits without damage to the biological, chemical, or physical properties of the soil; without reducing the productivity of the soil; and without causing undesirable shifts in weed populations. There is no evidence from this long and intensive research program that any weed species in the study has become more resistant to a specific herbicide (29, 30, 31).

Yields of corn and soybeans in the 14-year study were increased dramatically with the use of herbicides. Using a different herbicide treatment each year increased corn yields by 30 percent in a continuous corn system and by 25 percent when corn was rotated with other crops. Using a different herbicide treatment each year in soybeans increased yields by 17 percent, both in continuous soybeans and soybeans grown in rotation. Wheat yields were neither increased nor decreased as a result of herbicide treatment (29, 30, 31).

The net profit per acre, after all costs of production were deducted, was substantially higher when the cropping sequence included herbicides as compared to cultural weed control. For example, in a 3-year rotation of corn, corn, soybeans, the net profit per acre per year during the period was $35.46 using cultural practices. The same rotation with herbicides returned $57.97 per acre per year, or an increase of 64 percent on the net return (29, 30, 31).

In order to obtain maximum benefits and reduce costs and risks, our total weed control technology must be used in a directed IWM agroecosystem approach. In using herbicides as a part of IWMS, they must be rotated when a single crop is grown continuously. Greater effectiveness will be achieved when crops are rotated and herbicides are rotated on all crops in the rotation. Combination herbicide treatments, sequential treatments, and mixtures of herbicides, when integrated with cultural, mechanical, and biological methods, reduce the chance of undesirable ecological shifts to tolerant species, minimize the chance of an accumulation of herbicide residues in the soil, and facilitate a decrease in farm, area, and region-wide weed seed populations in soils. For the directed IWMS agroecosystem approach to be most effective, preventive weedcontrol must precede and accompany standard weed control practices (19).

Problems and Risks in IWMS

In discussing the benefits of IWMS we must not overlook potential problems and actual risks. Too often we have emphasized benefits without discussing associated risks. Perhaps the single greatest risk involved in chemical weed control is misuse. Inadequate training of operators as

[2] Similar results from related research have been reported by several U.S. Department of Agriculture scientists. They include: E. W. Hauser and C. C. Dowler for cotton, peanuts, soybeans, and vegetable crops at Tifton, GA; J. E. Dale and C. G. McWhorter for cotton, corn, soybeans, and sorghum at Stoneville, MS; R. J. Smith for rice and crops grown in rotation at Stuttgart, AR; E. E. Schweizer for sugarbeets at Fort Collins, CO; and the late J. M. Hodson for wheat, alfalfa, and several other crops at Bozeman, MT.

to proper safety precautions is common. Volatility and drift of sprays are serious problems. Drift not only damages beneficial plants, but may also contaminate the environment. We do not know what effects, if any, airborne herbicide molecules have on the photosynthetic efficiency of crops in large herbicide-use areas. This problem needs further study.

A common error is the transfer of herbicides to improper containers and the failure to provide for the safety of children and animals. Improper handling, storage, transport, and disposal of unused herbicides, herbicide wastes, and herbicide containers rank high among the problems and risks.

Environmental contamination or side effects not anticipated or fully comprehended--including human injury through unsuspected toxic metabolites or contaminants that may be detrimental to humans, animals, or the environment--must be monitored. Risks are also greatly increased by the improper use of herbicides, a practice that may result in toxic residues in food or feed (3, 6, 11).

We need a better understanding of the actual or potential long-range effects of continued and repeated use of herbicides. However, the evidence, after 20 years of rather intensive use, indicates that current practices will not cause serious problems in the future.

Perhaps the greatest reassurance to the general public that herbicides are being used safely and without significant effect on our environment is provided by the results of the national pesticide monitoring programs on food, water, soil, plants, domestic animals, and wildlife. These programs provide the best assessment of actual as well as potential risks from current use of herbicides. These results show that herbicides are rarely found in the food-monitoring studies conducted by the U.S. Department of Health, Education, and Welfare. Trace amounts that are occasionally found are well below tolerances established for these chemicals in food (6, 11).

The results of our national monitoring studies also show that herbicides have not been biomagnified in humans, domestic animals, wildlife, or other objects or organisms in the environment. There is no evidence that agricultural uses of herbicides cause an accumulation of residues in the environment. Herbicides used at agricultural rates on croplands dissipate rapidly. There is little evidence from our monitoring programs of any accumulation of herbicidal residues in soils.

Although it is genetically possible, and there is some academic concern that specific weeds may develop resistance to herbicides, many scientists believe that this in not a significant practical problem. There are a few instances of tolerant biotypes of weeds that cause some concern. There is greater concern regarding ecological shifts to weed populations that are resistant to control by herbicides. Although such ecological shifts may involve some risks, they will not become serious if cultural, mechanical, ecological, biological, and chemical methods are combined in an IWMS approach.

Many scientists believe that the risk of using herbicides can also be further reduced by the development of better knowledge of their toxicological effects. More emphasis is being given to understanding the carcinogenic, mutagenic, and teratogenetic effects of candidate herbicides during the research and development phase before their widespread use.

Impact of Herbicides in the Environment

We are beginning to develop a balance-sheet approach to understanding the spectrum of events associated with the uses of herbicides and their dissipation from the environment (Fig. 3). As our knowledge of these funtions increases, we should be able to identify those that are essential to the registration process. As we do so, we should also be able to arrive at a quantitative evaluation, at least to the exent of our knowledge, of each component in the registration formula. Quantitation of the registration process should enhance understanding by State, Federal, and industrial scientists, and should permit a better direction of their research to serve basic needs and registration requirements. This accomplishment would reduce costs and risks and increase benefits.

We need to establish classes of herbicides on the basis of their immediate, as well as their long-range, impact on the environment. Only after we have developed and published such information can we expect intelligent use by consumers and greater acceptability by those concerned about the effects of chemicals on environmental quality. Everyone agreees that scientific assessments should replace emotional concerns and reactionary responses. How can this be done? As our knowledge of the behavior and fate of pesticides grows, we should be able to develop a relative environmental exposure index for each pesticide. Such an index would require assessment of toxicity, dosage, total use, and persistence, among other factors (20).

At present, our knowledge of the behavior and fate in plants and soils of some of the important pesticides is sufficiently complete to permit an approximation of their environmental impact. We have developed preliminary mathematical models for predicting the impact of pesticides on the environment. These models have proven helpful in identifying research, regulatory, and monitoring needs, and in avoiding unnecessary

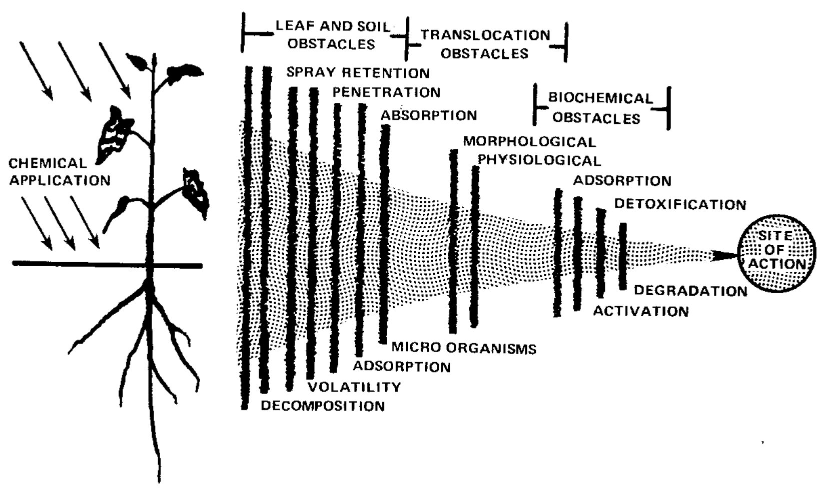


Figure 3. Obstacles which determine the concentration of toxic material at the site of action.

environmental risk in the use of pesticides. Current predictive models leave much to be desired. Nevertheless, we believe that such models represent a significant step in the quantitative assessment of the impact of pesticides on the environment (20).

Costs and Benefits of Presentive IWMS

Preventive weed control technology for use in IWMS in the United States is relatively ineffective. This inadequacy limits weed control progress to that obtained on a year-to-year basis. Little lasting progress is possible, except on an annual basis, because preventive control technology cannot be practiced effectively. The interfarm, interstate, and international movement of weed porpagules is not effectively regulated. Thus, seeds must be controlled annually with the same level of intensity of they will spread.

Public Law 90-583 was enacted October 17, 1968 "To provide for the control of noxious plants on land under the control or jurisdiction of the Federal Government." The Federal Noxious Weed Act (Public Law 93-629) was enacted January 3, 1975, "To provide for the control and eradication of noxious weeds, and the regulation of movement in interstate or foreign commerce of noxious weeds and potential carriers thereof, and for other purposes." The enforcement of these laws will enhance the development of preventive weed control technology in IWMS and reduce losses and the costs of control.

State and Federal legislative authority, regulations, and current programs do not provide for adequate protection against the importation or interstate movement of noxious weeds, weed propagation parts, and weed seeds, or of materials such as soil, manure, hay, straw, sod, feed grains, equipment, nursery stock, livestock, and other materials infested with noxious weeds, weed-propagation parts, or weed seeds. State weed control laws that would improve preventive technology are badly needed.

The Federal Seed act and state seed laws permit relatively high tolerances for weed seeds in crop seeds. About one-third of the states have no limitation on total weed seed permitted to be sold in crop seeds. Limitations that do exist in some states range from one to four percent by weight. Regulations of this type do not take into account the IWMS advances of the past 20 years. Effective preventive weed control technology cannot be developed unless the Federal Seed Act and state seed laws are amended and weed seed tolerances in crop seeds are established that are scientifically feasible and reasonable.

Costs and Benefits of Herbicide Registration Requirements

Policies and procedures for registration of herbicides need a careful review and assessment. Complaints that research is not directed toward the support of regulatory programs are often made. Criteria and protocols for the registration of herbicides need to be established and published. Only if these requirements are known and understood by the scientific community can research be effectively directed to produce efficacy and safety data that can be used in support of registration objectives.

Better guidelines are needed for registration of herbicides. What are the components of the registration formula? Research has identified some of the requirements for registration. They include: an understanding of acute and chronic toxicological properties of herbicides; absorption and translocation; mechanisms of action; sites of action; metabolism in plants and soils; behavior and fate in plants, animals, soil, water, and air; persistence; effects on target and nontarget organisms; patterns of use; and impact on the environment. These requirements increase costs and should reduce risks. Are the regulations excessive in view of the risk? How do we achieve the desired balance?

Industrial organizations are beginning to find it difficult to cope with the unusually high commercial costs of developing and registering new herbicides. In 1956 the overall cost of research to develop a pesticide was about $1.2 million. In 1975 it cost about $8-10 million. In 1978 the estimates ranged from $10-20 million. If such costs continue to increase, a shortage of herbicides could occur. If this happens, it will weaken IWMS and increase our vulnerability to weed attacks, especially in the production of small acreage crops.

The amount of time and resources used by scientists, administrators, and other personnel to defend current registered uses of herbicides and combat proposed bans on uses may have become excessive and counterproductive. If State, Federal, and industrial scientists are required to spend a disproportionate amount of their time, talents, and resources in defensive activities, the discovery and development of new herbicides and other pesticidal chemicals will be inhibited. Many already believe that work toward the discovery of improved pesticides has suffered.

Benefits from Expanded IWMS Research

We need to intensify our research programs to develop a better understanding of the ecology, phenology, physiology, biochemistry, and botanical aspects of weeds. We need to know more about their complete life cycles so that we can determine those stages in their growth and the physiological and biochemical systems that are most vulnerable to control (21, 22).

A much better understanding is needed of the acute and chronic toxicological effects of herbicides and their impact on the environment. Criteria and methods for measuring their environmental impact must be developed. A pool of fundamental information is gradually providing the data and knowledge necessary for predicting their environmental impact before they are widely used (20, 22).

We need to emphasize IWMS research approaches to the control of weeds as a part of total farm and regional management of agroecosystems rather than to apecialize too narrowly in our research. In an IWM agroecosystems approach to weed control, we need to rotate our crops, to rotate herbicides on crops, and to use combination herbicide treatments, sequential treatments, and mixtures of herbicides in a management system that includes mechanical, cultural, ecological, and biological methods (Tables 1 and 2).

Improved IWMS for aquatic weeds are needed for the solution of this increasingly serious problem. We need better methods for control of broadleaf weeds in soybeans. Current herbicides are not effective on many of the weeds that are rapidly becoming serious in this important crop. Herbicides that do not have excessive residual action are needed for the control of perennial weeds such as nutsedges, Canadian thistle, and milkweeds on cropland. Some of the newer herbicides have properties that should help solve these problems.

A better understanding of weed population dynamics, as influenced by chemical and nonchemical treatments, would enable us to predict

Table 1. Rotation of Different Herbicides on the Same Crop 1/

Year	Crop Sequence	Chemical Weed Control Treatments		
		Preplanting	Preemergence	Postemergence
First	corn	EPTC	atrazine	2,4-D
Second	corn	atrazine + alachlor	atrazine + propachlor	linuron
Third	corn	cyanazine + butylate	propachlor	dicamba
Fourth	soybeans	trifluralin	metribuzin	bentazon + 2,4-DB

Table 2. Rotation of Different Herbicides on All Crops 1/

Year	Crop Sequence	Chemical Weed Control Treatments		
		Preplanting	Preemergence	Postemergence
First	corn	atrazine + alachlor	atrazine + propachlor	2,4-D
Second	peanuts	vernolate	alachlor + dinoseb	2,4-DB
Third	cotton	trifluralin	fluometuron	MSMA + methazole
Fourth	soybeans	fluchloralin	metribuzin + alachlor	bentazon + 2,4-DB

1/ Hypothetical rotations used to illustrate the principles of keeping maximum pressure on the weed population by the use of a series of herbicides and mixtures that differ in their effectiveness in controlling various weed spectrums. This procedure reduces the chance of a species that is tolerant to a specific herbicide from becoming dominant. It also reduces the chance of an accumulation of herbicide residues in the soil.

ecological changes. This would facilitate an adjustment of treatments to prevent undesirable shifts that make control more difficult.

More research is needed on the effects of contaminants, analoges, isomers, and other ingredients in herbicides and formulations. Cross-contamination of herbicides and other pesticides is a growing problem--one of national concern--and research guidelines are needed to solve it.

We need to determine which herbicides and combination treatments are most effective in making minimum tillage and zero tillage possible in crop production. These practices conserve water, soil, and fossil fuel; reduce herbicide volatility; and reduce the loss of herbicides in sediment, sheet erosion, and runoff.

The effectiveness of most herbicides is reduced by their inadequate residual activity. To overcome these limitations, an excessive amount of herbicide is applied initially. In our future strategies, we shall need to develop herbicides with controlled-release characteristics. Intensive research is needed to exploit the potential controlled-release characteristics of polymerized herbicides, copolymers, encapsulation, crop seed coatings, and related formulation techniques. These would enhance the release of active moieties uniformly over predetermined periods of time. Succussful development of such technology would revolutionize chemical weed control. Initial rates of application could be reduced. Losses from volatility, undesirable downward movement through the soil profile, sheet erosion, drift, and other environmental problems could be reduced.

Faulty disposal of unused pesticides, pesticide wastes, and pesticide containers constitutes a threat to a quality environment. Disposal practices of the past will not be acceptable in the future. A significant expansion of research for the development of better disposal technology will be essential to the safe use of herbicides. Unless better disposal techniques are developed, constraints on current methods will undoubtedly be imposed that will inhibit expansion of chemical weed control and impair IWMS.

The development of weed seed germination stimulants could significantly improve weed management technology. If uniform germination for most weed species that infest a single crop could be induced through the use of germination stimulants, chemical weed control could be significantly improved. Many of the growth-regulating chemicals that are known to stimulate weed seed germination are not effective because of their rapid degradation in the soil. Techniques to increase their residual activity would greatly improve the chances of effective use.

We need improved methods for the detection, measurement, and elimination or minimization of herbicidal residues in plants, animals, soils, air, and water. Processes in need of more intensive research are adsorption, photodecomposition, absorption by plants, degradation by microorganisms, volatilization, drift, aerial dissipation, chemical reactions, leaching, and surface runoff.

Conclusions

Agricultural technology has assured an abundant and wholesome food supply produced on a continuously reduced cropland acreage. IWMS are an important part of this technology. The many advances have permitted us to save millions of acres of land for natural beauty, hunting, fishing, parks, wildlife preserves, and other forms of recreation. This contribution to an improved environment for all Americans must also be included in the cost/benefit/risk evaluations when agricultural practices are being judged.

The general public recognizes the growing need for food, feed, and fiber. We must, however, remain aware that population growth is combined with other social, cultural, and economic forces to raise the twin specters of famine and pollution. These are threats to the survival of civilization as we know it. The public view and expectation is that science will provide solutions. Solutions--if they are to be effective--must be developed quickly. Basic knowledge from agricultural research is desperately needed.

The greatest obstacle to increasing agricultural production is probably not technoloical, but psychological--the traditional fear that if farmers grow everything they can, they will only produce a glut that will depress prices. In the light of tomorrow's domestic and worldwide needs, we must avoid such negative strategies and psychological hangups. Moreover, some past criticism to the contrary, we can never over-produce knowledge from agricultural research. Let us articulate as well as we possibly can the truth that basic knowledge is invaluable, yet it has no sale price; it can be stockpiled; it will not depress prices; there are no storage costs; there is no loss from storage; it has no half-life; it cannot be taxed; it cannot be corrupted or cause corruption; it does not create a monopoly, nor can it be monopolized; and it does not wear out. However, we do need to have a constant and continuing concern that our research programs are balanced and responsive to America's needs.

When we speak of basic and mission-oriented research as having the capabilities to solve problems, just what do we mean? What could we expect from a 50 percent expansion, within the next 10 years, in public-supported weed research? What would be the total potential benefits from such an expansion? Can we state these in terms that laymen understand and the public will view with confidence?

The total net potential benefit from an expansion of weed research of this magnitude would include:

1. A reduction in crop losses caused by weeds from 10 percent to 7 percent, resulting in a net annual savings of $1.8 billion.

2. A reduction of 10 percent in the current cost of weed control, resulting in a net annual savings of $600 million.

3. An improvement in the quality of crops by one percent by preventing the occurrence of toxic and nontoxic weed seeds in food crops and weed debris in fiber crops, resulting in a net increase in crop value of $600 million each year.

4. An increase of four percent in crop production efficiency through improved weed control technology that improves our environment and wildlife habitats, reduces hand-tillage costs, mechanical-tillage costs, fertilizer costs, irrigation costs, harvest costs, crop yield losses, grain and forage drying costs, transportation and storage costs, numbers of laborers needed, and acres required for crop production at an annual saving estimated to be $2 billion.

5. A reduction in fuel requirements from 8 billion to 4 billion gallons per year by achieving optimun tillage through the use of improved IWMS technology at an annual savings of $4.0 billion.

Can we achieve an annual benefit of $10.4 billion through expanded weed research? Yes! Weed scientists believe it can be done. When we consider that the annual losses caused by weeds and the cost of their control total more than $18.2 billion, such an objective seems within reach and a goal that weed science should establish and attain.

Our future progress in developing IWMS will be determined largely by the resources we allocate to support research to develop: a) a better fundamental understanding of weeds and their vulnerability to control; b) new approaches and new, more effective biological, genetic, physical, cultural, ecological, and chemical control components, c) total farm agroecosystems approaches to weed management; d) an understanding of the effects of herbicides on human health, plant and animal growth, soils, water, and the total environment of man, domestic animals, and wildlife; e) knowledge of the benefits, costs, limitations, and risks of current weed management practices; f) formulations of economical, more selective, more efficient, and less toxic herbicides; g) safety measures that are practical and easy to follow in the application of herbicides; h) technology for combining these techniques and practices into productive IWMS and agroecosystems that are compatible with a quality environment; and j) regulations that minimize the importation of noxious weeds, restrict the intrastate and interstate flow of weeds, and provide Federal and state coordination and support for elimination of incipient infestations of newly introduced noxious weeds (22).

As agricultural scientists and administrators, we must be responsive to the problems and concerns of all citizens. The need for agricultural chemicals and all other agricultural technology must be related to the needs of society as a whole. We cannot ignore agricultural principles and practices that impair the environment. We must continue to identify, define, and assess actual and potential environmental problems. We must devote more effort to advanced assessments of technology--costs, benefits, and risks. Moreover, our criteria must evaluate social, aesthetic, and environmental parameters and be understood by, and credible to, the scientific community and the general public.

We must carefully examine the costs, benefits, and risks of all components in IWMS. When this has been done--using acceptable scientific criteria--if the risks remain questionable, such methods should be discontinued and replaced with safer alternatives. If such alternatives are not available, researchers must develop them (22).

We must achieve and maintain a fine balance. On the one hand, we must protect our health and comfort and our capacity for producing food and fiber from the hazards of weeds. On the other hand, we must understand the ecological significance of weeds and the methods of control. We must protect all of the important values in our environment against the potential hazards. Costs, benefits, and risks must be carefully weighed before decisions can be made that are clearly in the public interest. I am confident that we will succeed.

Selected Bibliography

1. Andrilenas, P. A. 1974. Farmers' use of pesticides in 1971--Quantities. Agric. Econ. Rpt. No. 252. 56 pp. Econ. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

2. Andrilenas, P. A. 1975. Farmers' use of pesticides in 1971--Extent of crope use. Agric. Econ. Rpt. No. 268. 24 pp. Econ. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

3. Bennett, I. L., Jr. 1967. The world food problem. A report of the President's Science Advisory Committee. Vol. I, 127 pp; Vol II, 772 pp; Vol. III, 332 pp. Supt. of Doc. U.S. Govt. Print. Off., Washington, D.C.

4. Blake, H. T. and P. A. Andrilenas. 1975. Farmers' use of pesticides in 1971--Expenditures. Agric. Econ. Rpt. No. 296. 42 pp. Econ. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

5. Butz, E. L. 1975. 100 years of responsible technology. USDA 3237-75 (4984). 8 pp. U.S. Dept. of Agric., Washington, D.C.

6. Byerly, T. C. 1968. A national program of research for environmental quality--Pollution in relation to agriculture and forestry. A report of a joint task force of the U.S. Department of Agriculture and the State Universities and Land-Grant College. 111 pp. U.S. Dept. of Agric., Washington, D.C.

7. Ennis, W. B., Jr., W. C. Shaw, L. L. Danielson, D. L. Klingman, and F. L. Timmons. 1963. Impact of chemical weed control of farm management practices. Adv. in Agron. 15:161-210.

8. Ennis, W. B., Jr., W. M. Dowler, and W. Klassen. 1975. Crop protection to increase food supplies. Science 188:593-598.

9. Ferguson, W. L. 1975. Farmers' expenditures for custom pesticide services, 1971. Agric. Econ. Rpt. No. 314. 31 pp. Econ. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

10. Fox, A. S., R. P. Jenkins, J. T. Holstun, Jr., and D. L. Klingman. 1971. Economic impact of banning the domestic use of 2,4,5-T. Agric. Econ. Rpt. 199. 21 pp. U.S. Dept. of Agric., Washington, D.C.

11. Freeman, O. L. and I. L. Bennett,Jr. 1969. Control of agriculture-related pollution. A report to The President, submitted by The Secretary of Agriculture and The Director, Office of Science and Technology. 102 pp. U.S. Dept. of Agric., Washington, D.C.

12. Fowler, D. L. and J. N. Mahan. 1976. The pesticide review, 1976. 42 pp. Agric. Stabilization and Conservation. Serv., U.S. Dept. of Agric., Washington, D.C.

13. Irving, G. W., Jr. 1970. Agricultural pest control. Science 168:1419-1424.

14. Irving, G. W., Jr. and E. L. LeClerg. 1965. Losses in agriculture. Agric. Hdbk. No. 291, 120 pp. Agric. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

15. Jansen, L. L. 1972. Extent and cost of weed control with herbicides and an evaluation of important weeds. 1968. ARS-H-1. 227 pp. Agric. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

16. Klassen, W. 1975. Pest management--Organization and resources for implementation. *In* Insects, Science, and Society. pp 227-256. Academic Press, New York, N.Y.

17. Shaw, W. C. 1964. Weed science--Revolution in agricultural technology. Weed Sci. 12:153-162.

18. Shaw, W. C. 1971. How agricultural chemicals contribute to our current food supplies. Proc. Symp. Agricultural Chemicals--Harmony or discord for food, people, and the environment. Sponsored by the Univ. of California. 19 pp. Plant Sci. Res. Div., Agric, Res. Serv., U.S. Dept. of Agric., Beltsville, MD.

19. Shaw, W. C. 1974. Total farm weed control concepts for pest management. 15 pp. Agric. Res. Serv., U.S. Dept. of Agric., Beltsville, MD.

20. Shaw, W. C. and L. L. Jansen. 1972. Chemical weed control strategies for the future. Proc. Symp., Pest Control Strategies for the Future. pp 197-215. Nat. Acad. Sci. ISBNO-309-01945-1. 376 pp. Washington, D.C.

21. Shaw, W. C., J. L. Hilton, D. E. Moreland, and L. L. Jansen. 1960. Fate of herbicides in plants. pp 119-133. *In* The Nature and Fate of Chemicals Applied to Soils, Plants, and Animals. ARS 20-9. 221 pp. Agric. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

22. Shaw, W. C., Agric, Res. Serv, Scientists, and Cooperating State Weed Scientists. 1976. Agricultural Research Service, National Research Program, ARS-NRP 20280, Weed control technology for protecting crops, grazing lands, aquatic sites, and noncropland. 185 pp. Agric. Res. Serv., U.S. Dept. of Agric., Beltsville, MD.

23. Upchurch, L. P. and C. P. Heisig. 1964. The economic importance of pesticides to the U.S. Consumer. 6 pp. Econ. Res. Serv., U.S. Dept. of Agric., Washington, D.C.

24. Handbook of agricultural charts. 1966. Agric. Hdbk. No. 524. 125 pp. U.S. Dept. of Agric. Supt. of Doc., U.S. Govt. Print. Off., Washington, D.C.

25. Bergland, R. S. 1977. USDA policy on management of pest problems. Secretary's Momo. No. 1929. 3 pp. U.S. Dept. of Agric., Washington, D.C.

26. Bertrand, A. R. 1978. Pesticide management and regulation issues. Regulatory Forum, Natl. Agric. Chems. Assoc. Mtg., Sept. 25, 1978, White Suphur Springs, WV. 8 pp. Science and Education Administration, U.S. Dept. of Agric., Washington, D.C.

27. Knake, E. L. 1978. The weed science phase of pest management. 8 pp. Dept. of Agronomy, Univ. of Illinois, Urbana, IL.

28. Good, J. M. 1978. Developing, planning, and coordinating IPM programs. Proc. Soc. of Nematol. Mtg., Hot Springs, AR. Extension, Science and Education Administration, U.S. Dept. of Agric., Washington, D.C.

29. Hawkins, D. E., F. W. Slife, and E. R. Swanson. 1977. Econmic analysis of herbicide use in various crop sequences. Ill. Agric. Econ. 17(1):

30. Slife, F. W. 1979. Weed control systems in the corn belt states. Proc. 2nd World Soybean Res. Conf., Raleigh, NC. March, 1979.

31. Slife, F. W. and L. M. Wax. 1976. Weed and herbicide management. Proc. 1st World Soybean Res. Conf., Urbana, IL. Sept., 1976.

32. Bertrand, A. R. 1980. EA integrated pest management programs. 69 pp. Science and Education Administration, U.S. Department of Agric., Washington, D.C.

USE OF HERBICIDES IN SOUTH VIETNAM, 1961-1971

Alvin L. Young[1]

Herbicides used in support of tactical military operations in South Vietnam from 1961 to 1971 are today, ten years after the last herbicide mission, the center of intense scientific debate involving not only medical but also legal, political, and ecological issues. This paper reviews the historical and operational concepts and some potential human exposure considerations involving the military use of herbicides in the Southeast Asian Conflict.

Herbicides used in South Vietnam. Sythesis technology, efficacy data, and field application techniques were developed for the two major phenoxy herbicides, 2,4-D [(2,4-dichlorophenoxy)acetic acid] and 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid], during World War II at Fort Detrick, Frederick, Maryland. Following World War II, the commercial use of these two "synthetic" organic herbicides revolutionized American Agriculture. In 1950, more than 10 million pounds of these materials were used annually for weed and brush control in the United States. By 1960, in excess of 36 million pounds were used.

In May 1961, the Office of the Secretary of Defense requested the Fort Detrick personnel to determine the technical feasibility of defoliating jungle vegetation in the Republic of Vietnam. By early fall, 1961, 18 different aerial spray tests (defoliation and anticrop) had been conducted with various formulations of commercially-available herbicides. The choice of these herbicides was based upon the chemicals that had had considerable research, proven performance, and practical background at that period in time. Also, such factors as availability in large quantity, costs, and known or accepted safety in regard to their toxicity to humans and animals were considered. The results of these tests were that significant defoliation and anticrop effects could be obtained with two different mixtures of herbicides. The first was a mixture of the n-butyl esters of 2,4-D and 2,4,5-T and the iso-butyl ester of 2,4,5-T. This mixture was code-named "Purple." The second "military" herbicide was code-named "Blue" and consisted of the acid and sodium salt of cacodylic acid. The colored bands which were painted around the center of the 55-gallon drums served as aid to the identification by support personnel.

The first shipment of Herbicides Purple and Blue was received at Tan Son Nhat Air Base, Republic of Vietnam, on 9 January 1962. These were the first military herbicides used in Operation RANCH HAND, the tactical military project for the aerial spraying of herbicides in South Vietnam. Two additional phenoxy herbicide formulations were received in limited quantities in South Vietnam and evaluated during the first two years of operation RANCH HAND. These were code-named Pink and Green. By January 1965, two additional military herbicides, code-named Orange and White, had been evaluated and brought into the spray program. Herbicide Orange replaced all uses of Purple, Pink, or Green, and eventually became the most widely used military herbicide in South Vietnam. The composition of the three major herbicides used in South Vietnam were as follows:

1. Herbicide Orange. Orange was a reddish-brown to tan colored liquid soluble in diesel fuel and organic solvents, but insoluble in water.

---

[1]Major, USAF, Ph-D, Air Command and Staff College, Air University, Maxwell Air Force Base, AL 36112

One gallon of Orange theoretically contained 4.21 pounds of the active ingredient 2,4-D and 4.41 pounds of the active ingredient 2,4,5-T. Orange was formulated to contain a 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-T. The percentages of the formulation typically were:

n-butyl ester of 2,4-D	49.49
free acid of 2,4-D	0.13
n-butyl ester of 2,4,5-T	48.75
free acid of 2,4,5-T	1.00
inert ingredients (e.g., butyl alcohol and ester moieties)	0.62

2. Herbicide White. White was a dark brown viscous liquid that was soluble in water but insoluable in organic solvents and diesel fuel. One gallon of White contained 0.54 pounds of the active ingredient picloram (4-amino-3,5,6-trichloropicolinic acid) and 2.00 pounds of the active ingredient of 2,4-D. White was formulated to contain a 1:4 mixture of the triisopropanoamine salts of picloram and 2,4-D. The percentages of the formulation were:

triisopropanolamine salt of picloram	10.2
triisopropanolamine salt of 2,4-D	39.6
inert ingredient (primarily the solvent triisopropanolamine)	50.2

3. Herbicide Blue. Blue was a clear yellowish-tan liquid that was soluble in water, but insoluble in organic solvents and diesel fuel. One gallon of Blue contained 3.10 pounds of the active ingredient cacodylic acid (hydroxydimethylarsine oxide). Blue was formulated to contain cacodylic acid (as the free acid) and the sodium salt of cacodylic acid (sodium cacodylate). The percentages of the formulation were:

cacodylic acid	4.7
sodium cacodylate	26.4
surfactant	3.4
sodium chloride	5.5
water	59.5
antifoam agent	0.5

As previously noted, not all of the herbicides used in South Vietnam were used throughout the entire 10 years (1962-1971) encompassed by the Department of Defense defoliation program. In addition, 2,4,5-T formulations used early in the program are believed to have contained higher levels of the toxic contaminant TCDD (2,3,7,8-tetrachlorodibenzo-*p*-dioxin) or "dioxin" than did the formulations used in the later years. The three time periods shown in Table 1 can be differentiated on the basis of specific herbicides used and the mean dioxin content.

Herbicide Orange was the most extensively used herbicide in South Vietnam. Orange accounted for approximately 10.7 million gallons of the total 17.7 million gallons of herbicide used (Table 2). It was used from mid-1965 to June 1970. However, as noted in Table 2, Orange was not the only 2,4,5-T containing herbicide used in the defoliation program. Small quantities of Purple, Pink, and Green, all containing 2,4,5-T, were used from 1962 through mid-1965. In subsequent sections of this document, the term "Herbicide Orange" will refer to all of the 2,4,5-T containing herbicides used in Vietnam (Purple, Pink, Green, and Orange).

Use patterns of individual herbicides. Each of the three major herbicides (Orange, White, and Blue) had specific uses. Ninety-nine percent of

Table 1. Differentiation of three time periods during the U.S. military defoliation program in South Vietnam and mean dioxin content.

Period	Herbicides Used (Code Names)	Mean Dioxin Content (parts per million)*
January 1962- June 1965	Purple, Pink, Green Blue	∿32** 0
July 1965- June 1970	Orange White, Blue	∿ 2+ 0
July 1970- October 1971	White, Blue	0

*Found only in 2,4,5-T containing formulations.
**Value based on analyses of five samples.
+Value based on the analyses of 488 samples.

Table 2. Numbers of gallons of military herbicide produced by the U.S. Department of Defense and disseminated in South Vietnam during January 1962 - October 1971.

Code Name	Herbicide	Quantity	Period of Use
Orange	2,4-D; 2,4,5-T	10,646,000	1965-1970*
White	2,4-D; Picloram	5,633,000	1965-1971**
Blue	Cacodylic Acid	1,150,000	1962-1971**
Purple	2,4-D; 2,4,5-T	145,000	1962-1965
Pink	2,4,5-T	123,000	1962-1965
Green	2,4,5-T	8,200	1962-1965
	Total	17,705,200	

*Last fixed-wing mission of Orange 16 April 1970; last helicopter mission of Orange 6 June 1970.
**Last fixed-wing mission 9 January 1971; all herbicides under US control stopped 31 October 1971.

Herbicide White was applied in defoliation missions. It was not recommended for use on crops because of the persistence of picloram in soils. Because the herbicidal action of woody plants was usually slow, full defoliation did not occur for several months after spray application. Thus, it was an ideal herbicide for use in the inland forests in areas where defoliation was not immediately required, but where it did occur it would persist longer than if the area were sprayed with Orange or Blue.

Herbicide Blue was the herbicide of choice for crop destruction missions involving cereal or grain crops. Approximately 50 percent of all Blue was used in crop destruction missions in remote or enemy controlled areas with the remainder being used as a contact herbicide for control of grasses around base perimeters.

Ninety percent of all Herbicide Orange was used for forest defoliation and it was especially effective in defoliating mangrove forests. Eight percent of Herbicide Orange was used in the destruction of broadleaf crops (beans, peanuts, ramie, and root or tuber crops). The remaining 2 percent was used around base perimeters, cache sites, waterways, and communication lines.

Table 3 shows the number of acres sprayed with herbicides in South Vietnam within the three major vegetational categories.

Table 3. Number of acres treated in South Vietnam, 1962-1971, with military herbicides within the three major vegetational categories.

Vegetational Cateroty		Acres Treated*
Inland forest		2,670,000
Mangrove forests		318,000
Cultivated crops		260,000
	Total	3,248,000

*Areas receiving single or multiple coverage.

Certain portions of South Vietnam were more likely to have been subjected to defoliation. Herbicide expenditures for the four Combat Tactical Zones of South Vietnam are shown in Table 4. These data were obtained from the HERBS tape (a computer listing of all herbicide missions in South Vietnam from 1965 through 1971). Total volume is in close agreement with the actual procurement data shown in Table 2.

In addition to the herbicides, numerous other chemicals were shipped to South Vietnam in 55-gallon drums. These included selected fuel additives, cleaning solvents, cooking oils, and a variety of other pesticides. The insecticide Malathion was widely used for control of mosquitoes and at least 400,000 gallons of it were used from 1966 through 1970. In addition, much smaller quantities of Lindane and DDT were used in ground operations throughout the war in Southeast Asia. The distribution of the herbicides within Vietnam after their arrival did not occur randomly. About 65 percent was shipped to the 20th Ordnance Storage Depot, Saigon, and 35 percent was shipped to the 511th Ordnance Depot, Da Nang.

Military aircraft and vehicles used in the dissemination of herbicides. Numerous aircraft were used in the air war in Vietnam, but only a few of these aircraft were used for aerial dissemination of herbicides. The

Table 4. U.S. herbicide expenditures in South Vietnam, 1962-1971: A breakdown by Combat Tactical Zone*

Combat Tactical Zone	Herbicide Expenditure (gallons) Orange	White	Blue
CTZ I	2,250,000	363,000	298,000
CTZ II	2,519,000	729,000	473,000
CTZ III (includes Saigon)	5,309,000	3,719,000	294,000
CTZ IV	1,227,000	435,000	62,000
Subtotals	11,305,000	5,246,000	1,127,000
Grand total			17,678,000

*Source: HERBS tape

"work horse" of Operation RANCH HAND was the two-engine aircraft C-123/UC-123 called the "Provider." This cargo aircraft was adapted to receive a modular spray system for internal carriage. The module (the A/A 45 Y-1) consisted of a 1,000-gallon tank, pump, and engine which were all mounted on a frame pallet. An operator's console was an integral part of the unit, but was not mounted on the pallet. Wing booms (1.5 inches in diameter, 22 feet long) extended from the outboard engine nacelles toward the wing tips. A short tail boom (3 inches in diameter, 20 feet long) was positioned centrally near the aft cargo door. Each aircraft normally had a crew of three men: the pilot, co-pilot (navigator), and flight engineer (console operator). During the peak activity of RANCH HAND operations (1968-1969), 33 UC-123K aircraft were employed. The "U" designated modification for aerial spraying and the "K" designated modification with jet boosters. However, many other squadrons of non-RANCH HAND C-123 aircraft were routinely used throughout South Vietnam in transport operations.

The control of malaria and other mosquito-borne diseases in South Vietnam necessitated an extensive aerial insecticide application program in order to control these vector insects. From 1967 through 1972, three UC-123K aircraft were used to spray Malathion, an organophosphate insecticide. These aircraft could be distinguished from the herbicide-spraying aircraft because they were not camouflaged. These aircraft routinely sprayed insecticide adjacent to military and civilian installations, as well as in areas where military operations were in progress, or about to commence.

Approximately 10 to 12 percent of all herbicides used in South Vietnam was disseminated by helicopter or ground application equipment. Generally, helicopter crews were not assigned to herbicide spray duries on a full-time basis and rotated duties with other mission requirements. The military UH-1 series of helicopters, deployed by the Air Force, the Army, and Navy units, generally sprayed the herbicides. The most common spray system used was the AGRINAUTICS unit. This unit was installed in or removed from the aircraft in a matter of minutes because it was "tied down" to installed cargo shackles and aircraft modifications were not required for its use. The unit consisted of a 200-gallon tank and a collapsible 32-foot spray boom. The unit was operated by manual controls to control the flow valve and a windmill brake. Generally, each helicopter had three crew members.

A summary of the aircraft used in herbicide and insecticide operations is shown in Table 5.

Table 5. U.S. military aircraft used in the dissemination of herbicides and insecticides in South Vietnam.

Aircraft	Camouflaged	Chemical Disseminated
UC-123K	Yes	All herbicides
UC-123K	No	Malathion
Helicopter		
Air Force UH-1 Navy UH-1B/UH-1D Navy UH-1E	Yes	Orange, Blue

Various ground delivery systems were also used in South Vietnam for control of vegetation in limited areas. Most of these units were towed or mounted on vehicles. One unit that was routinely used was the Buffalo turbine. It developed a wind blast with a velocity up to 150 mph at 10,000 ft^3/minute volume. When the herbicide was injected into the air blast, it was essentially "shot" at the foliage. The Buffalo turbine was useful for roadside spraying and applications of perimeter defenses. The herbicides of choice in these operations were Blue and Orange.

Exposure consideration: Applicationa and environmental parameters. There were relatively few military operations that involved the handling of herbicides by military personnel. A review of operations involving Herbicide Orange in South Vietnam from January 1962 to April 1970 revealed that there were essentially three groups of U.S. military personnel potentially exposed to Herbicide Orange and its associated dioxin contaminant. These groups were:

1. "Operation RANCH HAND" personnel actively involved in the defoliation program. This group included aircrew members and maintenance and support personnel directly assigned to RANCH HAND squadrons.
2. Personnel assigned to selected support functions that may have resulted to exposure to Herbicide Orange. This group included, for example, personnel who sprayed herbicides, using helicopters or groud application equipment; personnel who may have delivered the herbicides to the units performing the defoliation missions; aircraft mechanics who were specialized and occasionally provided support to RANCH HAND aircraft; or, personnel who may have flown contaminated C-123 aircraft, but were not assigned to RANCH HAND (e.g., during the Tet Offensive, all RANCH HAND aircraft were reconfigured to transport supplies and equipment, and were assigned to non-RANCH HAND squadrons).
3. Ground personnel who may have been inadvertently sprayed by defoliation aircraft or who, during combat operations, may have entered an area previously sprayed with Herbicide Orange.

The total number of U.S. military personnel exposed to Herbicide Orange is not known. Approximately 1,200 RANCH HAND personnel were exposed in direct support of the defoliation operations; however, there are no data on the number of non-RANCH HAND personnel who may have been exposed. The actual number of people may be in the thousands since at least 100 helicopter spray equipment units were used in South Vietnam, and most military bases had vehicle-mounted and backpack spray units available for use in routine vegetation control programs. The number of military ground personnel who may have inadvertently been sprayed by RANCH HAND aircraft, or who may have entered areas recently sprayed with Herbicide Orange during combat operations is not known. Approximately 10 percent of South Vietnam was sprayed with herbicides, and most of this area was contested and/or controlled by enemy forces. Most areas sprayed were remote, unpopulated and forested. Because of the dense canopy cover, the target of the defoliation operation, the amount of herbicide penetrating to the forest floor would have been small. The exposure of personnel could have occurred by essentially three routes:

1. Percutaneous absorption and inhalation of vapors/aerosols by direct exposure to sprays.
2. Percutaneous absorption and inhalation of vapors by exposure to treated areas following spray application, and
3. Ingestion of food contaminated with material.

The chemical and physical characteristics of Herbicide Orange and the spray, as it would have occurred following dissemination from a UC-123K, are important factors in assessing relative exposures to the Herbicides and TCDD.

Table 6 reviews the pertinent chemical and physical characteristics of Herbicide Orange. Table 7 reviews both the application parameters of the spray system used in the UC-123K aircraft and the characteristics of the spray itself. Generally, herbicides were sprayed in the early morning or late afternoon, so as to minimize the effects of air movement on particle dispersion.

Table 1. Pertinent chemical and physical characteristics of Herbicide Orange.

Formulation concentrated		(8.6 lb ai/gal)*
Water insoluble		Density = 1.28
Vapor pressure		3.6×10^{-4} mm Hg at 30°C
NBE** 2,4-D	: 1.2×10^{-4}	
NBE 2,4,5-T	: 0.4×10^{-4}	
TCDD	: 1×10^{-7}	
Viscous		40 centipoises at 20°C
Noncorrosive to metal		
Deleterious to paints, rubber, neoprene		
Long shelf life		

*Pounds active ingredient (2,4-D and 2,4,5-T) per gallon.

**NBE - normal butyl ester

Ground forces normally would not have been expected to have entered a previously treated area for several weeks after treatment, during which time numerous environmental factors would have reduced the portential for exposure to military personnel. An indepth review of the environmental

Table 7. Application parameters and spray characteristics of the UC-123K/ AA 45 Y-1 internal spray system.

Aircraft speed	130 KIAS*
Aircraft altitude	150 feet
Tank volume	1,000 gallons
Spray time	3.5-4 minutes
Particle size:	
<100 microns: 1.9%	
100-500 microns: 76.2%	
>500 microns: 21.9%	
87% impacted within 1 minute	
13 % drifted or volatilized	
Mean particle volume	0.61 microliters
Spray swath	260 ± 20 feet
Mean deposition	3 gallons/acre
Total area/tank	340 acres

*Knots indicated air speed

fate of Herbicide Orange and TCDD concluded that the vast majority of the phenoxy herbicides would have impacted forest canopy, the intended target. Rapid uptake (e.g., within a few hours) of the ester formulations of 2,4-D and 2,4,5-T would have occurred. Most of the herbicide probably would have undergone rapid degredation (weeks) within the cellular matrix of the vegetation. However, some of the herbicide may have remained unmetabolized and would have been deposited on the forest floor at the time of leaf fall. Soil microbial and/or chemical action would likely have completed the degradation process. Herbicide droplets that impacted directly on soil or water would have probably hydrolyzed rapidly (within hours). Biological and nonbiological degradative processes would have further occurred to significantly reduce these residues. Some volatilization of the esters of 2,4-D and 2,4,5-T would have occurred during and immediately after application. The volatile material most likely would have dissipated within the foliage of the target area. Photodecomposition of TCDD would have minimized the amount of biologically active volatile residues moving downwind of the target area.

Accumulation of phenoxy herbicides in animals may have occurred following ingestion of treated vegetation. The magnitude of this accumulation would have likely been at non toxic levels. Herbicide residues in animals would have rapidly declined after withdrawal from treated feed.

Most TCDD sprayed into the environment during defoliation operations would have probably photodegraded within 24 hours of application. Moreover, recent studies suggest that even within the shaded forest canopy, volatilization and subsequent photodecomposition of TCDD can occur. Since translocation into vegetation would be minimal, most TCDD that escaped photodegradation would probably have entered the soil-organic complex on the forest floor following leaf fall. Soil chemical and microbial processes would have further reduced TCDD residues. Bioconcentration of the remaining minute levels of TCDD may have occurred in liver and fat of animals ingesting contaminated vegetation or soil. However, there are no field data available that indicate that the levels of TCDD likely to have accumulated in these animals would have had a biological effect.

The environmental generation of TCDD from 2,4,5-T residues, through thermal or photolytic processes, would have been highly unlikely and of no consequence.

Summary

The choice of herbicides used in South Vietnam on Operation RANCH HAND, 1962-1971, was based upon those herbicides that had been widely used in world agriculture, shown to be effective in controlling a broad spectrum of vegetation, and proven safe to humans and animals. The major herbicides used in South Vietnam were the phenoxy herbicides 2,4-D and 2,4,5-T. These two herbicides were formulated as the water insoluble esters and code-named by the military of Purple, Orange, Pink and Green. A water soluble amine formulation of 2,4-D was used in Herbicide White. Two other herbicides were extensively used by the military, picloram (in White) and cacodylic acid (in Blue).

An estimated 107 million pounds of herbicides were aerially-disseminated on 3 million acres in South Vietnam from January 1962 through October 1971. Approximately 94 percent of all herbicides sprayed in Vietnam were 2,4-D (56 million pounds or 53 percent of total) or 2,4,5-T (44 million pounds or 41 percent of total). The 44 million pounds of 2,4,5-T contained an estimated 368 pounds of the toxic contaminant, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD or dioxin). Ninety six percent of all 2,4,5-T was contained in Herbicide Orange; the remaining 4 percent in Herbicides Green, Pink and Purple. However, Herbicides Green, Pink, and Purple contained approximately 40 percent of the estimated amount of TCDD disseminated in South Vietnam. Green, Pink, and Purple were sprayed as defoliants on less than 90,000 acres from 1962 through 1964, a period when only a small force of U.S. military personnel were in South Vietnam. Ninety percentof all the Herbicide Orange (containing 38.3 million pounds of 2,4,5-T and 203 pounds of TCDD) was used in defoliation operations on 2.9 million acres of inland forests and mangrove forests of South Vietnam.

The handling, transport, and storage procedures employed for the herbicide generally precluded physical contact with the herbicides by most military personnel. However, personnel assigned to the RANCH HAND squadron and to individual helicopters responsible for the dissemination of herbicides were the most likely military personnel exposed to the herbicides.

The methods employed in spraying the herbicides, the geographical areas designated for dissemination of the herbicides, and the action of the environment on the herbicides generally precluded direct physical contact with the herbicide by military personnel assigned to other military programs.

OVERVIEW OF USDA STUDY ON ORGANIC FARMING

R. I. Papendick[1]

The intensive and highly mechanized agricultural technologies now utilized in our U.S. agricultural production system have led not only to greatly increased productivity and labor efficiency, but also to a concomitant decrease in energy efficiency, massive soil deterioration from erosion, and to other concerns involving both farmers and the general public. There is a growing concern about the adverse effects of intensive production of cash grains and about the extensive, and sometimes excessive, use of chemical fertilizers and pesticides. Among the matters in question are these:

- Increased cost and uncertain availability of energy and chemicals.
- Increased resistance of weeds and insects to pesticides.
- Decline in soil productivity from erosion and accompanying loss of organic matter and plant nutrients.
- Pollution of surface waters with agricultural chemicals and sediment.
- Destruction of wildlife, bees, and beneficial insects by pesticides.
- Hazards to human and animal health from pesticides and feed additives.
- Detrimental effects of agricultural chemicals on food quality.
- Depletion of finite reserves of concentrated plant nutrients; for example, phosphate rock.
- Decrease in numbers of farms, particularly family-type farms, and disappearance of localized and direct marketing systems.

Some previous assessments of organic farming systems have suggested that this method of farming is associated with a low level of productivity and is essentially unadaptable to widespread use in the United States for adequate food and fiber production. In view of recent efforts by the U.S. Department of Agriculture to assess possible consequences of certain trends in the structure of our agricultural production and marketing system, certain questions have arisen. For example, were earlier assessments of the productivity of organic agriculture in the United States valid? Under what specific circumstances and conditions can organic farming systems produce a significant portion of our food and fiber needs? What are the costs and benefits of organic farming, and what are the relationships between energy and labor?

Proponents of organic agriculture face many of the same problems that confront those who practice chemical-intensive (conventional) farming. Both must provide adequate supplies of nutrients, water, and energy for crop and livestock production. The basic difference, however, is that organic farmers avoid or restrict the use of synthetic fertilizers and pesticides, and must therefore achieve nutrient recycling and pest control by other means. These include proper management of crop residues and animal manures, green manure crops, crop rotations, and use of nonsynthetic fertilizers and pesticides. The productivity of any agricultural system, organic or chemical, depends primarily on the level of available and applicable imputs in accord with climatic, soil, and cropping considerations.

---

[1]Soil Scientist, USDA-SEA-AR, Pullman, WA. Chairman, USDA Study Team for Organic Farming, 1979-80.

The growing interest in organic agriculture reflects an ideology shared by many urban and rural people, that is, that a stable and sustainable agriculture can be attained only through the development of technologies that are less demanding of nonrenewable resources, less exploitive of our soils, and at the same time environmentally, socially, and economically acceptable. It was because of these interests and concerns that the U.S. Department of Agriculture decided to conduct a comprehensive study of organic farming in the United States. In April, 1979, Dr. A. R. Bertrand, Director of Science and Education, USDA, designated a coordination team for organic farming, and the study was begun.

Accordingly, the team assessed the nature and activity of organic farming both here and in Europe and Japan; explored the broad sociopolitical character of the organic movement; evaluated the level of success of organic farmers and the economic impacts, costs, benefits, and limitations to organic farming; identified research and education programs that would benefit organic farmers; and recommended plans of action for implementation. The results of this study were published in the USDA "Report and Recommendations on Organic Farming," July 1980.

In conducting the study, the team relied on a variety of methods and sources to obtain information. These included:

- Selected on-farm case studies of 69 organic farms in 23 states.
- A Todale Press survey of *The New Farm* magazine readership.
- An extensive review of the literature on organic farming published both here and abroad.
- Interviews and correspondence with knowledgeable organic farming leaders, editors, spokesmen, and practitioners.
- Two study tours of organic farms and research institution in Europe and Japan.

While other definitions exist, for the purpose of this report organic farming is defined as follows:

> Organic farming is a production system which avoids or largely excludes the use of synthetically compounded additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests.

The following is a brief summary of the principal findings of this study:

1. The study team found that the organic movement represents a spectrum of practices, attitudes, and philosophies. One the one hand are those organic practitioners who would not use chemical fertilizers or pesticides under any circumstances. These producers hold rigidly to their purist philosophy. At the other end of the spectrum, organic farmers espouse a more flexible approach. While striving to avoid the use of chemical fertilizers and pesticides, these practitioners do not rule them out entirely. Instead, when absolutely necessary, some fertilizers and also herbicides are very selectively and sparingly used as a second line of defense. Nevertheless, these farmers, too, consider themselves to be organic farmers. Failure to recognize that the organic farming movement is distributed over a spectrum can often lead to serious misconceptions. We should not attempt to place all of these organic pratitioners in the same category. For example, we should not lump "organic farmers" and "organic gardeners" together.

2. Organic farming operations are not limited by scale. This study found that while there are many small-scale (10 to 50 acres) organic farmers in the northeastern region, there are a significant number of large-scale (more than 100 acres and even up to 1,500 acres) organic farms in the West and Midwest. In most cases, the team members found that these farms, both large and small, were productive, efficient, and well managed. Usually the farmer had acquired a number of years of chemical farming experience before shifting to organic methods.

3. Motivations for shifting from chemical farming to organic farming include concern for protecting soil, human, and animal health from the potential hazards of pesticides; the desire for lower production inputs; concern for the environment; and protection of soil resources.

4. Contrary to popular belief, most organic farmers have not regressed to agriculture as it was practiced in the 1930's. While they attempt to avoid or restrict the use of chemical fertilizers and pesticides, organic farmers still use modern farm machinery, recommended crop varieties, certified seed, sound methods of organic waste management, and recommended soil and water conservation practices.

5. Most organic farmers use crop rotations that include legumes and cover crops to provide an adequate supply of nitrogen for moderate to high yields.

6. Animals comprise an essential part of the operation of many organic farms. In a mixed crop/livestock operation, grains and forages are fed on the farm and the manure is returned to the land. Sometimes the manure is composted to conserve nitrogen, and in some cases farmers import both feed and manure from off-farm sources.

7. The study team was impressed by the ability of organic farmers to control weeds in crops such as corn, soybeans, and cereals without the use (or with only minimal use) of herbicides. Their success here is attributed to timely tillage and cultivation, delayed planting, and crop rotations. They have also been relatively successful in controlling insect pests.

8. Some organic farmers expressed the feeling that they have been neglected by the U.S. Department of Agriculture and the land-grant universities. They believe that both Extension agents and researchers, for the most part, have little interest in organic methods and that they have no one to turn to for help on technical problems.

9. In some cases where organic farming is being practiced, it is apparent from a study of the nutrient budget that phosphorus (P) and potassium (K) are being "mined" from either soil minerals or residual fertilizers applied when the land was farmed chemically. While these sources of P and K may sustain high crop yields for some time (depending on soil, climatic, and cropping conditions), it is likely that eventually some organic farmers will have to apply supplemental amounts of these two nutrients.

10. The study revealed that organic farms on the average are somewhat more labor intensive but use less energy than conventional farms. Nevertheless, data are limited and a thorough study of the labor and energy aspects of organic and conventional agriculture is needed.

11. This study showed that the economic return above variable costs was greater for conventional farms (corn and soybeans) than for several crop rotations grown on organic farms. This was largely due to the mix of crops required in the organic system and the large portion of the land that was in legume crops at any one time.

12. There was detrimental aspects of conventional production, such as soil erosion and sedimentation, depleted nutrient reserves, water pollu-

tion from runoff of fertilizers and pesticides, and possible decline of soil productivity. If costs of these farmers are considered, then cost comparisons between conventional (that is, chemical-intensive) crop production and organic systems may be somewhat different in areas where these problems occur.

In conclusion, the study team found that many of the current methods of soil and crop management practiced by organic farmers are also those which have been cited as best management practices (USDA/EPA joint publication of "Control of Water Pollution from Cropland," Vol. I, 1975, U.S. Government Printing Office) for controlling soil erosion, minimizing water pollution, and conserving energy. These include sod-based rotations, cover crops, green manure crops, conserving tillage, strip cropping, contouring, and grassed waterways. Moreover, many organic farmers have developed unique and innovative methods of organic recycling and pest control in their crop production sequences. Because of these and other reasons outlined in this report, the team feels strongly that research and education programs should be developed to address the needs and problems of organic farmers. Certainly, much can be learned from a holistic research effort to investigate the organic system of farming, its mechanisms, interactions, principles, and potential benefits to agriculture both at home and abroad.

MICROBIAL TRANSFORMATIONS OF HERBICIDES IN SOIL

J. P. Martin and Diane E. Stott[1]

Introduction

When herbicides and other pesticides are applied to the soil or reach the soil they are subject to numerous transformations or reactions which influence their effectiveness and the time required for degradation or detoxication (2, 4, 9, 16, 17, 20, 21, 34). These reactions include absorption by plants, adsorption on soil colloids, photochemical degradation, chemical alterations, diffusion, volatilization, movement with soil water, and microbial degradation with ultimate release of the constituent elements as simple inorganic compounds, use of partially degraded components for microbial synthesis, and stabilization of partial degradation products or products of resynthesis by linkage into the relatively stable and beneficial soil humus or by physiochemical interactions with metal ions and soil colloids. Although most of these reactions are of significance for one or more of the herbicides the overall most important transformations are those induced by the soil microorganisms (13).

Microbes have been decomposing organic substrates since shortly after life existed on the earth several billion years ago. Presently the greatest quantities of organic materials synthesized by plants, animals, and microorganisms are polysaccharide, lignin, and protein polymers. However, relatively large quantities of smaller organic molecules including highly toxic compounds are synthesized by living things (7, 30). Many volumes have been written on natural toxic organic substances. During the last 10

[1]Department of Soil and Environmental Sciences, University of California, Riverside, CA 92521.

years Academic Press has announced over 8 volumes on microbial toxins. Toxic substances synthesized by common soil organisms include botulin, aflatoxins, coumarins and related compounds, lactones, numerous phenolic compounds and anthraquinones. Some common soil fungi synthesize up to 50 phenolic substances (23) and some 15 or more anthraquinones (Fig. 1).

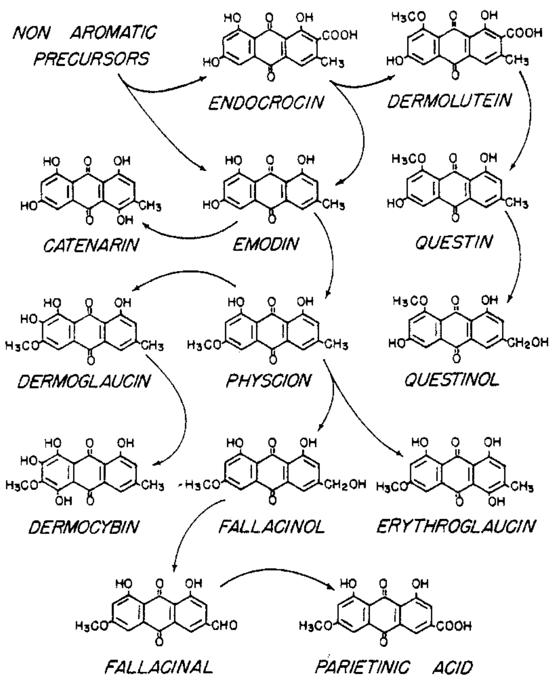


Figure 1. Some anthraquinones synthesized by *Eurotium echinulation* and other soil fungi (31).

Many of the natural substances also include clorinated hydrocarbons, some of which are toxic (7).

The plant, animal, and microbial toxic substances have not accumulated in the soil but have been degraded relatively quick or detoxified by partial degradation and by incorporation of the molecules or partially altered structures into the soil humus. When organic herbicides and other pesticides were developed and applied to the soils it was logical to assume that they would undergo the same reactions in soil as would other organic compounds, including the toxic molecules. After about 40 years of extensive use of these synthesized compounds, our soils are still fertile and team with myriads of microbes which certainly shows they are being degraded and detoxified in the soil.

Decomposition of Organic Compounds and Herbicides

The rate of microbial degradation of both natural organic compounds and synthesized herbicides varies greatly (Fig. 2). Generally, about 60 to 80 percent of the carbon of most comples plant and animal residues reaching the soil is released as CO_2 in one year (14, 22, 32). Some of the specific constituents such as sugars, some polysaccharides, simple aliphatic acids and amino acids decompose more rapidly and may be largely metabolized within a few days to a few weeks. If an organic compound is readily utilized by the soil organisms, about 70 to 90% of the carbon will be released as CO_2 in one year and the greatest carbon loss will occur during the first few weeks of active degradation. Initially up to 40 to

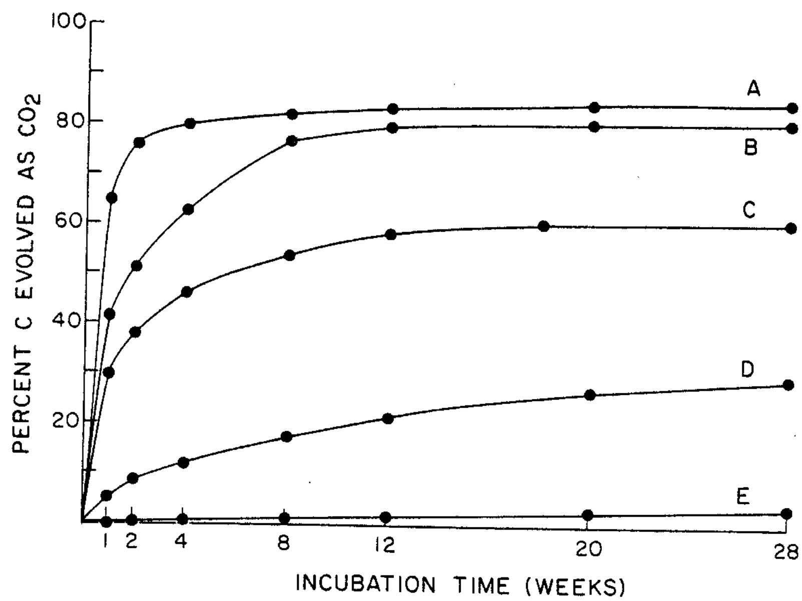


Figure 2. Approximate decomposition curves for various organic substrates and compounds assuming no lag phase. A. Sugars, simple aliphatic acids, most amino acids, pryimidines, cyanuric acid, and others. B. Polysaccharides, proteins, bacterial cells, earthworms, light colored fungal cells, succulent plant parts, 2,4-D, dalapon, and others. C. Mature plant leaves, cereal straws, many fungal cells, phenols, some anthraquinones, some woods, fresh manures, cysteine, tyrosine, and others. D. Lignins, bromacil, some peats, some fungal melanins, some woods and barks, sewage sludge, 2-chloro-4,6-diamino-*S*-triazine, composts, aged manures, reactive phenols, and others. E. Soil humus, most funal melanins, model humic acid polymers, black peat and others.

60 percent of the carbon may be incorporated into the microbial cells and products (35), but these are degraded after the death of the cells, and after one year only about 1 to 1.5 percent of the original carbon or 10 percent of the residual carbon will be present in the biomass and the remainder will be stabilized in the soil humus. If the original compound disappears but smaller quantities of carbon are released as CO_2 it is an indication that some of the partially altered or degraded structures are stabilized in the humus or through physiochemical interactions with clays and metal ions.

If an organic compound is fully metabolized by soil organisms, a small amount of the residual carbon will be present as aromatic units synthesized by the soil flora and incorporated into humic acid polymers (28). The major portion, however, will be present as peptides and polysaccharides which can be solubilized by acid hydrolysis. If the organic substrate contains aromatic components and some of these, after alterations, are linked into the humic acid polymers, then smaller amounts of residual carbon will be solubilized by acid hydrolysis. For example, after one year only 20 to 30 percent of lignin carbon is released as CO_2 and less than one percent of the residual carbon is present in biomass (27). The greater portion of the residual carbon is present in aromatic units of the soil humus. Loss of anthraquinone carbons in soil varies from about 20 to 68 percent during 90 days. Losses from phenolic compounds vary from about 10 to 70 percent in one year. A portion of these aromatic substances are stabilized by linkage into humic acid polymers and therefore smaller quantities are metabolized by the soil organisms and smaller amounts of the residual carbons are solubilized by acid hydrolysis. If these compounds were metabolized through ring cleavage then 80 percent or more of the ring carbons would be released as CO_2 in one year.

In a recent study by J. S. Angle and G. H. Wagner (1) a fungal aflatoxin could not be detected after 49 to 77 days, but only 14 percent of the carbon had evolved as CO_2 after 112 days. It is thus evident that partial degradation products are stabilized in humus.

As with natural organic compounds, numerous soil organism including bacteria, actinomyces, and fungi have been shown to degrade organic herbicides. Also, as with the natural substrates, the number of species metabolizing specific compounds and the rate of degradation varies (Table 1). Dalapon (2,2-dichloropropionic acid), diquat (6,7-dihydrodipyridol[1,2-α:2',1'-*c*]pyrazinediium ion), and 2,4-D [(2,4-dichlorophenoxy)acetic acid] may disappear within 2 to 4 weeks while dicamba (3,6-dichloro-*o*-anisinic acid), diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine], atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine], and bromacil (5-bromo-3-*sec*-butyl-6-methyluracil) may persist up to one year or longer (5, 13, 17).

The herbicides which are readily metabolized are largely utilized as a carbon and energy source by the soil organisms. Cometabolism amy be involved in the degradation of some of the more resistant compounds. The herbicide 2,4-D, for example, is initially, after a short lag period, rapidly metabolized during which time about 60 percent or more or the carbon is released as CO_2. This loss follows a typical microbial growth curve. Bromacil, on the other hand, is slowly metabolized (37). After one year its toxic effect may be largely dissipated, but only 10 to 20 percent of the 2-ring carbon is released as CO_2. This indicates that partial decomposition structures are stabilized by incorporation into humus or by complexing with soil colloids and metal ions. The CO_2 release pattern from bromacil is not typical of a normal bacterial growth curve

Table 1. Approximate time required for degradation of herbicides to nontoxic compounds or complexes.

2 to 4 weeks	2-3 months	6-10 months	About 1 year
2,4-D and most derivatives	Bentazon	Atrazine	Bromacil
Dinoseb	Butylate	Alachlor	Terbacil
Paraquat	Chloramben	Simazine	Picloram
Dalapon	Propachlor	Dicamba	
Endothal	Diallate	Ametryn	
MSMA	EPTC	Linuron	
DSMA	CDEC	Trifluralin	
Barban	Diphenamid	Prometryn	
Propham	TCA	Diuron	
MCPA	Naptalam	Fluometuron	
Diquat	Vernolate	DCPA	
Nitrofen	2,4,5-T	Oryzalin	
AMS	Chlorpropham	Metribuzin	
Amitrole	Cycloate	Chlorobromuron	
Cacodylic acid	Pyrazon	Bromoxynil	
	Triallate		

and suggests that cometabolism may be involved in its degradation to the ring cleavage stage (Fig. 3).

Various environmental factors greatly influence the rate of decomposition of herbicides (7) and other organic substances in soils (Table 2).

Table 2. Some factors influencing rate of decomposition of herbicides in soil.

Moisture	Soil reaction
Aeration	Dosage rate
Biota	Previous applications
Organic matter content	Distribution (Particle size)
Fresh organic residues	Solubility
Available nutrient	Combination treatments with other pesticides
Soil texture	
Temperature	

In general, conditions which favor microbial activity favor decomposition. Moisture is necessary for microbial growth and for microbial decomposition of herbicides. Too much water, however, reduces the oxygen supply and may

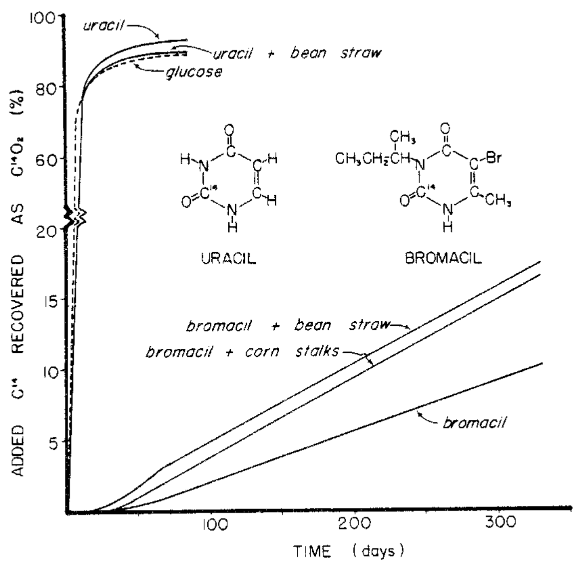


Figure 3. Decomposition of bromacil and uracil in a neutral soil as influenced by plant residue applications.

retard decomposition of some herbicides or their partial degradation structures but may accelerate initial degradative reactions of others. Also, herbicides may persist longer in soils which remain dry for long periods of time. Soils containing intermediate amounts of clay and relatively high amounts of humus contain higher numbers and kinds of microbes and hence are more favorable for decomposition of most herbicides. Sometimes, however, the chemical may be adsorbed so strongly by the clay or humus that the decomposition rate is reduced. This appears to be true for the phenylurea herbicides such as chloroxuron (3-[*p*-(*p*-chlorophenoxy) phenyl]-1,1-dimethylurea). The number and variety of species of flora and fauna, both macro- and micro- present in the soil will affect the degradation rates of herbicides. The greater the variety, the faster the rate of decomposition. Additions of fresh organic matter may enhance pesticide decomposition. An increase in nutrient availability may increase the variety of microbial species present, thereby enhancing herbicide degradation. Higher temperatures, namely up to 30 to 40°C or more, favor the microbial decomposition of organic compounds. Therefore, herbicides will decompose more rapidly in Texas or Central America than in the soils of Canada.

Soil reaction (pH) may influence the reactivity of the chemical and exert a great influence on the kinds of organisms active in the soil (19). In an alkaline soil, for example, 2,4-D exists as a salt while in an acid soil it may remain in the acid form. In neutral to alkaline soils in temperate climates bacteria and actinomycetes predominate, while in acid soils fungi are most numerous. If bacteria and actinomycetes are primarily involved in the decomposition of an herbicide, then neutral soil would favor decomposition. If fungi are more active, acid soils may be more conducive to degradation.

The dosage, particle size, solubility, distribution and previous applications, all affect the rate of decomposition of herbicides in soils. High dosages may be toxic to some species which would decompose the same chemical at lower concentrations. This phenomenon is true even with such a nontoxic substance as sugar, but with sugar, much higher concentrations are involved. Materials of relatively large particle size will decompose more slowly than those of smaller size because they will present less surface area for organisms to attack. The greater the solubility of a compound, the more readily available it is to microbial attack, especially by bacteria. Previous applications will generally stimulate the growth of organisms capable of degrading a particular compound. Subsequent additions will therefore decompose more quickly.

If an herbicide is applied to a soil in combination with other biocides, the rates of decomposition may sometimes be retarded. One chemical may be toxic to an organism which decomposes the other compound. If the soil has been treated with a highly toxic chemical such as methyl bromide, the organisms which would normally decompose a less toxic herbicide may be killed. Decomposition would then be delayed until active species became re-established in the soil. This type of reaction may be beneficial or harmful depending upon the purpose of the treatment and the time during which the chemical remains active.

Effect of Concentration on Biodegradation

The degradation of both herbicides and natural organic substances may be greatly influenced by the concentrations of the substrates applied to the soil (25). In Chino loam, about 19, 37, and 65% of the carbon of *p*-hydroxycinnamic acid was released as CO_2 in 12 weeks at applied concentrations of 1, 10 and 1000 ppm, respectively. Similar values were noted for ferulic acid. At still higher concentrations a lag period may be required, but after degradation starts a greater percentage of CO_2 is released from the higher applications. Even with sugar, a concentration effect is noted. In Chino loam, loss of carbon from glucose varied from 47 to 83% in 12 weeks as the dosage increased from 1 to 50,000 ppm.

One might surmise that readily degradable herbicides such as 2,4-D, chlorpropham (isopropyl-*m*-chlorocarbanilate), and dalapon are mineralized at about the same rate as plant and microbial polysaccharides, plant leaves, and cereal straw. However, when one considers the concentration effect and the fact that herbicides are generally applied in very small amounts, one could conclude that they decompose at about the same rate as sugar. The more resistant herbicides, such as bromacil and atrazine, are mineralized at about the same rate as plant lignins, that is, about 15 to 30% of their carbon is released as CO_2 in one year. Only about 2 to 5% of soil humus is mineralized in one year.

Mechanisms of Decomposition

Microorganisms degrade herbicides and other pesticides in a manner similar to that or natural organic substances (8, 15). The specific mechanisms vary depending on the chemical structure of the compound and upon the particular organism or organisms involved. The reactions in the degradation pathways are carried out by numerous enzymes systhesized by the organisms. Some of the important reactions are as follows:

1. Oxidation of methyl carbons: Methyl, alchol, and aldhyde groups on the ends of aliphatic chains or attahced to aromatic rings are readily oxidized to carboxylic groups. An initial step in the degradation of propane or 2,4-dihydroxytoluene would be the oxidation of a methyl group to an alcohol by monoxygenases, further oxidations convert the alcohol to an aldehyde and then to a COOH group. Likewise the methyl group of the herbicides, MCPA ([(4-chloro-*o*-tolyl)oxy]acetic acid), and 2-methyl-4-chlorophenoxyacetic acid, is readily oxidized to the carboxylic acid group.

2. Beta oxidation: Long chain fatty acids are commonly degraded by the oxidation of the beta carbon with the splitting off of acetic acid units (36). This reaction involving an herbicide may be illustrated with 2,4-DB [4-(2,4-dichlorophenoxy)butyric acid]. An acetic acid unit is released from the aliphatic side chain with the formation of 2,4-D.

3. Demethoxylation: Methoxyl groups on benzene rings are readily removed or oxidized by microbial enzymes. The methoxyl group of ferulic and vanillic acids, which are partial degradation products of lignin, is quickly oxidized or utilized by numerous organisms with the formation of caffeic or protocatechic acids. Oxidation of the methoxyl group of dicamba yields 3,6-dichloro-2-hydrobenzoic acid.

4. Decarboxylation: 3,5-dihydroxybenzoic acid, a common product synthesized by soil fungi, is readily decarboxylated to form resorcinol. Likewise, numerous COOH groups attached to other aromatic rings or aliphatic chains may be removed by enzymatic action and released as CO_2. In a similar manner COOH groups of herbicides or their partail degradation products may be removed. An example is the decarboxylation of 3,6-dichloro-2-hydroxybezoic acid, a partial degradation product of dicamba, to form 2,5-dichorophenol.

5. Cleavage of ether linkages: Ether bonds may be broken to form small molecules. A good example of this is the splitting of the ether bond of 2,4-D to form 2,4-dichlorophenol and glyoxylic or acetic acid (Fig. 4).

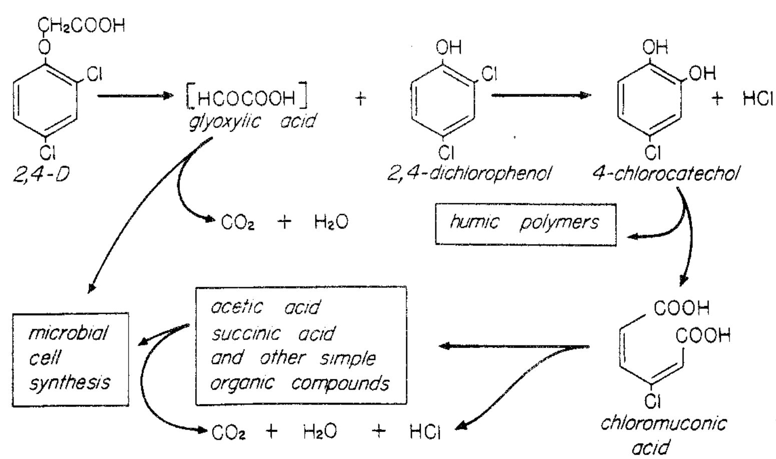


Figure 4. Biodegradation of 2,4-D by *Aspergillus niger*.

6. Hydrolysis of esters: Esterification involves the linkage of an acid and an alcohol through the removal of an OH and an H group to form water and the ester. Ester groups readily undergo enzymatic hydrolysis to form the original two compounds, for example, an ester of acetic acid and ethyl alcohol is hydrolyzed to from acetic acid and ethyl alcohol. The ester linkage in chlorpropham is cleaved to form isopropyl alcohol and an unstable acid which spontaneously degrades to 3-chloroanaline and CO_2.

7. Hydroxylation: Before microbial enzymes can cleave the benzene ring hydroxyl groups must be introduced. This is accoplished by monoxygenases. The hydroxyl groups may be introduced to almost any free position on the ring. Benzoic acid, for example, may have a hydroxy group introduced in the 4 position to form *p*-hydroxybenzoic acid which is readily hydroxylated to form protocatechuic acid. Another hydroxyl may be placed in the 5 or 2 positions to form gallic or 2,3,4-trihydroxybenzoic acid. Likewise, hydroxyl groups may be introduced to the benzene ring of herbicides before or after the removal of side groups. An example is monuron [3-(*p*-chlorophenyl)-1,1-dimethylurea], a substituted urea herbicide. A hydroxyl group may be introduced to the ring of the intact molecule or the side chain may be degraded to form an aliphatic acid or alcohol, NH_3, CO_2, and chloroanaline and the hydroxyl groups may then be introduced in to chloroanaline degradation compound.

8. Aromatic ring cleavage: Benzene rings are cleaved my microbial dioxygenases after at least two hydroxyl groups have been added to the rings (12). Generally cleavage occurs between two adjacent hydroxyls or next to one of the hydroxyls. This forms aliphatic chain compounds, commonly muconic acids, which are further metabolized to smaller organic acids which are utilized for cell synthesis or for energy with the release of CO_2 and water.

The pathway for degradation of condensed ring structures such as naphthalenes and anthracene derivatives involves hydroxylation, cleavage of one of the rings, oxidative degradation of the side chains formed and possibly decarboxylation. The process may then be repeated on another ring.

9. Deamination: Usually nitrogen is released from organic compounds as ammonia by oxidative or reductive deamination. Oxidative deamination of alanine will yield pyruvic acid and ammonia. Reductive degradation will yield propionic acid and ammonia. Deamination of the substituted urea herbicide, diuron, after removal of the alkyl groups yields an alanine, ammonia and CO_2.

10. Dehalogenation: Halogens are generally replaced by hydroxyl or H groups at various stages of the biodegradation of chlorinated hydrocarbons (6, 15). 3-Bromopropionic acid may be dehalogenated to form 3-hydroxypropionic acid and HBr. Dalapon is dehalogenated to form pyruvic acid. Presumably the halogens are replaced with hydroxyl groups and water is split off leaving the O atom at the 2 position. Fumigants are sometimes used as herbicides. The release of inorganic Cl^- from the fumigant D-D, a dichloropropene-dichloropropane mixture, closely resembles a typical microbial growth curve with an initial lag phase.

If sulfur is present in an organic compound it will be released as hydrogen sulfide or sulfate during the biodegradation process. Phosphorus is released as phosphate.

Most of the studies on the biodegradation of pesticides have been made in pure cultures in the laboratories. Some of the processes in the natural soil where numerous species are present may be different. For example, some species are capable of utilizing side chains of aromatic compounds and of the incorporation of hydroxyls on the benzene rings but cannot cleave the ring. The partially degraded and altered molecules would therefore be released into the soil and other species would continue the degradation process.

Also in pure culture most organisms may not be able to metabolize a resistant herbicide, but in the soil it may be slowly degraded by cometabolism. This would be similar to lignin biodegradation. Most soil forms do not readily degrade pure lignin but if another source of carbon is available such as cellulose, the lignin is degraded by numerous organisms (18).

Another difference is the amount of partail degradation products which are stabilized in polymers. If the pure culture does not synthesize phenolic polymers, as do the melanin fungi, and other resistant organic substances up to 70% or more of the carbon may eventually be released as CO_2. In the soil, a portion of the ring carbons may be stabilized by the linkage of the ring moieties into the soil humus (24, 29). This reaction can be illustrated with catechol and chlorocatechols which are partial degradation products of 2,4-D and other herbicides. They are readily degraded in pure culture but in soil only 10 to 30% of the carbon is readily released as CO_2 as most of the ring structures are quickly incorporated into the humus molecules.

Incorporation into Soil Humus

As previously indicated, herbicides and other organic molecules or their partial degradation products are not completely decomposed to CO_2, H_2O, NH_3, H_2S, $SO_4^{=}$, Cl^- or $PO_4^{\equiv}$. The organisms utilize a portion of the carbon and other elements for the synthesis of cells and products, and some of the intermediate compounds or compounds of synthesis are stabilized by linkage into the beneficial soil humus. The main constituent of humus, humic acid, appears to be a phenolic polymer with linked peptides, amino acids, amino sugar polymers, and other aromatic compounds such as naphthalenic and antracene derivitives (10, 11, 33).

Plant lignins and microbial synthesis or aromatic compounds are important sources of these phenolic units (11, 38). Both plant derived and microbial phenolic compounds may be altered by oxidation of side chains, additions of hydroxyl groups, decarboxylation and other reactions to form numerous phenolic compounds (Fig. 5). When two adjacent hydroxyls are present the ring may be cleaved (8), but at this stage the compounds are highly active and a certain percentage of the molecules will be polymerized or linked into the existing humus through the action of phenolase or peroxidase enzymes present in the soil or produced by soil organisms or by autoxidative mechanisms. Amino acids, peptides and amino sugar compounds may be linked into the polymers through any free NH_2 or SH groups present on the compounds (Fig. 6). Peptides link much more readily than individual amino acids.

Catechols or chlorocatechols are intermediate degradation products of many of the herbicides containing ring structures. These catechols readily link into humic acid polymers (Fig. 7). Studies underway by Diane Stott at the University of California at Riverside indicate that 80 to 90% of chlorocatechols present in model polymer reaction mixtures containing peroxidase as the catalyst are linked into the model humic acids formed. Chlorocatechols linked into humic acid type model polymers decompose just as rapidly as linked catechol. The relative amounts of a variety of organic compounds recovered in model humic compounds are presented in Table 3.

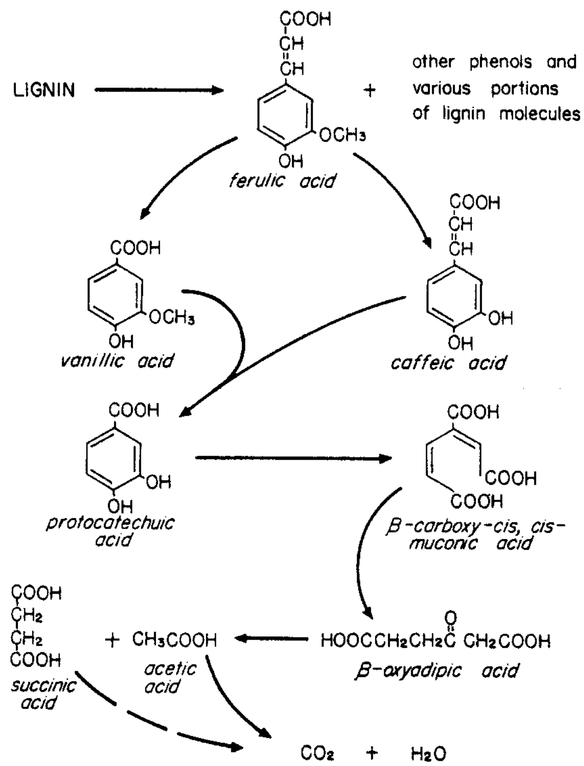


Figure 5. A mechanism for the biodegradation of lignin through ferulic acid, a partial degradation compound.

In a study by D. C. Wolf and J. P. Martin (38), melanic fungi were shown to inporporate significant amounts of the benzene ring portion of the herbicides 2,4-D and chlorpropham into relatively resistant humic acid type polymers (melanins) that they formed, while the side chain carbons were utilized for synthesis of general cell components which were readily degraded by soil microorganisms.

After ring cleavage some of the carbon of the simple aliphatic compounds formed could be incorporated into microbial polysaccharides which contribute to the polysaccharide fraction of soil humus. A scheme summarizing the reaction of natural and pesticidal organic molecules including partial and complete degradation, resynthesis and polymerization mechanisms is presented in Figure 8. The center square at the left should read "plant and microbial peptides and polysaccharides containing amino sugar units."

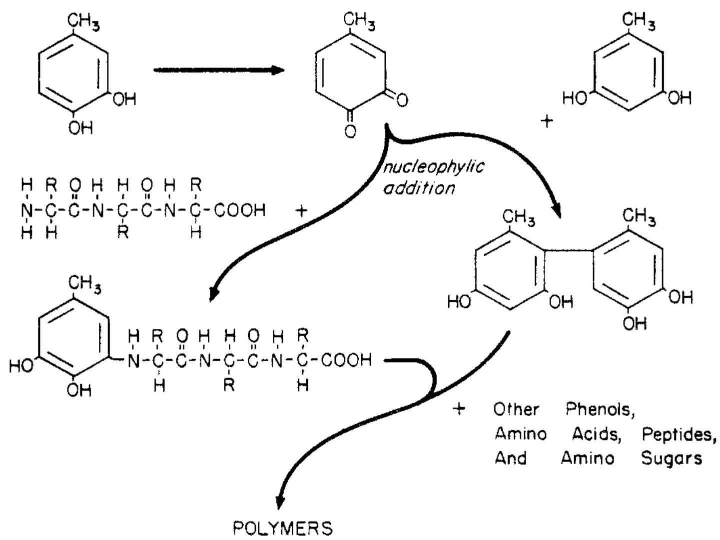


Figure 6. A mechanism for the enzymatic linkage of peptides into humic acid polymers.

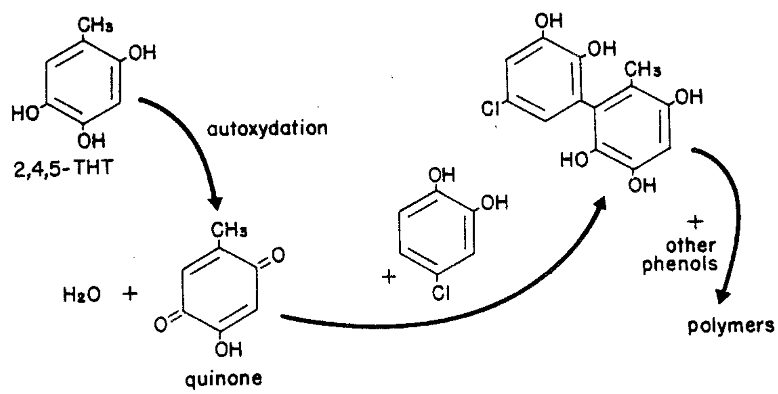


Figure 7. A mechanism for the autoxidative linkage of 4-chlorocatechol into humic acid polymers. Linkage could also occur through enzymatic oxidation of di-or-tri-hydroxy phenols including chlorocatechols to quinones or to radicals.

Table 3. Approximate amounts of various natural and synthetic compounds and partial degradation products linking into model peroxidase humic acid polymers.

Unit	Percentage in polymer[1]
Protein	99
Catechol	96
4-Chlorocatechol	93
4,5-Dichlorocatechol	80
Ferulic acid	75
Cysteine	63
Tyrosine	40
Lysine	34
Glucosamine	28
Glycine	23
2-Thiouracil	5
Cytosine	4
5-Bromouracil	2
Uracil	2
Cyanuric acid	0
2,4-D	0

[1]Percentage of compound in reactive mixture recovered in humic polymers (26 and unreported data).

Linkage into Humus and Future Environmental Contamination Considerations

Recently several investigators have expressed a concern that pesticide residues or toxic partial decomposition products could be stabilized in soil humus and at a later date could be released, be adsorbed by soil organisms and plants, and thereby present a serious environmental contamination problem (3). Such a phenomenon would be extremely unlikely. It should be stressed first that toxic compounds have been linked into humic molecules since humus was first formed on the earth. As briefly mentioned previously, these compounds include phenols, naphthalenes, anthracene derivatives, and other toxic substances. Soil organisms and plants also synthesize chlorinated hydrocarbons such as the fungal toxins grisefulvum, islanditoxin, and ochratoxin (7). The latter contains a chlorinated phenol component. During the linkage of amino acids into humic acid molecules analine structures may be formed. The linkage of toxic compounds into soil humus can more logically be viewed as a detoxication process.

A second important consideration is that during the microbial degradation of humic polymers the original toxic compounds may not be released. If ring structures are involved the ring could be cleaved while the compound is still linked to the polymer and the side chains could be degraded

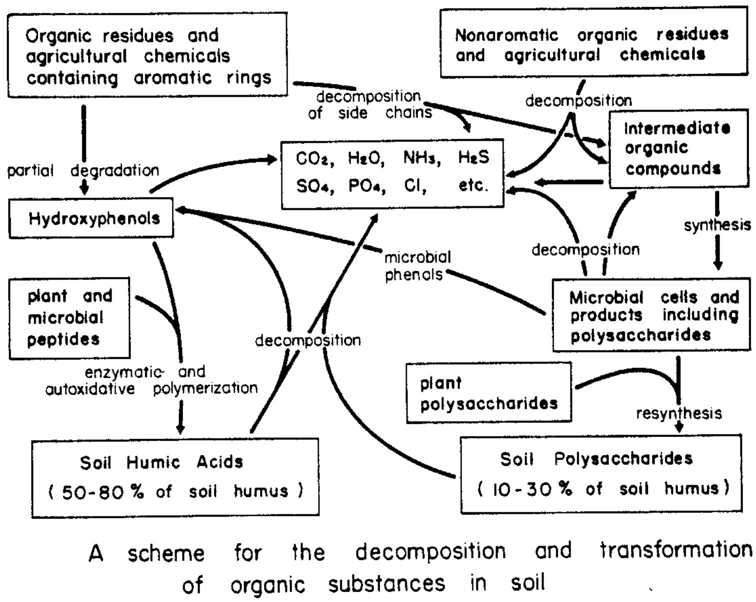


Figure 8. A scheme for the decomposition and transformation of organic substances in soil.

by oxidation and decarboxylation reactions. If the compound is released in its original form it is immediately subject to microbial degradation or repolymerization mechanisms.

A third point is that the natural toxic compounds linked into humus have not caused a toxic condition in the soil as they are slowly released or degraded, nor is there any evidence that toxic components of pesticide molecules linked into humus have been released and contaminated the soil environment, soil organisms, or plants, during the 40 years of extensive use.

Summary

Organic herbicides are utilized or partly utilized as a carbon and energy source by one or more organisms or are degraded by cometabolism reactions. The mechanisms are similar to or the same as those involved in the degradation of the infinitely large numbers of organic compounds synthesized by plants, animals, and microorganisms. Portions of the altered or partially degraded herbicide molecules may be utilized for microbial cell synthesis, may be incorporated into the beneficial soil humus, or may be stabilized by physiochemical interactions with inorganic soil colloids

and metal ions. As with natural toxic compounds the linkage into the beneficial soil humus as well as the degradation to inocuous products, can best be viewed as a detoxication process. It is important to know how each new herbicide reacts in the soil. With proper and intelligent use, repeated applications of herbicides will not make our soils sterile or infertile.

Literature Cited

1. Angle, J. S. and G. H. Wagner. 1980. Decomposition of aflatoxin in soil. Soil Sci. Soc. Amer. J. 44:1237-1240.
2. Audus, L. J. 1976. Herbicides: Physiology, Biochemistry, Ecology. Vol. 2. Academic Press. New York
3. Bartha, R. 1980. Pesticide residues in humus. ASM News. 46:356-360.
4. Bollen, W. B. 1961. Interactions between pesticides and soil microorganism. Ann. Rev. Microbiol. 15:69-92.
5. Brown, A. W. A. 1978. Ecology of Pesticides. John Wiley and Sons. New York.
6. Castro, C. E. and N. O. Belser. 1968. Biodehalogenation: Reductive dehalogenation of the biocides ethylene dibromide, 1,2-dibromo-3-chloropropane and 2,3-dibromobutane in soil. Environ. Sci. Tech. 2:779-783.
7. Ciegler, A., S. Kadis, and S. J. Ajl (Eds.). 1971. Microbial Toxins. Vol. 6: Fungal Toxins. Academic Press. New York.
8. Dagley, S. 1967. The microbial metabolism of phenolics. *In* McLaren, A. D. and G. H. Peterson (Eds.) Soil Biochemistry. Marcel Dekker, Inc. New York.
9. Day, B. E., L. S. Jordan, and R. T. Hendrixson. 1961. The decomposition of amitrole in California soils. Weeds 9:443-456.
10. Flaig, W., H. Beutelspacher, and E. Rietz. 1975. Chemical composition and properties of humic substances. *In* Gieselking, J. E. (Ed.), Soil Components, Vol. 1, Organic Components. Springer-Verlag, New York.
11. Haider, K, J. P. Martin, and Z. Filip. 1975. Humus biochemistry. *In* Paul, E. A. and A. D. McLaren (Eds.), Soil Biochemistry. Vol 4, pp. 195-244. Marcel Dekker, Inc. New York.
12. Hayaishe, O. and M. Nozaki. 1969. Nature and mechanisms of oxygenases. Science 164:389-395.
13. Hill, I. R. and S. J. L. Wright (Eds.). 1978. Pesticide Microbiology. Academic Press. New York.
14. Jenkinson, D. S. 1971. Studies on the decomposition of ^{14}C-labeled organic matter in soil. Soil Sci. 11-64-70.
15. Kaufman, D. D. 1974. Degradation of pesticides by soil microorganisms. *In* Guenzi, W. D. (Ed.), Pesticides in Soil and Water. Soil Sci. Soc. Amer., Madison, Wisconsin.
16. Kearney, P. C., D. C. Kaufman, and M. Alexander. 1967. Biochemistry of herbicide decomposition in soils. *In* McLaren, A. D. and G. H. Peterson (Eds.), Soil Biochemistry. Marcel Dekker, Inc. New York.

17. Kearney, P. C. and D. D. Kaufman (Eds.). 1975. Herbicides: Chemistry, Degradation, and Mode of Action. Vol. 1 and 2. Marcel Dekker, Inc. New York.

18. Kirk, T. K., T. Higuchi, and H. Chang (Eds.). 1980. Lignin Biodegradation: Microbiology, Chemistry, and Potential Applications. Vols. I and II. CRC Press, Boca Raton, Florida.

19. Martin, J. P. 1946. The hormone weed killer, 2,4,-D. Calif. Citrog. 31:248, 264-265.

20. Martin, J. P. 1963. The influence of pesticide residues on soil microbiological and chemical properties. Res. Rev. 4:96-129.

21. Martin, J. P. 1972. Side effects of organic chemicals on soil properties and plant growth. *In* Goring, C. A. I. and J. Hamaker (Eds.), Organic Chemicals in the Soil Environment. Vol. II. pp. 733-792. Marcel Dekker, Inc. New York.

22. Martin, J. P. and D. Focht. 1977. Biological properties of soils. *In*: Soils for Management of Organic Wastes and Waste Waters. Amer. Soc. Agron., Madison, Wisconsin.

23. Martin, J. P. and K. Haider. 1971. Microbial activity in relation to soil humus formation. Soil Sci. 111:54-63.

24. Martin, J. P. and K. Haider. 1976. Decomposition of specifically carbon-14-labeled ferulic acid: Free and linked into model humic acid-type compounds. Soil Sci. Soc. Amer. J. 40:377-380.

25. Martin, J. P. and K, Haider. 1979. Effect of concentration on decomposition of some ^{14}C-labeled phenolic compounds, benzoic acid, glucose, cellulose, wheat straw and *Chlorella* protein in soil. Soil Sci. Soc. Amer. J. 43:917-920.

26. Martin, J. P. and K. Haider. 1980. A comparison of the use of phenolase and peroxidase for the synthesis of model humic acid-type polymers. Soil. Sci. Soc. Amer. J. 44:983-988.

27. Martin, J. P., K. Haider, and G. Kassim. 1980. Biodegradation and stabilization after 2 years of specific crop, lignin, and polysaccharide carbons in soil. Soil Sci. Soc. Amer. J. 44:1250-1255.

28. Martin, J. P., K. Haider, W. J. Farmer, and E. Fustec-Mathon. 1974. Decomposition and distribution of residual activity of some microbial polysaccharides and cell, glucose, and wheat straw in soil. Soil Biol. Biochem. 6:221-230.

29. Martin, J. P., K. Haider, and L. F. Linhares. 1979. Decomposition and stabilization of ring-^{14}C-labeled catechol in soil. Soil Sci. Soc. Amer. J. 43:100-104.

30. Miller, M. W. 1961. The Pfizer Handbook of Microbial Metabolites. McGraw-Hill Book Co., Inc., New York.

31. Saiz-Jimenez, C., K. Haider, and J. P. Martin. 1975. Anthraquinones and phenols as intermediates in the formation of dark-colored humic acid-like pigments by *Eurotium echinulatum*. Soil Sci. Soc. Amer. Proc. 39:649-653.

32. Sauerbeck, D. and M. A. Gonzalez. 1977. Field decomposition of carbon-14-labeled plant residues in various soils of the Federal Republic of Germany and Costa Rica. *In*: Soil Organic Matter Studies,

Vol. I. Int. Atomic Energy Agency, Vienna.

33. Schnitzer, M. 1977. Recent findings on the characterization of humic substances extracted from soils from widely differing climatic zones. *In*: Soil Organic Matter Studies, Vol II, pp. 117-130. IAEA, Vienna.

34. Stevenson, F. J. 1972. Organic matter reactions involving herbicides in soil. J. Environ. Qual. 1:333-343.

35. Wagner, G. H. 1974. Microbial growth and carbon turnover. *In*: Paul, E. A. and A. D. McLaren (Eds.), Soil Biochemistry, Vol. 3, Chapter 6. Marcel Dekker, New York.

36. Webley, D. M., R. B. Duff, and V. C. Farmer. 1958. The influence of chemical structure on β-oxidation by soil nocarias. J. Gen. Microbiol. 18:733-746.

37. Wolf, D. C. and J. P. Martin. 1975. Microbial degradation of 2-carbon-14 bromacil and terbacil. Soil Sci. Soc. Amer. Proc. 38:921-925.

38. Wolf, D. C. and J. P. Martin. 1976. Decomposition of fungal mycelia and humic-type polymers containing carbon^{14} from ring and sidechain labeled 2,4-D and chlorpropham. Soil Sci. Soc. Amer. J. 40:700-704.

R-33865 - HERBICIDE EXTENDER FOR THIOCARBAMATE HERBICIDES

C. L. Prochnow[1]

Persistence of any soil-active herbicide is dependent on its volatility, leaching, soil adsorption, and degradation by microorganisms. The latter is one of the major pathways for removal of a herbicide from the soil environment. It is very important that a herbicide biodegrade so it can be eliminated from the soil environment after it has accomplished its task.

There are a number of factors which determine the microbial rate of breakdown on a compound. Soil type, organic matter, nutrients, moisture, types of soil microorganisms, pH, sunlight, and temperature all have an impact.

The half-life of the thiocarbamate herbicides depends upon those chemical and physical properties which influence the ease with which they biodegrade. The half-life of EPTC (*S*-ethyl dipropylthiocarbamate) is approximately 1 to 1-1/2 weeks in the greenhouse, in moist soil at temperatures of 20 to 32°C, i.e. where conditions are favorable for microbial degradation.

Compounds such as captan [*N*-(trichloromethyl)-4-cyclohexene-1,2-dicarboximide], metham (sodium methyldithiocarbamate), fonofos (*O*-ethyl *S*-phenyl ethylphosphonodithioate), diazinon [*O*,*O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl)phosphorothiote], and potassium azide have been observed to reduce the microbial metabolism or biodegradation of herbicides (1). Similar compounds have been tank mixed with the thiocarbamates in an attempt to alter soil microbial breakdown. Several such materials have given a positive response. Some of these "extenders" have provided 1 to 2 weeks' additional residual control. However, high application

[1]Stauffer Chemical Company

rates are required.

A few years ago, midwest soils were sampled where residual weed control seemed to be shorter than normal. These soils were taken from fields where there was a history of Eradicane [commercial mixture of EPTC + R-25788 (*N*,*N*-diallyl-2,2-dichloroacetamide)] use and where the degree of weed control seemed to decrease with repeated use. Laboratory studies with these soils showed Eradicane to have a half-life of less than a week. In research conducted by Stauffer Chemical Company it was determined that when R-33865 was added, the Eradicane half-life was increased in these soils to a more normal laboratory level of 1 to 1-1/2 weeks. This corresponds to the normal Eradicane residual of 2-4 weeks under field conditions. In other soils, Eradicane in combination with R-33865 has shown extended weed control of 1 to 2 weeks beyond that of Eradicane alone.

Laboratory studies on isolated fungal cultures that are able to degrade EPTC show that R-33865 will delay the degradation of EPTC. Interestingly, R-33865 does not affect the growth of the fungi.

It is known at this time that R-33865 selectively inhibits enzyme systems of certain fungi which are responsible for rapid degradation of EPTC. The inhibition is not total nor does it affect the overall ability of the microorganisms to survive in the presence of additional nutrient sources. When the level of R-33865 drops to a point where it no longer modifies the enzymatic pathway, the fungus is again able to use EPTC as one of its substrates. This inhibition adds 1 to 2 weeks' residual activity to the herbicides.

Biodegradation of herbicides by soil microorganisms is desirable and is optimal when the rate of degradation is consistent with the duration of weed control required. R-33865 presents a new approach to enhanced herbicidal effectiveness by providing a way to control the rate of thiocarbamate degradation by soil microorganisms.

Literature Cited

1. Kaufman, D. D. 1976. Biodegradation and persistence of several acetamide, acylanilide, azide, carbamate and organophosphate pesticide combinations. Soil Biol. Biochem. 9:49-57.

EXTENDER STUDIES WITH THIOCARBAMATES IN PROBLEM SOILS IN OREGON

A. P. Appleby, B. D. Brewster, Q. C. Coleman, and D. McAuliffe[1]

Abstract. Growers in western Oregon who have used EPTC (*S*-ethyl dipropylthiocarbamate) for a number of years to control yellow nutsedge (*Cyperus esculentus* L.) and a variety of annual and perennial grasses in vegetable crops, have found that the effectiveness of EPTC has diminished considerably in recent years. This is particularly noticed with yellow nutsedge whose tubers do not sprout during the season until after EPTC has disappeared. The reason for this reduced effectiveness is believed to be due to a build-up of microbes capable of degrading EPTC very rapidly. Studies

[1]Professor, Senior Instructor, Graduate Research Assistant, and Graduate Research Assistant, respectively, Crop Science Department, Oregon State University, Corvallis OR 97331.

in 1979, in two "problem" soils and a non-problem soil, indicated that the addition of extender R-33865 in various ratios with EPTC can delay the degeneration of EPTC significantly. In the non-problem soil, this resulted in unacceptable injury to sweet corn. The substitution of a more effective safener might prevent such injury. Results from 1979 greenhouse studies were puzzling. EPTC, as measured by chemical analysis, disappeared rapidly from both problem soils and the non-problem soil. The extender combinations were only slightly effective at slowing this rapid decrease. Autoclaving was completely ineffective at preventing EPTC degradation and potassium azide at 500 ppm was only slightly effective. In 1980 field studies, the extender R-33865 was more effective than PPG-124 in preventing EPTC loss. Pre-treatment with methyl bromide slowed the breakdown of EPTC significantly. EPTC alone was providing less than 20% control of oats seeded 2 weeks following treatment. When mixed with R-33865 at 0.5 lb/A in soils that had received a methyl bromide treatment, oats were being controlled at 93%, even 6 weeks following EPTC treatment. These field studies indicate that EPTC is rapidly broken down in certain problem soils due to the action of microbes and that microbial inhibitors, especially R-33865, can increase EPTC presistence.

MICROBIAL INHIBITOR EXTENDS ACTIVITY OF CHLORPROPHAM IN SOIL

J. H. Dawson[1]

Chlorpropham (isopropyl *m*-chlorocarbanilate) controls dodder (*Cuscuta* spp.) in alfalfa (*Medicago sativa* L.). The total value of chlorpropham for dodder control is reduced because the herbicidal activity of chlorpropham is short-lived in soil. Applied at 6.7 kg/ha in early spring, chlorpropham usually controls dodder for about 4 weeks. For effective full-season control in alfalfa seed fields in the Pacific Northwest, dodder must be controlled for a period of about 4 months.

Microbial decomposition and volatility are primarily responsible for the short residual life of chlorpropham in the soil. The nonphytotoxic compound, PCMC (*p*-chlorophenyl-*n*-methylcarbamate), protects chlorpropham from microbial decomposition. Research in the field and greenhouse has shown that the period of dodder control from chlorpropham can be extended by applying PCMC with the herbicide.

In the greenhouse, chlorpropham alone at 6.7 kg/ha controlled dodder for about 4 weeks. The same rate of chlorpropham plus PCMC at 1.7 kg/ha controlled dodder for 8 or 9 weeks.

In Washington, chlorpropham is commonly applied for dodder control in mid-April. In field studies, chlorpropham was applied with and without PCMC at this time, as well as 1 month earlier. Irrigation water was so manipulated that dodder emerged in two separate and distinct flushes. By measuring dodder control separately in the two flushes, it was possible to determine the period of control provided by chlorpropham treatments. Dodder control was considered satisfactory when attachment to host plants was reduced by 95 to 100%.

Chlorpropham alone at 6.7 kg/ha applied in mid-April consistently

[1]Research Agronomist, Agric. Res., Sci. and Educ. Admin., U.S. Dept. of Agric., Irrigated Agriculture Research and Extension Center, Prosser, WA 99350.

controlled the first flush of dodder satisfactorily. When applied in mid-March, chlorpropham alone often had dissipated to the extent that it did not control the first flush of dodder. Chlorpropham alone never controlled the second flush of dodder satisfactorily, whether applied in mid-April or mid-March. In contrast, chlorpropham plus PCMC applied either in mid-April or mid-March controlled both flushes of dodder satisfactorily is almost all instances.

In one greenhouse experiment, the PCMC was combined with chlorpropham in a controlled release formulation. In this experiment, chlorpropham alone at 6.7 kg/ha controlled dodder for only 3 weeks. When it was combined with PCMC or formulated alone within microcapsules, the period of dodder control was extended to 5 weeks. When both the herbicide and the PCMC were formulated together within the microcapsules, the period of dodder control was extended to 11 weeks.

The microbial inhibitor consistently extended the period of dodder control from chlorpropham. The possibility exists of prolonging the period of control still more by formulating the herbicide and the microbial inhibitor together in a controlled release formulation.

COMMON CRUPINA - A PROBLEM WEED IN IDAHO RANGELANDS

D. L. Kambitsch, D. C. Thill, G. A. Lee, and T. L. Miller[1]

Abstract. Common crupina (*Crupina vulgaris* Cass.), an introduced species from the Mediterranean region of Europe, was first reported in North America in 1968 near Grangeville, Idaho. Common crupina, a broadleaf winter annual, is a member of the Compositae family. The seed germinates in the fall and overwinters as a basal rosette. In the spring, the plant will resume active growth and bolts when the day length reaches 12 to 16 hours. Flowering occurs 4 to 6 weeks after bolting with an everage plant producing approximately 130 seeds. The seeds are large, cylindrical, and silvery fawn to black in color. Around the basal end of the seed are dark, stiff, hair-like structures (pappus) approximately 0.64 cm in length. Dissemination is usually by animals and flowing water. It is associated with moderate to steep canyons, well drained rocky to silt loam soils, and is found at elevations ranging from 363 to 1060 m in regions with an average rainfall of 38 to 76 cm annually. An intensive aerial and ground survey was conducted in 1980 in northern Idaho to determine exact boundaries and detect all localized common crupina infestations within these boundaries. From the information that was collected from the survey, it was determined that common cuprina now infests approximately 8000 ha. of rangelands. Common crupina is very competitive, producing massive stands which can reduce forage production and range carrying capacity. Cattle will graze on common crupina only where solid stands occur. However, the nutritive value and livestock toxicity of the weed are not yet know, which makes this weed a potential threat to the livestock industry throughout the western United States. Detailed tests are being conducted to determine the efficacy of various herbicides on the control of common crupina. The herbicides being tested include: glyphosate [*N*-(phosphonomethyl)glycine], dicamba

[1]Department of Plant and Soil Sciences, University of Idaho, Moscow, ID 83843.

(3,6-dichloro-*o*-anisic acid), 2,4-D amine [(2,4-dichlorophenoxy)acetic acid], picloram (4-amino-3,4,6-trichloropicolinic acid), DPX-4189 {2-chloro-*N*-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)aminocarbonyl]-benzene sulfonamide}, and combinations of 2,4-D amine and picloram. To date, 2,4-D at 2.24 kg ai/ha and picloram at 0.28 kg ai/ha are providing the best control under rangeland conditions.

THE USE OF GLYPHOSATE FOR FOREST RENOVATION IN THE PACIFIC NORTHWEST

Darlene M. Frye[1]

Since 1978, the commercial formulation of isopropylamine (IPA) salt of glyphosate [*N*-(phosphonomethyl)glycine] has been used commercially in forest renovation projects west of the crest of the Cascade Mountains in Oregon and Washington under state registration. When fall-applied at a rate of 1.13 lb ae/A for conifer release, IPA glyphosate controls cascara (*Rhamnus purshiana*), elderberry (*Sambucus* spp.), hazel (*Corylus cornuta*), salmonberry (*Rubus spectabolis*), snowberry (*Symphoricarpos* spp.), and thimbleberry (*Rubus parviflorus*). IPA glyphosate applied at a rate of 0.75 lb ae/A no later than two weeks prior to bud burst of the conifers in the spring controls the labeled, annual grasses and broadleaved weeds and supresses some of the perennial weeds. For site preparation, applications made three to four weeks prior to leaf abscission of deciduous brush species produces best results although applications may be made as early as eight weeks prior to leaf abscission. Cherry (*Prunus* spp.), himalayan blackberry (*Rubus thyrsanthus*), and vine maple (*Acer circinatum*) are controlled by 1.50 lb ae/A IPA glyphosate while alder (*Alnus* spp.), brackenfern (*Pteridium aquilinum*), swordfern (*Polystichum munitum*), and evergreen blackberry (*Rubus laciniatus*) are controlled by 2.25 to 3.00 lb ae/A. Sprouted bigleaf maple (*Acer macrophyllum*) stumps are effectively controlled with a 1.00% v/v IPA glyphosate solution sprayed-to-wet as a spot treatment.

During 1977 to 1979, the performance of IPA glyphosate was evaluated for brush control and conifer safety in the eastern portions of the Pacific Northwest under an Experimental Use Permit. A total of 26 large plot and eight small plot trials were established between site preparation and conifer release locations. IPA glyphosate rates of 0.75 to 3.00 lb ae/A were evaluated for both conifer release and site preparation. Safety to Douglas fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), ponderosa pine (*Pinus ponderosa*), and western white pine (*Pinus monticola*) was maintained at a conifer release rate of 1.50 lb ae/A IPA glyphosate. In addition to the brush and weed species mentioned as being controlled by 1.50 lb ae/A IPA plyphosate, elk sedge (*Carex geyeri*), Klamath plum (*Prunus subcordata*), oceanspray (*Holodiscus discolor*), pinegrass (*Calamagrostis rubescens*), and redstem Ceanothus (*Ceanothus sanguineus*) were also controlled.

With the approval of the federal silviculture site label for IPA glyphosate, the first commercial applications east of the crest of the Cascade Mountains began in the fall of 1980.

[1]Product Development Representative II, Monsanto Company, Yakima, WA 98908

CONTROL OF WOODY PLANTS WITH TEBUTHIURON BY WAY OF LOCALIZED PLACEMENT TECHNIQUES

Donald H. Ford[1]

Tebuthiuron {*N*-[5-(1,1-dimethylethyl)-1,3,4-thialdizol-2-yl]-*N*,*N*'-dimethylurea}, a soil applied, non-selected substituted urea herbicide, is registered and marketed under the trade name, Spike, for total vegetation control on noncropland. Formulations of tebuthiuron currently available include a 80% wettable powder, 1% and 5% granules, and 10% and 20% pellets.

Toxicology

Although tebuthiuron is a highly active herbicide, extensive studies on laboratory animals and wildlife species, including mammals, birds, and fish, have shown that it possesses a low order of toxicity. The compound is rapidly absorbed and metabolized by animals with no significant binding in the tissues. In recommended use situations, tebuthiuron is safe to users, applicators, and the environment.

Control of Woody Plants

When broadcast applied to noncropland for total vegetation control, tebuthiuron at rates of 2 to 5 pounds per acre have demonstrated effective control of a wide variety of woody plants. However, in noncrop situations where control of specific woody plants is desired, but injury to herbaceous and woody understory species is not acceptable, more efficient methods had to be developed for localized application of tebuthiuron to target species.

Two procedures have been used successfully to concentrate the herbicide in the vicinity of woody plants with minimal damage to understory species. These include the application of tebuthiuron as spot treatments at the base of target plants and the placement of regularly spaced parallel bands of concentrated chemical on sites to be cleared of woody vegetation.

Spot Treatments

Tebuthiuron spot treatments may be made at the base of target trees will small quantities of the granule or pellet formulations applied from a delivery container of known volume. Treatment of individual woody species may also be accomplished with the tebuthiuron wettable powder formulation suspended in water and delivered to the base of the target plant by means of a back pack sprayer or spot gun fitted with a suitable straight stream nozzle. In cases where larger trees are to be controlled by means of spot treatment, concentrated tebuthiuron may need to be placed at two or more locations around the perimeter of the tree trunk.

In research conducted in California, Oregon, and Washington, tebuthiuron spot treatments at 1 to 5 grams per plant have provided 95 to 100% control of the woody species shown in Table 1 following a 6 to 12 month exposure period and 5 to 45 inches of rainfall.

Tebuthiuron spot applications at 15 to 20 grams per tree were required for effective kill of the woody plants shown in Table 2 over a period of 12 to 24 months with 25 to 75 inches of rainfall.

Tebuthiuron, applied at 2 to 5 pounds per acre concentrated in parallel bands spaced 4 to 10 feet apart, has performed well in controlling unwanted woody plants on terrain accessible to spray equipment. This method of of application is becoming popular in the East and Midwest where

[1]Research Advisor, Lilly Research Laboratories, Fresno, CA 93706

Table 1. Woody species controlled (95 to 100%) with tebuthiuron at 1 to 5 grams per tree 6 to 12 months after application.

Douglas Fir (*Pseudotsuga menziesii*)
Western Hemlock (*Tsuga heterophylla*)
Red Alder (*Alnus rubra*)

Table 2. Woody plants controlled (95 to 100%) with tebuthiuron at 15 to 20 grams per tree 12 to 24 months after application.

Sitka Spruce (*Picea sitchensis*)
Coast Redwood (*Sequoia sempervirens*)
Bigleaf Maple (*Acer macrophyllum*)
Madrone (*Arbutus menziesii*)

a high population of herbaceous vegetation exists on the sites to be cleared of woody species.

Spacing of the tebuthiuron-treated bands is based on the size of woody species on the treatment site and the degree of injury to understory herbacous vegetation that can be tolerated. In cases where target species are small or have limited lateral root development, closely spaced bands are most effective; whereas, on sites where more mature woody species are to be controlled, wider spaced bands may be utilized. Within the treated area, virtually all vegetation is killed back and plants adjacent to the band may be severly injured. However, since herbaceous species tend to possess restricted root systems, most species outside the treated band are not permanently damaged.

Parallel band application of tebuthiuron may be accomplished with both self-propelled and hand sprayers fitted with straight stream nozzles. Under windy conditions, the addition of drift control agents is often required to insure delivery of intact spray streams to the soil surface.

Factors Affecting Efficacy on Tebuthiuron

Tebuthiuron, like many other soil-applied herbicides, is relatively slow to kill woody plants when compared with widely used foliar-applied brush control agents. Since the chemical must be absorbed by plant roots before herbicidal activity is manifested, several factors are important in determining its efficacy against woody species including: 1. Amount and frequency of rainfall, 2. Soil texture and organic matter (CEC), and 3. Concentration of the herbicide.

Tebuthiuron requires repeated significant rainfall before it is moved deep enough in soil to be herbicidally active against established woody species. In general, minimum rainfall in the range of 4 to 6 inches is needed to achieve acceptable results on a medium textured soil over an exposure time of 12 to 18 months under western conditions.

Since tebuthiuron is readily adsorbed on soil colloids, its mobility is greatest in soils with low organic matter and low clay content. When applied to fine textured or high organic soils, movement of the herbicide in the soil profile is reduced significantly resulting in slower kill of target plants. The cation exchange capacity of a soil is the best indicator of the rate of tebuthiuron required for control of a given plant species.

By increasing the concentration of tebuthiuron through the use of localized spot or band applications, movement of the herbicide in the soil is enhanced and more rapid kill of woody plants can be achieved.

Summary

In summary, tebuthiuron has demonstrated excellent potential for control of undesirable woody vegetation on noncropland and rangeland sites. Localized application of concentrated herbicide in the form of spot or parallel band treatments has shown several advantages over broadcast applications including: selective control of unwanted woody plants, reduced injury to desirable herbaceous and woody understory species, more efficient use of the herbicide, and reduced exposure of the environment to the herbicide.

BASAL TREATMENT OF WOODY PLANTS WITH TRICLOPYR

P. M. Ritty[1]

There are many advantages in using basal sprays to control unwanted woody plants on rights-of-way and in forests. Usually a higher percentage of plant kill can be expected from basal applications of herbicides than from foliage applications. Direction of spray toward the lower portions of individual plants results in less danger to herbicide drift to susceptible broadleaf crops. The greatest advantage of basal sprays is that they can be applied effectively anytime during the year.

The availability of herbicides, which are effective as basal sprays, has been limited. The most commonly used was 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid] prior to its suspension by the Environmental Protection Agency. The most effective was a mixture of 2,4,5-T and picloram (4-amino-3,5,6-trichloropicolinic acid). Tordon 155 Mixture Herbicide contains 1 lb ai of picloram and 4 lbs ai of 2,4,5-T per gallon. Because of the 2,4,5-T content, its use was also suspended. This action by the EPA left the right-of-way industry without an effective basal spray herbicide.

In an effort to fill this void, the Dow Chemical Company began to evaluate triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid} for activity as a basal spray.

Materials and Methods

For basal spray evaluations, triclopyr was applied in oil and oil-water-surfactant mixes one pint to 4 gal/hg of spray mixture. Each individual plant was sprayed with a backpack sprayer to the point of run-off completely around the stem from ground level to a height of approximately 18 inches. Special care was taken to wet the ground area adjacent to each tree to insure treatment of the root collar.

Tests were conducted in the states of Maine, New Hampshire, Maryland, Virginia, Pennsylvania, Wisconsin, Minnesota, Indiana, Kansas, Colorado, Oregon, and Washington. In these experiments, applications were made at three stages of growth: full foliage, dormant, and bud break. Evaluations were made one year after application by visual estimates of defoliation and two years after application by estimates of stem kill. Only second year results will be reported in this paper.

---

[1]Research Associate, Dow Chemical USA, Shawnee Mission, KS 66210

Results and Discussion

In summarizing results from all tests, it was found that triclopyr provided good control of most woody plants when used at rates of 4 to 8 lbs ai/hg of oil. The product was labeled at these rates and the results are reported here.

Excellent control of the woody plant species listed in Table 1 were obtained with the indicated rates of triclopyr except when applied on dormant basswood at 4 lbs ai/hg and on red alder in full foliate at 8 lbs ai/hg.

Table 1. Percent control of woody plant species with basal sprays of triclopyr.

	Triclopyr (lb ai/hg oil)			
Species	4 lb	6 lb	8 lb	State of Growth[1]
Ailanthius	100		100	FF
Alder (Red)			79	FF
Ash (Green)	100		100	D
	100	100	100	FF
Aspen	100		100	D
	100		100	FF
Basswood	66		88	D
Beach (American)	100		100	FF
Birch (Black, Paper)	95		100	D
	100		100	FF
Blackgum	100		100	FF
Boxelder		96		FF
Cedar (Eastern Red)			100	D
Cherry (Sweet, Black	100		100	D
Wild, Pin)	100		100	FF
Chokecherry			100	FF
Dogwood	100		100	FF
Elm (American)		91		FF
	100		91	D
Hazel			100	FF
Hickory			95	D
			100	FF
Huckleberry	81		97	D
Locust (Black)	100		100	FF

[1]D = dormant, FF = full foliage

Control of the species listed in Table 2 was excellent except in two cases. Seventy-four percent control of vine maple resulted when it was treated under full foliage with triclopyr at 8 lb ai/hg. However, a Dormant treatment at the same rate resulted in 100% control. Dormant treatments of manzanita at 4 lb ai/hg resulted in 100% control, but when triclopyr was applied at 6 and 8 lb ai/hg only 10 to 53% control was obtained respectively.

Table 2. Percent control of woody plant species with basal sprays of triclopyr.

	Triclopyr (lb ai/hg oil)			
Species	4 lb	6 lb	8 lb	State of Growth[1]
Mandrone	100		100	D
	100		100	BB
Mansanita	100	10	53	D
Maple (Bigleaf)	100		100	D
	100		90	D
Maple (Red, Mountain	94		100	D
Sugar, Silver)	93	92	96	FF
Maple (Vine)			74	FF
			100	FF
Oak (Black)	100		99	FF
	100	90	91	D
	100		100	BB
Oak (Chestnut)	100		100	FF
	100		100	D
Live Oak	100		100	FF
	100		100	BB
	90			D
Oak (Red)	100		95	FF
	88			D
Oak (Scarlet)			100	FF
Oak (Tan)	80		96	D
	83		84	BB
Oak (White)	88			FF
	100		100	D

[1]BB = budbreak, D = dormant, FF = full foliage

As shown in Table 3, similar results occurred with dormant treatments of ponderosa pine. Triclopyr at 4 lb ai/hg gave 100% control but only 10% at 6 lb and 55% at 8 lb ai/hg. Excellent control was obtained on the other species with the exception of full foliage treatments of salal. Triclopyr at 8 lb ai/hg provided 71% control of this species.

Through field trials with basal applications of oil-water-surfactant mixtures, it was determined that 8 lbs a.i. of triclopyr plus 0.5 gallon of Spronto 712 in 15 to 30 gallons of diesel oil plus 70 to 75 gallons of water was effective. Results of this treatment are shown in Table 4. Control of all treated species was good except for dormant elm, red oak, and Virginia pine. Also, poor control resulted from treatments of ponderosa pine and tan oak at bud break.

Table 3. Percent control of woody plant species with basal sprays of triclopyr.

	Triclopyr (lb ai/hg oil)			
Species	4 lb	6 lb	8 lb	State of Growth[1]
Oleaster (Russion Olive)			100	FF
Persimmon	100			FF
Pine (Jack, Red, White)	100		100	FF
Pine (Ponderosa)	100	10	55	D
	100		100	FF
	100		100	BB
Poplar (Yellow, Tulip)	100		100	FF
	100		90	D
Salal			71	FF
Sassafras	100		100	FF
	100		100	D
Sumas (Smooth,	100		100	FF
Staghorn)	100		95	D
Sycamore	100			D
Tamarack	100			FF
Walnut	100			D
Willow		99		FF
		100	100	D

[1]BB = bud break, D = dormant, FF = full foliage

Table 4. Control of woody plants with basal applications of oil-water mixture sprays containing triclopyr[1]

Species	Stage of growth	Percent control
Alder	Dormant	100
Cherry	Dormant	95
Elm	Dormant	75
Live Oak	Bud break	100
Madrone	Bud break	100
Maple, Big Leaf	Full foliage	98
Maple, Red	Dormant	100
Oak, Black	Dormant	55
Oak, Black	Bud break	100
Oak, Red	Dormant	55
Oak, Tan	Bud break	60
Oak, White	Dormant	88
Pine, Ponderosa	Full foliage	93
Pine, Ponderosa	Bud break	62
Pine, Virginia	Dormant	75

[1]Sprays contained 8 lb a.i. of triclopyr plus 0.5 gallon Sponto 712 in 15 to 30 gallons of diesel oil and 70 to 75 gallons of water. Trunks of trees were thoroughly wet to a height of 12 to 15 inches.

Conclusions

Results from field trials throughout the United States show triclopyr to be an effective herbicide for basal sprays. When used in oil sprays, good control was attained on all woody plant species evaluated east of the Rocky Mountains. West of the Rockies, it was shown to be weak only on dormant manzanita.

These studies also show that it is possible to obtain good control of woody plants with triclopyr in low oil, basal spray mixtures. Comparable control to that of total oil sprays was obtained on all treated species with the exception of elm, red oak, Virginia pine in the dormant stage and tan oak and ponderosa pine at bud break. Due to the high price of oil, its reduction in basal sprays will significantly reduce the cost of application.

SKELETONWEED--OREGON ATTEMPTS ERADICATION

Lenord Craft and David Humphrey[1]

Skeletonweed (*Chondrilla juncea* L.), a deep-rooted herbaceous perennial native of the Mediterranean areas, was accidently introduced into Australia around 1920 and, once established, began to spread. In 1974, it covered approximately 75 million acres. Losses in small grain production were reported to be between 50 and 70%, with a dollar value of $25 million annually. Skeletonweed is a serious competitor in agriculture and forestry production, and has the potential to alter Oregon agriculture as we know it today. If the weed grew unchecked, losses in Oregon agriculture would be immeasurable--not only from the standpoint of lost forage or grain production, but also from the impact of quarantines on nursery, grain and seed industries, should even limited infestations occur in areas of the state where these crops are produced.

Dr. Gary Lee, Professor of Weed Science, University of Idaho, reports that 60 acres of skeletonweed discovered in Idaho in 1963 has spread and now infests 3.5 million acres (primarily rangeland) and is increasing at the rate of 100,000 acres per year. Skeletonweed has also been reported to infest approximately three million acres in the state of Washington.

In 1977, the Pacific Northwest Regional Commission provided federal funds for an Oregon-Washington-Idaho skeletonweed control program. With its share of funds, the Oregon Department of Agriculture set up a prevention-survey program in eastern Oregon and a survey-treatment program in Douglas County. Oregon's first approach was to use biological agents. This program continued until April, 1979, when a significant new infestation of nearly 120 acres was discovered in and around a sand and gravel operation in the tri-city area of Douglas County.

With this latest find, county, state, and federal weed control officials met with private individuals. All agreed to shift to a chemical approach as an attempt at eradication--provided that appopriate chemicals were available and that permission could be obtained from the Bureau of Land Management to treat scattered skeletonweed infestations on federal lands. Complete cooperation was received and permission was granted to use the necessary chemicals.

In the past, it was believed that once skeletonweed had become established, chemical control was not possible. The plant contains a latex that prevents translocation to all parts of the root system. This is only partially true. According to experienced chemical specialists, the real problem is finding each plant for treatment. With the use of picloram (4-amino-3,5,6-trichloropicolinic acid), where the individual plant can be found, it can be eliminated. Skeletonweed seeds only remain viable in the soil for 18 months, so eradication is possible if all scattered infestations can be treated.

Douglas County and the State of Oregon geared up for a full-scale assault. The plan of attack called for the state to provide technical assistance, manpower, equipment, and chemicals; Douglas County was to provide supervision of the entire project and additional manpower as available and as needed.

The full scale assault began in 1979. The Oregon Department of Agriculture declared Douglas County a skeletonweed control area, prohibiting the movement of seed, plants, or contaminated material from infested

[1]Noxious Weed Control, Oregon Department of Agriculture, Salem, OR.

zones. A survey began, including a check of each location as well as an area of one mile surrounding each known infestation. Any plants found were treated using a mix of one lb picloram and one lb 2,4-D [(2,4-dichlorophenoxy)acetic acid] amine per 100 gallons of water, drenching the plant and surrounding soil.

One of the larger infestations was in the area of the sand and gravel operation, where many other small infestations got their start via sand, gravel, or topsoil delivered to other locations. The owners of the operation were very cooperative, giving specialists a list of locations where material had been delivered during the past two years. A follow-up of these locations showed approximately 50% to be infested with skeletonweed.

One infestation along a pipeline right-of-way had spread over an area of approximately 80 acres of very rough terrain, making it nearly impossible to treat with ground equipment. With the permission of the landowner, the Oregon Department of Agriculture hired an aerial applicator to bring in a helicopter and aerially apply one lb picloram plus one lb 2,4-D amine per acre in eight gallons of water. At the completion of the spray operation, the weed control staff conducted an aerial survey of the area using the same helicopter. One additional spot infestation was located and six more suspected. Later checks showed these were skeletonweed.

In environmentally sensitive areas where the use of picloram would not be permitted, control specialists have been burning mature plants and making fall applications on the new seedlings and regrowth using glyphosate [*N*-(phosphonomethyl)glycine] at two ounces per gallon of water. These areas have required some extra applications as the results have been somewhat less than that achieved with the picloram and 2,4-D combination. Results to date are:

Three hundred acres of skeletonweed, scattered over 192,000 acres were treated in 1979; in June and July 1980 an evaluation showed this net acreage was reduced to 30 acres of skeletonweed scattered over 192,000 acres (this figure includes 15 additional acres found in 1980 which have also been treated).

The latest and possibly the most significant infestation found to date is in a wheat field. Approximately three acres of a 50-acre wheat field were moderately infested. Monitoring during harvest revealed a yield reduction of 42% from the infested portion. Following harvest the stubble in this field was burned to remove any chance of skeletonweed seed development. When regrowth of the weed occurred, the area was treated with glyphosate, and will continue to be monitored. It is still too early to predict total skeletonweed eradication in Douglas County but, to be successful, projects of this type require:

1. Dedication of parties involved (A special word of appreciation to Burl Oar, County Weed Control Supervisor, and the Douglas County officials for their dedication and tenacity in attempting eradication of this serious weed pest).
2. Monetary support from the Oregon legislature.
3. Support from the Oregon Department of Agriculture and the affected counties.
4. Cooperation of federal and state agencies involved.
5. Cooperation and involvement of private citizens.
6. Availability of technology in both chemicals and equipment.

Many noxious weeds which are now causing severe economic losses in agriculture were recognized as having the potential to do so while they were still limited in distribution. The warnings of weed control professionals were ignored until the weed spread to a point where readication was not practicable. With skeletonweed, the citizens of Oregon have the opportunity to halt the spread of a weed of tremendous importance. We must break the precedent of watching weed problems develop until they can no longer be stopped.

INFLUENCE OF LOW VOLUME HORMONE HERBICIDES ON BUD, FLOWER, AND SEED DEVELOPMENT OF RUSH SKELETONWEED

T. M. Cheney, D. C. Thill, and G. A. Lee[1]

Rush skeletonweed (*Chondrilla juncea* L.) is a relatively shortlived, taprooted perennial. Rush skeletonweed is a serious threat to dryland agriculture. Rush skeletonweed infests 40 million acres in Idaho alone with additional infestations in Washington, Oregon, and California. The weed infests an additional 100,000 acres in Idaho annually. Rush skeletonweed reproduces vegetatively and sexually, producing as many as 50,000 seeds per plant. Chemical application of auxin-type herbicides will burn the weed back, but results in an increase of satellite plants six months after application. A study initiated in July of 1980 was evaluated in mid-August and the first of September. Evaluations on number of buds present six weeks after application showed no significant differences from the check plots. The number of flowers per plant was reduced with all aplications except 2,4-D [(2,4-dichlorophenoxy)acetic acid] plus dicamba (3,6-dichloro-*o*-anisic acid) at 0.28 and 0.14 kg/ha respectively. The most significant reduction was in the number of seeds per plant. Applications of 2,4-D plus 0.07 and 0.14 kg/ha of dicamba resulted in the most reduction of seeds per plant. Complete suppression of seed set was observed with applications of picloram (4-amino-3,5,6-trichloropicolinic acid) at 0.07 and 0.14 kg/ha, 2,4-D plus picloram at 0.14 kg/ha, and 2,4-D plus 0.07 and 0.14 kg/ha picloram.

[1]Department of Plant and Soil Sciences, University of Idaho, Moscow, ID 83843

EFFECTS OF HERBICIDES ON GUAYULE (*PARTHENIUM ARGENTATUM*)

Don Clark and J. W. Whitworth[1]

Abstract. Weed control is a major problem facing the future production of guayule as a native rubber crop. The plant's ability to withstand weed competition calls for the use of wide spectrum herbicides to solve this problem.

Studies were and are being carried out to determine the response of guayule to herbicides. Response in measured in terms of stand, dry matter, resin, and rubber production.

From greenhouse and preliminary field tests, ten herbicides were chosen for these studies. Of these ten, diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine], and fluridone {1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1*H*)pyridinone}

[1]New Mexico State University, Agronomy Department, Las Cruces, NM 88003.

showed the most promise but their performance was highly variable. Variations in response were aften associated with soil composition, but differences in response of selected cultivars was also noted. In the sandy, coarse textured soils where guayule is well adapted, simazine and diuron showed inadequate selectivity towards guayule transplants. Oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene] showed promise for both selectivity on guayule and for weed control. Resin and rubber production data have not as yet been taken for this herbicide.

Initial injury to the stands of guayule was much less for the granular formulation of simazine than for the wettable powder formulation on plots that fell on the extremely sandy areas of the field. However, when data were taken on plots on the finer textured soil, rubber and resin yields showed serious reduction only on the granular plots. While stand reduction for the granular treatment was only nine percent, the reduction in resin yield was 26 percent and in rubber 34 percent. Fluridone and diesel oil treatments caused little or no reduction in stand, rubber, or resin content.

PERSISTENCE, BIOACCUMULATION, AND TOXICOLOGY OF TCDD IN AN ECOSYSTEM TREATED WITH MASSIVE QUANTITIES OF 2,4,5-T HERBICIDE

A. L. Young, C. E. Thalken, and D. D. Harrison[1]

Abstract. Field investigations were conducted during 1973-1978 on a Km^2 military test area (Test Area C-52A, Eglin Air Force Base, Florida) that received 73,000 kg of 2,4,5-T [(2,4,5-trichlorophenoxy)acetic acid] during the period 1962-1970. No residues of 2,4,5-T were detected (detection limit of 10 ppb) in any soil samples collected during 1971-1972. However, residues of the contaminant, TCDD (2,3,7,8-tetachlorodibenzo-*p*-dioxin) were still present in 1978.

During the period 1974-1978, 54 soil samples were collected to a depth of 15 cm from throughout the test area. TCDD levels ranged from <10 to 1,500 parts per trillion (ppt). The median concentration was 30 ppt while the mean was 165 ppt. The ecological survey extending over a five-year period documented the presence of at least 123 different plant species, 77 bird species, 71 insect families, 20 species of fish, 18 species of reptiles, 18 species of mammals, 12 species of amphibians, and 2 species of mollusks. At least 250 biological samples were analyzed for TCDD, including 30 species of animals. No TCDD was found in any of the plant species examined. However, TCDD was found in nine species of animals including two rodent species: beachmouse (300-2,400 ppt, liver) and hispid cotton rat (<10-210 ppt, liver); three species of birds: meadowlark (100-1,020 ppt, liver), mourning dove (50 ppt, liver), and Savannah sparrows (69 ppt, liver); three species of fish: spotted sunfish (85 ppt, liver), mosquitofish (12 ppt, whole body), and sailfin shinner (12 ppt, whole body); and one reptile, the six lined racerunner (360-430 ppt, muscle).

Gross pathology was done on all species collected for TCDD residue analyses. Histopathological examinations were performed on over 300 beachmice or hispid cotton rats from the test area and a control field site. Examinations were performed on the heart, lungs, trachea, salivary glands, thymus, liver, kidneys, stomach, pancreas, adrenals, large and small intestine, spleen, genital organs, bone, bone marrow, skin, and brian. Initially,

[1]USAF School of Aerospace Medicine/Epidemiology Division and the USAF Occupational and Environmental Health Laboratory, Brooks Air Force Base, TX.

the tissues were examined on a random basis without the knowledge of whether the animal was from a control or test area. All microscopic changes were recorded, including those interpreted as minor or insignificant. The tissues were then reexamined on a control and test basis, which demonstrated that the test and control mice could not be distinguished histopathologically. Similar histopathological studies were conducted on the fish and racerunner, and again no significant abnormalities were found.

Introduction

Concern over the level of contamination of 2,4,5-T herbicide by the teratogen TCDD has prompted discussion on the safety of using 2,4,5-T in forest and rangeland environments. Although numerous reports have recently appeared in the scientific literature, most of these deal with effects of 2,4,5-T and TCDD in laboratory systems.

In general the effects and mode of action of TCDD on laboratory animals can be characterized by a relatively small number of clinical signs. It is reported that a single oral dose (25 μg TCDD/kg) caused an actual weight loss for one week in young female rats and young male rats receiving the same dose had significantly decreased weight gain over a two week period. Slight thymic atrophy, related to TCDD dose levels, was a common finding in young mice receiving a single oral dose (50 μg TCDD/kg), while severe thymic atrophy in young mice receiving a single oral dose of TCDD (150 μg TCDD/kg) or four separate oral doses (25 μg TCDD/kg x 4) was reported. A single oral dose of TCDD (50 μg TCDD/kg) in young adult rats and (3 μg TCDD/kg) in young guinea pigs caused severe thymic atrophy. At these same dose levels slight to severe centrilobular liver necrosis and degeneration of parenchymal cells in mice, rats, and guinea pigs, together with ceroid pigment deposits and hepatic porphyria in mice given four oral doses of TCDD (25 μg TCDD/kg) at weekly intervals were seen. Acute death in guinea pigs has occurred following a single (3 μg TCDD/kg) oral dose of TCDD. A recent report indicated that four doses of TCDD (25 μg TCDD/kg) given at weekly intervals to young mice induced the production of δ-aminolevinic acid (ALA) synthetase and hepatic porphyria.

Laboratory data for rodents strongly suggest a correlation between histological lesions in the liver and lymphatic system and the amount of TCDD ingested. Unfortunately, data relating to any actual effects on wild populations in their natural habitat are lacking. The problem of finding a field site where a wild population of rodents has been exposed to significant quantities of TCDD is improbable because of (1) low levels of TCDD (<0.1 ppm) found in currently produced phenoxy herbicide, and (2) low rates of 2,4,5-T applied for brush control on rangelands or for reforestation (1.1 to 2.2 kg/ha). This report, however, documents the effects of residual TCDD on selected animal populations inhabiting a unique test site: a site previously treated with massive quantities of 2,4,5-T herbicide and located on the Eglin Air Force Base Reservation, Florida.

The Eglin Reservation has served various military uses, one of them having been development and testing of aerial dissemination equipment in support of military defoliation operations in Southwest Asia. It was necessary for this equipment to be tested under controlled situations that would simulate actual use conditions as near as possible. For this purpose an elaborate testing installation, designed to measure deposition parameters, was established on the Eglin Reservation with the place of direct aerial application restricted to an area of approximately 3.0 km^2 within Test Area C-52A in the southeastern part of the reservation. Massive quantities of herbicide, used in the testing of aerial defoliation spray equipment from 1962 through 1970, were released and fell within the instrumented test area. The uniqueness of the area has promoted continued ecological surveys since 1967. As a result, few ecosystems have been so well studied and documented.

Materials and Methods

Description of field. Test Area C-52A (TA C-52A) covers an area of approximately eight square kilometers and is a grassy plain surrounded by a forest stand that is dominated by longleaf pine (*Pinus palustris*), sand pine (*Pinus clausa*), and turkey oak (*Quercus laevis*). The actual area for test operations occupies an area of approximately three square kilometers and is a cleared area occupied mainly by broomsedge (*Andropogon virginicus*), switchgrass (*Panicum virgatum*), woolly panicum (*Panicum lanuginosum*) and low growing grasses and herbs. Much of the center of the range was established prior to 1960, but the open range as it presently exists was developed in 1961 and 1962. The test grid is approximately 28 m above sea level with a water table of six to ten feet. The major portion of this test area is drained by five small creeks whose flow rates are influenced by an average rainfall of 150 cm. The mean annual temperature for the test area is 17.9°C while the mean annual relative humidity is 70.8 percent. For the most part, the soil of the test grid is a fine white sand on the surface, changing to yellow beneath. The soils of the range are predominantly well drained, acid sands of the Lakeland Association with 0 to 3 percent slope. A typical three-foot soil core contained approximately 92 percent sand, 3.8 percent silt, and 4.2 percent clay with an organic matter content of 0.17 percent, an average pH of 5.6, and a cation exchange capacity of 0.8.

Although the total area for testing aerial dissemination equipment was approximately 3.0 km^2, the area actually consisted of four separate testing grids. The primary area was located in the southwest portion of the testing area and consisted of 37 ha instumented grid. This was the first sampling grid and was in operation in June 1962. It consisted of four intersecting straight lines in a circular pattern, each being at a 40° angle from those adjacent to it. Although this grid was discountinued after two years it received the most intense testing program. From 1962 to 1964, this grid (called Grid I) received 39,550 kg of 2,4-D [(2,4-dichlorophenoxy)acetic acid] and 39,500 kg of 2,4,5-T. The herbicide was disseminated as the water insoluble n-butyl and iso-butyl esters (their military code names were Orange and Pruple). Two other testing grids were sprayed with 2,4,5-T. Grid II was an area of 37 ha and located immediately north of Grid I. Grid II received 15,890 kg 2,4,5-T from 1964 through 1966. Grid IV was the latest and final Grid established on Test Area C-52A. It was approximately 97 ha and received 17,440 kg 2,4,5-T from 1968 through 1970. Both Grids II and IV received Herbicide Orange (a 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-T).

Despite excellent records as to the number of missions and quantity of herbicide per mission, there was no way to determine the exact quantity of herbicide deposited at any point on the instrumented grid. The first extensive soil sampling for residues of herbicides was initiated in 1969 for Grid I (five years after the last mission) and in 1970 for Grids II and IV. At that time traces (parts per billion) of 2,4,5-T were detected in soils of Grid I and in parts per million for Grids II and IV. Analyses for TCDD were initiated in 1972. By midsummer 1973 analysis of soil samples indicated that TCDD was detected only in the top 15 cm of soil (e.g., analysis of soil cores at 15 cm increments to a depth of one meter indicated no detectable TCDD in increments below 15 cm. Therefore, fifty four sites on three Grids were sampled for TCDD in the top 15 cm increment. One of the sites was also subsampled at increments of 0-2.5, 2.5-5, 5-10, and 10-15 cm. Analysis of soil samples for TCDD was accomplished by three different commercial laboratories.

Vegetation. Detailed studies of the vegetative composition of Test Area C-52A were conducted in 1971, 1973, and 1976. Transect analyses were conducted on all test grids. Frequencies and densities of monocotyledonous and dicotyledonous species were determined. Representatives of all plant species were collected and mounted. Photographic records of numerous sites were maintained through the years of study.

Animals. Studies of the animals began in 1970. However, detailed investigations of the beachmouse, hispid cotton rat, and six-lined race-runners were conducted in 1973 and 1974. The beachmouse was further studied in 1975 and 1978. The birds were studies in 1974 and 1975. The insect studies were conducted in 1971 and 1973, while the aquatic communities were initially examined in 1970 and again in 1973 and 1974. Lists of species, description of habitats and diets and residue analysis were conducted throughout all years of study.

Results

The results of these studies are summarized in the following 13 Tables (slides for oral presentation).

Table 1. Test Area C-52 A
Eglin Air Force Base, Florida

A test range used in the development of defoliation spray equipment for Southeast Asia

Herbicides sprayed on the test area, 1962-1970.

Table 2. Test grids and quantities of 2,4,5-T applied to test area C-52A, Eglin AFB, FL

Grid	Area (ha)	Years	2,4,5-T (kg)
I	37	1962 - 1964	39,550
II	37	1964 - 1966	15,890
IV	97	1968 - 1970	17,440
		Total	72,880

Table 3. Ecological investigations, Test area C-52A, 1973 - 1978

Soil residues: 2,4,5-T, TCDD

Terrestrial Ecosystems
- Vegetation
- Animals
  - Vertebrate
  - Invertibrate
- Microorganisms

Aquatic Ecosystems
- Animals
  - Vertebrate, Invertebrate
- Microflora

Table 4. Ecological survey, Test area C-52A, 1973 - 1978

Number of species	Organisms
123	plants
77	birds
71	insect families
20	fish
18	reptiles
18	mammals
12	amphibians
2	molluscs

170 biological samples analyzed for TCDD

Table 5. Concentration of TCDD (ppt) in test grid soils

Grid	Number samples*	Range	Median	Mean
I	22	<10 - 1,500	110	326
II	6	<10 - 470	30	117
IV	26	<10 - 150	19	27

*0 - 15 cm increment

Table 6. Disappearance of TCDD from soils of Grid I (parts per trillion)

Plot Number*	August 1974	January 1978
1	1,500	420
2	610	300
3	1,200	580
4	270	100
5	400	400
Mean	804	360

*Five subsamples from each 1-m^2 plot composited (0-10 cm depth)

Table 7. Investigations of bird species, test area C-52-A, 77 species observed

	TCDD residue analysis (ppt)			
Dominant species	No. samples*	Organ	Range	Mean
Southern meadowlark	3	liver	100 - 1,020	440
	1	stomach		10
Mourning dove	2	liver		50
	1	stomach		10
Savannah sparrow	1	liver		69
	1	stomach		84

*Composites from at least 6 birds

Table 8. Investigation of insects, test area C-52A, 71 families observed

Family	TCDD residue analysis (ppt)
Grasshopers	ND (3)*
Crickets	26
Composite of soi/plant insects	40

*Detection limit

Table 9. Investigations of mammals, test area C-52A

		TCDD residue analysis (ppt)	
Species	Organ	Concentration	Detection limit
Deer	fat	ND	4
	liver	ND	5
	kidney	ND	4
Opossum	fat	ND	10
	liver	ND	10
Rabbit	liver	ND	8
	pelt	ND	2
Cotton rat	liver	10 - 210	
Beachmouse	liver	300 - 1,500	
	pelt	130 - 140	

Table 10. Studies of the beachmouse, *Peromuscus polionotus*, Grid I, Test area C-52A, Eglin AFB, FL

Location Maturity, Sex	1973	1974	1975	1978	Total
Control Area					
Mature					
Male	4	11	3	2	20
Female	3 (3)*	8 (3)	3 (1)	2 (2)	16 (9)
Immature					
Male	1	1	0	0	2
Female	0	2	0	0	2
Fetuses	12	11	3	5	31
				Total	71

*( ) = Number of pregnant females
Fetuses/pregnancy = 3.4

Table 11. Studies of the beachmouse, *Peromyscus polionotus*, Grid I, test area C-52A, Eglin AFB, FL

Location Maturity, Sex	1973	1974	1975	1978	Total
Test Grid I					
Mature					
Male	18	14	7	7	46
Female	15 (6)*	9 (6)	6 (4)	6 (6)	36 (22)
Immature					
Male	8	3	7	6	24
Female	1	4	3	3	11
Fetuses	25	9	12	21	67
				Total	184

* ( ) = Number of pregnant females; Fetuses/pregnancy = 3.1

Table 12. Mean liver weight (mg) of pregnant beachmice, test area C-52A

Location	Year	Liver weight (mg)
Control	1973	929
	1974	765
	1975	934
	1978	919
Grid I	1973	1,247
	1974	1,019
	1975	1,109
	1978	1,101

Differences Statistically Significant!

Table 13. Histological parmeters

Heart	Pancreas
Lungs	Adrenals
Trachea	Large/small intestine
Salivary glands	Spleen
Thymus	Genital organs
Liver	Bone
Kidneys	Bone Marrow
Stomach	Skin
Brain	

All microscopic changes recorded. Test and control mice could not be distinguished.

Discussion

The data suggest that TCDD may persist for long periods of time in the environment. However, caution must be expercised in making such a statement. As noted from the above tables, it was probable that Grid I received highly contaminated herbicide. The herbicide was most likely produced in the 1950's or early 1960's and thus was subjected to preparation treatment different from those controlled procedures subsequently used. A conservative estimate for TCDD contamination may be 8 ppm in the formulation. Using the 8 ppm figure for all of the herbicide applied to Grid I, the amount of TCDD applied would have been at a concentration equal to 12,267 ppt TCDD in the top 15 cm of soil. At least, this has declined to 710 ppt in about 8 years. This is a loss of about 95 percent. Thus, the apparent high residue is probably due to the massive quantities applied rather than to the resistance of TCDD to biological and/or physical degradation.

The levels of TCDD in the livers of beach mice and birds collected from the test grids substantiated bioaccumulation of TCDD; i.e., an accumulation of TCDD *in* an organism from its environment. In general, levels of TCDD in the livers were *no greater* than the most concentrated zones of TCDD in the soil. There are no data from this study to support biomagnification of TCDD; i.e., an increase in concentration of TCDD in successive organisms ascending the trophic food chain.

The only significant lesions seen on histopathologic examination of 255 adult and fetal beach mice were two instances of moderarely severe multifocal, necrotizing, hepatitis and a single mouse with severe venous ectasia of the renal veins in one kidney. All other lesions were of the minor or insignificant type, normally observed in microscopic surveys of large numbers of field animals. The absence of liver lesions (necrosis and prophyria) in animals that had liver levels of TCDD from 300 ppt to 1,500 ppt is most significant in view of the massive quantities of both 2,4,5-T and TCDD that must have been applied to the test site. Moreover, a report of a previous study of this area, which terminated in the summer of 1970, indicated that a significant population of beach mice were inhabiting the test site.

The average life-span of a related species, *Peromyscus maniculatus*, has been recorded to be less than five months and only a few mice lived the full potential of three or more years. A single female beach mouse is capable of producing 80 or more young under laboratory conditions with litters being born at approximately 26 day intervals. It is further reported that beach mice on Santa Rosa Island, Florida (within 32 km of Test Area C-52C), may have produced 10 generations per year. At this frequency the animals collected in 1974 on Grid I may be 40 generations removed from the population first noted in 1970. However, a more conservative estimate would be 6 generations per year (giving a female 60 days to reach sexual maturity), for a total of 24 generations.

It must be stressed that the populations of beach mice noted in 1970 were probably subjected to much greater levels of residual TCDD in the soil than those animals collected in subsequent years. The absence of pathological signs in these mice indicated that TCDD was neither mutagenic (somatic or germinal) nor carcinogenic in the field at the concentrations noted and during the life span of the animals studied. Since none of the 67 fetuses examined from animals captured on the test grid showed teratogenic defects it must also be concluded that the levels of TCDD encountered failed to induce observable developmental defects.

WEED SEED PRODUCTION

Harold M. Kempen and Joseph Graf[1]

Weed Science is a remarkably new science. Herbicide usage has been doubling every few years. Largely because of escalating regulations on how research is conducted on toxicology, environmental effects, sales, and usage, new herbicide introductions have dropped precipitously in the past four years.

As a result the large public infrastructure of weed scientists which has developed, has had the ability to "catch up" on the biological end of weed management, including a bit of the interaction with other pest control disciplines. Massive IPM (Integrated Pest Management) funds have been released recently, which enables scientists to hire the hands to do the tedious work involved in plant morphology and competitive studies.

Such information will provide certain insights into the characteristics and competitive ability of a few of the 200 or so major weeds in the world described by Holm et al. (5). At the moment most growers and/or their advisors are still groping with identification of the weeds they are trying to manage. Recent publications have aided them in that respect (2, 9).

Studies of weed seed dynamics have been the forte of Roberts at the National Vegetable Research Station, Wellsbourne U.K. (10). His work certainly deserves review. Competitive studies in cereals by Professor Koch of Hohenheim University, West Germany also deserve review (8). Studies in the United States by several researchers are summarized by Zimdahl (11), and Furrer at Nebraska (3), and provide additional insights into weed seed dynamics. Buchanan at Auburn has concluded a number of competitive studies in cotton and peanuts (1).

These studies were conducted in Kern County, California to make a preliminary assessment of seed production capabilities of various weeds in cotton and its many rotational crops.

I have long felt that weed management programs (6) on farms are very complex and that San Joaquin farmers will not be capable, because of time constraints, of utilizing detailed weed data. Perhaps, at a later year, their consultants will make better usage of developed data, especially with the aid of computers. But even then, the expense of collecting the data for introduction into computer systems will be limiting. The pest management computer system recently obtained by the University of California, with all its hardware, software, programmers, and research assistants, is already costing over $1 million, with only 10 million acres of cropland in the state.

A good consultant would cost $2 to $3 per acre (7). He can interpolate and integrate the many on-site factors which impinge on every day weed management. Such factors can include number and population of various weed species, their competitiveness, time of planting, method used, rainfall prediction, when to irrigate, when to cultivate, how to cultivate, farm personnel capabilities, cost of factors, rotation limits, equipment limits, harvest schedules, regulatory limitations, insect or disease interactions, herbicide availability, optimum placement and activation, rotational limitations due to herbicides or crops, retreatment needs, interactions with soil type, irrigation amounts, soil pH, etc.

We need some of both, but at this date more can be done with a good observant weed manager than through "IPM" studies. Probably several

---

[1]Agriculturist and Research Technician, University of California, Cooperative Extension, P.O. Box 2509, Bakersfield, CA 93303.

replicated observations are better than several replicated studies.

These studies were conducted to give a quick assessment of the seed productive capacity of some of our common weeds. This data, along with the guides of Roberts (10) and Koch (8) for prognostication of subsequent problems, might then reinforce my viewpoint that preventative weed management practices and zero threshold levels in crops are logical with most weeds.

Weed Seed Production Studies

The objective of this study was to evaluate the reproductive potential characteristic of various weedy plant species in Kern County. This would have various implications as far as its utilization in weed management.

It would aid in understanding: (1) Why non-native and native weed species can invade and infest crop areas; (2) What the manageable levels of various weeds species are, or whether the concepts of zero tolerance vs. weed threshold concepts can be better determined; and (3) Whether improved management, cultural, mechanical, or chemical techniaues may be needed to combat certain weedy species.

Procedure. Weedy species collection began in early spring of 1980 in rotational crops and unplanted fields. Vigorous growing plants were collected either as escapes in a field or roadside, or in direct competition with field crops. Collection continued throughout the growing season of primary crops from February through October. Plants were collected from roadsides, cotton, sugar beets, alfalfa, fresh onions, garlic, melons, wheat, and potatoes, but not from every crop since different weeds species exist in different crops because of time of year, management, and cultural practices.

Results

A. Family: Cyperaceae; Tuber production in cotton

Species	Date	Tubers/Ft^2 of sample	Tubers/A
Yellow nutsedge *Cyperus esculentus*	9/28/79 (cultivated 5 times)	117.2	5,105,000
Purple nutsedge *Cyperus rotundus*	9/11/90 (cultivated 8 times)	25.9	1,138,000

B. Family: Compositae; Sampled from, in order: beets, roadside, 2nd cut alfalfa, fresh onions, roadside.

Species	Date	Seeds/head	Ave/plant	Mean	Maximum
Groundel *Senecio vulgaris*	3/80	45	38,343	--	40,687
Pineapple weed *Matricaria suaveolens*	6/80	140	69,020	--	69,020
Sow thistle *Sonchus oleraceus*	5/80	138	17,238	11,200	35,828
Fleabane, flaxleaf *Conyza bonariensis*	6/80	290	266,753	311,750	357,561
Marestail *Conyza canadensis*	9/80	51	237,456	216,342	258,570

C. Family : Solanaceae; sampled from garlic, cotton, melons, and roadside.

Species	Date	Seeds/berry	Ave/plant	Mean	Maximum
Black nightshade *Solanum nigrum*	8/80	60	60,486	40,800	155,547
Hairy nightshade *Solanum sarrachoides*	8/80	20	16,211	16,700	31,800
Silverleaf nightshade *Solanum elaeaggnifolium*	9/80	35	25,670	23,680	27,660
Groundcherry *Physalis lancifolia*	9/80	250	--	--	11,250

D. Family: Malvaceae; April to June harvest from cotton, potatoes, alfalfa, or roadside.

Species	Seeds/capsule	Ave/plant	Mean	Maximum
Cheeseweed *Malva parviflora*	10	12,900	6,030	32,000

E. Family: Convolvulaceae; Severe September infestation in cotton.

Species	Seeds/pod	Seeds/ft^2	Seeds/A
Morningglory *Ipomoea hederacea*	5-7	329	14,311,240

F. Family: Cruciferae; Harvested from April to June in cotton, wheat or potatoes

Species	Seeds/pod	Ave/plant	Mean	Maximum
London Rocket *Sisymbrium irio*	70	72,991	26,342	178,123
Short podded mustard *Brassica incana*	8	49,265	--	87,363
Oriental hedge mustard *S. orientale*	180	136,106	--	174,140

Discussion

The counts of seed per plant from these samples give further insight into the variation in quantity produced, but demonstrate vividly the prolific reproductive capacity of certain species. The more prolific species do, in fact, appear to be the most serious weeds and most rapidly spreading.

The obvious conclusion is that not many black nightshade or flax-leaf fleabane plants need go to seed to cause a well replenished soil reservoir. That fact plus Robert's seed depletion studies (10) which show 30 to 60% seed loss per year, shows that annual weeds can return to haunt crop production perennially. The data would also indicate the desirability to maximize control efforts, including roguing certain species, to keep seed populations down and, with obnoxious competitors such as annual morningglory or cocklebur or sunflower, to prevent their entry onto the farm if at all possible. Composite species, which blow in, or nightshade species which come in on bird droppings, are next to impossible to prevent.

Adding the factors of numerous weed species, each one's seed production potentials, each weed's competitive potential, dormancy factors both innate and induced, crop competitiveness, and the other factors previously mentioned which impinge on optimum weed management techniques, makes me feel more convinced that further biology and competition studies will not be as productive toward IPM concepts as if more time was spent on in-field analysis of each weed/crop situation.

Literature Cited

1. Buchanan, G. A. and E. R. Burns. 1970. Influence of weed competition on cotton. Weed Sci. 18:149-154.
2. Fischer, B. B., A. H. Lange, and J. McCaskill. Growers Weed Identification Handbook. University of California.
3. Furrer, J. D. 1980. Proc. 1979-80 Protection Clinics for: Dealers, Applicators, Farmers. 245 pp.
4. Fye, R. E. Weed sources of lygus bugs in the Yakima Valley and Columbia Basin in Washington. J. Econ. Entomol. 73:469-473.
5. Holm, L. G., D. L. Plucknett, J. V. Panchio, and J. P. Herberger. 1977. The World's Worst Weeds. Distribution and Biology. Univ. Press of Hawaii. 609 pp.
6. Kempen, H. M. 1980. The place of the weed manager in today's crop management system. Proc. West. Soc. Weed Sci. 33:133.
7. Kempen, H. M. 1980. Is weed management consulting in your future? Agr. Consultant and Fieldman. May-June pp 17-19.
8. Koch, W. and M. Hess. 1980. Weeds in wheat. Wheat. Documenta Ciba-Geigy. pp. 33-40.
9. Miller, J. F. Common weed seedlings of the U.S. and Canada. Univ. of Georgia. 31pp.
10. Roberts,H. A. 1970. Rept. Natl. Veg. Res. Sta., Wellesbourne, Warwickshire, U.K. 1969. pp. 25-38.
11. Zimdahl, R. L. 1980. Weed-crop competition, a review. 138 pp. International Plant Protection, Center, Oregon State Univ., Corvallis, OR.

LONGEVITY OF BURIED YELLOW NUTSEDGE TUBERS

R. J. Thullen and P. E. Keeley[1]

Abstract. The longenity of yellow nutsedge (*Cyperus esculentus* L.) tubers burried 11 to 15 inches deep in soil for 4 years in a non-replicated test and 5 years in a replicated test was investigated. Both tests had two treatments, rainfall (non-irrigated) and rainfall plus irrigation. Tubers were dug in June of the first year and in December of the 1st, 2nd, 3rd, 4th, and in the case of the replicated test, the 5th year. The tubers were planted in vermiculite in a greenhouse and all sprouts formed were counted.

[1]USDA-SEA/AR, U.S. Cotton Research Station, Shafter, CA

The tubers of the irrigated treatments had the shortest life; many tubers did not sprout after the first year of burial. Although sprouting declined with time for the non-irrigated tubers, they did sprout well through the third year of burial. Few tubers sprouted after the fouth or fifth year of burial.

Introduction

Little is know of tuber longevity under the growing conditions of the irrigated Southwest. To learn how long tubers of yellow nutsedge would survive under irrigated and non-irrigated conditions in arid regions, we began this study. The objectives were to find out how long tubers would remain sproutable when buried, by a deep plowing, with natural precipitation only or with the addition of irrigation.

Materials and Methods

Tubers used in two longevity experiments were dug in December, 1971 and 1974 and were those which would not pass through a 1/4-inch mesh screen. Some of the tubers used in the 1971 experiment were washed for 3 hours under running water to break dormancy (1). Other tubers used in 1971 and all tubers used in 1974 were dormant. In both experiments, the tubers were mixed with soil in one-quart plastic containers. The bottoms of the containers had drainage holes. The containers with tubers were buried outdoors in two separate areas so that the tubers were 11 to 15 inches below the soil surface. Before the containers were buried, the burial sites were tilled and fumigated with methyl bromide (bromomethane) to kill the natural tubers and weed seeds.

In 1971, 10 containers each with 50 tubers, 5 containers with dormant and 5 with non-dormant tubers, were buried under irrigated and non-irrigated conditions. Irrigation consisted of a preplant irrigation and up to 5 growing-season irrigations. The irrigation schedule was similar to that for cotton grown in the Shafter area. Both the irrigated and non-irrigated tubers received rainfall (Table 1). Sprouts emerging from the soil surface above the buried containers were removed at two-week intervals to prevent production of new tubers. A single container of tubers was dug in June of the first year and in December of the 1st, 2nd, 3rd, and 4th years. After separation from the soil, the tubers were planted in vermiculite and grown in a greenhouse. Tubers which sprouted were counted and recorded.

In 1974, 30 replicates per treatment, each containing 20 tubers, were buried under irrigated and non-irrigated conditions. Based on some randomly selected tubers, the average weight per tuber was 233 mg. Compared with tuber weights from another experiment conducted by the authors (2), the tubers were medium size. Site preparation and irrigation were the same as that used for the 1971 experiment. Five replicates from each treatment were dug in June of the first year and in December of the 1st, 2nd, 3rd, 4th, and 5th years. The tubers were planted in vermiculite and grown in a greenhouse. Tubers which sprouted were counted and recorded. In addition to the resprouting data, the shoots emerging from the soil surface above the buried containers were counted and recorded for each growing period every 2 weeks. Then the shoots were removed to prevent the formation of new tubers in the buried containers.

Results and Discussion

The results of the non-replicated test in 1971 are shown in Table 2. Non-irrigated tubers, whether dormant or non-dormant, sprouted well (96 to 32%) when planted after 6 months to 3 years of burial. When dormant

Table 1. Precipitation data for Shafter, California, 1972 - 1979.

Year	Inches of precipitation		
	January thru June	July thru December	Total
1972	.50	3.12	3.62
1973			7.65
1974			6.41
1975	2.51	.94	3.45
1976			5.61
1977			4.91
1978	11.09	2.40	13.49
1979			6.01

Table 2. Percent sprouting of yellow nutsedge tubers after burial for 6 months to 4 years at Shafter, California, June 1972 to December 1975[a].

Tuber treatment	Percent sprouted after burial of				
	6 mo	1 yr	2 yr	3 yr	4 yr
Non-dormant[b]					
Non-irrigated[c]	92	96	92	32	8
Irrigated	96	0	10	0	8
Dormant					
Non-irrigated	88	64	60	68	6
Irrigated	80	20	20	8	0

[a]Fifty tubers per container were buried in December, 1971 at a depth of 11 to 15 inches.

[b]The tubers were washed for 3 hr under running water before burial to break dormancy.

[c]The non-irrigated treatments received only rainfall. In addition to rainfall, the irrigated treatments were irrigated on the same schedule as cotton grown in the Shafter area, a preplant irrigation in March and up to five irrigations during the growing season.

and non-dormant tubers, respectively, were planted 6 months after burial, 80 and 90% sprouting occurred. When irrigated tubers were planted after a year or more of burial, 20 to 0% of them sprouted. Difinite conclusions could not be drawn from this experiment as to why the tubers sprouted poorly after 1 year of burial when irrigated. It was not known whether the tubers had sprouted during the summer and exhausted most buds and food reserves or whether they simply became infected and rotted.

The results of the 1974, replicated experiment are shown in Table 3. Results of this experiment were similar to those of the 1971 experiment (Table 2). Although sprouting was significantly reduced for the non-irrigated treatment after the second year of burial, in comparison with tubers buried for 6 months and 1 year, sprouting was good, above 40%, after 3 years of burial. As in the 1971 experiment, the irrigated treatment sprouted poorly after the 6 months of burial and there were essentially no tubers that sprouted after the first year of burial.

Table 3. Percent sprouting of yellow nutsedge after burial for 6 months to 5 years at Shafter, California, June 1975-December 1979[a].

	Percent sprouting after burial of					
Tuber treatment[b]	6 mo	1 yr	2 yr	3 yr	4 yr	5 yr
Non-irrigated	85a[c]	84a	47b	43b	2d	1d
Irrigated	50b	19c	0d	0d	1d	0d

[a]Thirty replicates of 20 tubers per replicate were buried in December, 1974 so that the tubers were 11 to 15 inches deep.

[b]The non-irrigated treatment received only rainfall. In addition to rainfall, the irrigated treatment followed the same schedule as cotton grown in the Shafter area, one preplant irrigation in March and up to five irrigations during the growing season.

[c]Numbers followed by the same letter are not significantly different at P = .01.

Six months after burial, the 1974 irrigated tubers sprouted significantly less than the non-irrigated tubers. No analysis could be run on the 1971 experiment; however, the number of dormant or non-dormant tubers sprouting after 6 months burial was about equal for non-irrigated and irrigated tubers.

Tubers buried in December, 1971 received only .20 inches of percipitation through March, 1972. The first moisture to reach 11 to 15 inches deep in the soil was the March irrigation that simulated a preplant irrigation for cotton. In 1975, about 1.5 inches of moisture fell before the preplant irrigation was applied. Because most of this precipitation came in February of that year, the soil was probably wet to 15 inches before the preplant irrigation was applied. This meant that the tubers were wet for a longer period of time during the first 6 months of the 1974 experiment than they were in the 1971 experiment.

The soil in February of both 1972 and 1975 was cold. (There was no soil temperature data, but the air temperatures were similar for the 2 years.) The soil was cold and dry in 1972, whereas it was cold and wet in 1975. Normally, sprouting in the field does not occur until the last half of March in the Shafter area. The tubers probably did not sprout before the last of March in either year, but in 1975 the cold wet conditions were adequate for infection of some of the tubers.

The total number of sprouts emerging at the soil surface for each growing period can be seen in Figure 1. The irrigated tubers sprouted well during the first year of burial. There was an average of just over

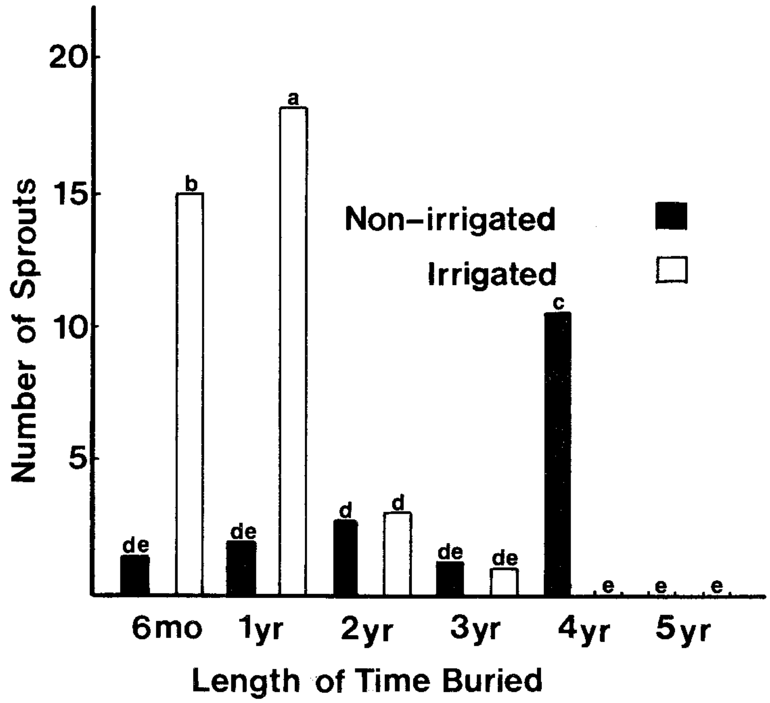


Figure 1. Average number of shoots produced by 20 tubers of yellow nutsedge from December 1974 through December 1979 for each growing season. Bars with the same letter are not significant at P = .01.

18 sprouts for 20 tubers. Because more than one bud per tuber may have sprouted (2), this data does not necessarily represent 18 sprouted tubers. There were significantly more shoots at the soil surface for the irrigated treatment than for the non-irrigated treatment, however.

During the fourth year, the non-irrigated tubers produced significantly more sprouts than in any other year (Fig. 1). This is probably due to moisture. A total of 13.49 inches of precipitation fell in 1978, the fourth year of burial (Table 1). Of the 13.49 inches of moisture, 11.09 inches occurred from January through April of that year. The tubers received adequate moisture for sprouting for the first time. No sprouting occurred from tubers replanted in a greenhouse in December of the fourth or the fifth year of burial indicating they spent themselves in the summer of 1978.

Moisture, however, is not the only governing factor in tuber longevity. Sprouting of non-irrigated tubers had begun to decline before the heavy precipitation of 1978 (Table 3). Non-irrigated tubers might have lived longer than the 4 years indicated in this experiment if they had not received the abnormally abundant rainfall of 1978.

Several conclusions can be drawn from these experiments. Tubers are capable of sprouting and producing a plant at the surface from as deep as 15 inches if conditions are right. Tubers have a short longevity in soil if they sprout. If no new tubers were allowed to form, a field would have few yellow nutsedge plants within about 2 years. Without the necessary moisture for sprouting, however, tubers can survive in adequate numbers to reinfest a field for 4 years and possibly longer.

Literature Cited

1. Andersen, R. N. 1968. Germination and establishment of weeds for experimental purposes. Weed Sci. Soc. Amer., Urbana, IL. 236 pp.

2. Thullen, R. J. and P. E. Keeley. 1975. Yellow nutsedge sprouting and resprouting potential. Weed Sci. 23:333-337.

THE USE OF DPX 4189 FOR WEED CONTROL IN SMALL GRAINS

W. E. Dyer and P. K. Fay[1]

Abstract: DPX 4189 {2-chloro-*N*-[(methoxy-6-methyl-1,3,5-triazine-2-yl) aminocarbonyl]-benzene sulfonamide} is a promising new herbicide for the control of annual and perennial weeds in small grains. Field trials were initiated in 1979 to study the effects of DPX 4189 on Canada thistle (*Cirsium arvense*) regrowth the year after treatment. Rates of .03, .06, and .12 kg/ha were applied in July as salvage treatments in heavily infested spring wheat. There was excellent control of Canada thistle and no crop injury. The highest rate provided 90% control of regrowth through June of the following year. Common labeled treatments provided less than 50% control one year after application.

Field tests were conducted in 1980 to study the tolerance of spring wheat to DPX 4189. The herbicide was applied once a week for 7 weeks to weed-free wheat. There was a slight reduction in plant height and yield at several stages of development. Greenhouse studies indicate that DPX 4189 is subject to leaching in soil columns.

[1]Research Assoc, and Asst. Professor, Plant and Soil Science Department, Montana State University, Bozeman, MT 59717.

GLYPHOSATE PHYTOTOXICITY AND TRANSLOCATION IN POTATOES PRIOR TO TUBER INITIATION

Larry K. Hiller and Douwe Smid[1]

Abstract. The objective of these studies was to determine the potential use of glyphosate [*N*-(phosphonomethyl)glycine] for control of volunteer potatoes (*Solanum tuberosum* L. cv. Russet Burbank). Field and greenhouse experiments were conducted to observe and measure glyphosate phytotoxicity when applied at different stages of potato growth and to determine if glyphosate was translocated into the seed piece (mother tuber) prior to

[1]Assoc. Prof. and Graduate Research Asst., Department of Horticulture and Landscape Architecture, Washington State Univ., Pullman, WA 99164

initiation of daughter tubers. Symptoms of glyphosate injury appeared one day following treatment and at least 50% of the foliage was necrotic within seven days. Significant decreases in plant height, shoot and root dry matter content, and daughter tuber production were measured at the 0.28 and 0.56 kg/ha rates. Higher rates of 1.12 and 2.24 kg/ha did not produce further significant reductions.

Maximum levels of ^{14}C activity was found in all plant parts four days following application of the ^{14}C-glyphosate. The ^{14}C-glyphosate accumulated primarily in the apical meristem and roots. Extremely low levels of ^{14}C activity were detected in the original mother tuber regardless of plant age when treated. Phytotoxicity to the buds ("eyes") of the mother tuber increased in severity with increasing rates of glyphosate as shown by abnormal sprouting.

BIOASSAY AND LEACHING STUDIES WITH FLURIDONE

W. Powell Anderson and Gary Hoxworth[1]

Abstract: Fluridone {1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1*H*)-pyridinone} could be detected in soils in greenhouse studies at broadcast dosages as low as 9 gm/ha (.008 lb/A) incorporated to a depth of 5 cm by bioassaying the treated soil with barley or sorghum seedlings. The presence of fluridone was indicated by the induced chlorosis of the foliage of the bioassay plants.

Leaching studies, using sorghum as the bioassay plant, with fluridone applied to the surface of columns (11.4 cm diam. by 12.5 cm high) of air-dry and pre-wetted (field capacity) clay and sandy loam soils at an equivalent dosage of 1.12 kg/ha indicated that:

A. When applied to the surface of the air-dry, clam loam soil columns, 2.5 ha-cm of water did not leach detectable amounts of fluridone below the layer of soil initially treated with the herbicide. Similarly applied, 10 ha-cm of water leached detectable amounts of fluridone to a depth of about 6.4 cm, and fluridone was distributed throughout the soil profile down to this depth.

B. When applied to the surface of the pre-wetted, clay loam soil columns, 2.5 ha-cm of water leached detectable amounts of fluridone to a depth of about 1.25 cm. Similarly applied, 10 ha-cm of water leached detectable amounts of fluridone to about 8 cm. In both cases, the fluridone was distributed throughout the soil profile down to the maximum depth of leaching. With the pre-wetted soil columns, the amount of water added to the surface of the columns apparently passes through the columns, as an equal amount of water was caught and measured at the base of the columns.

C. Fluridone was more readily leached in the sandy loam soil than in the clay loam soil. When applied to the columns of air-dry, sandy loam soil, 2.5 ha-cm of water leached detectable amounts of fluridone to a depth of about 5 cm; 10 ha-cm of water leached fluridone to a depth of about 10 cm.

When applied to the columns of pre-wetted, sandy loam soil, 2,5 ha-cm of water leached fluridone in detectable amounts to a depth of about 7.5 cm; 10 ha-cm of water leached fluridone to a depth of more than 12.5 cm. In each case, fluridone was distributed throughout the soil profiles down

[1]Agricultural Experiment Station, New Mexico State Univ., Las Cruces, NM 88003.

to the maximum depth of leaching. With the pre-wetted soil columns, the amount of water added to the surface of each column apparently passed through the column, as an equal amount of water was caught and measured at the base of the column.

D. Fluridone was "reverse leached" in pre-wetted (subirrigated) soil columns in detectable amounts to heights of about 4 cm, 5 cm, and 6 cm by 5 ha-cm, 7.5 ha-cm, and 10 ha-cm of water, respectively, passing upward by capillarity through the layer of fluridone-treated soil and through 12.5 cm of soil located above the layer of treated soil.

THE EFFECT OF S-TRIAZINE HERBICIDES WITH NOTOX ON S-TRIAZINE SENSITIVE CROPS

Randi K. Nelson and K. C. Hamilton[1]

Abstract: Atrazine [2-chloro-(4-ethylamino)-6-(isopropylamino)-*s*-triazine] or simazine [2-chloro-4,6-bis-(ethylamino)-*s*-triazine], and NoTox 'Triazine Neutralizer' were soil-applied under greenhouse conditions to determine their effect on survival and growth of the s-triazine sensitive crops: cotton (*Gossypium hirsutum* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), and alfalfa (*Medicago sativa* L.). Time of application, time of planting, soil moisture, prior absorption of s-triazine in the soil, reaction in solution, and rates or ratios of herbicide and neutralizer were tested as to their effect on possible s-triazine-NoTox interactions in the soil.

Time of application. Atrazine at 1 lb/A and NoTox at 2 lb/A were applied preplant incorporated, preemergence, and postemergence over the top. Cotton stands were reduced and plants stunted whenever atrazine was applied preplant, regardless of the time of NoTox application.

Time of planting. A 7-day interval between preplant incorporated atrazine at 1 lb/A and NoTox at 2 lb/A and planting was made to determine the effect of extended reaction time on cotton. Stands were reduced in the presence of atrazine with and without NoTox at immediate and delayed planting dates.

Soil moisture. Cotton was planted in soil treated with 1 lb/A atrazine and 2 lb/A NoTox. Half of the treatments were pre-irrigated after herbicide-NoTox application and half remained dry for the 7 days between application and planting. Cotton stands were reduced in the presence of atrazine with and without NoTox under pre-irrigated and dry soil conditions.

Prior adsorption of s-triazine. Two lb/A NoTox application was delayed 23 days after application of atrazine or simazine at 1 lb/A. Wheat was planted 7 days after delayed NoTox application. The 23-day delay allowed time for s-triazine to be adsorbed prior to NoTox application. Wheat stands were reduced in the presence of herbicide regardless of the time of application of NoTox.

Reaction in solution. A tank mixed solution of 0.5 lb/A atrazine and 1 lb/A NoTox was soil-applied and incorporated 4 days prior to planting alfalfa. Stands were reduced in the presence of atrazine and NoTox applied as a pre-mixed solution and as separate consecutive sprays.

Rates and ratios. In four separate tests, cotton, wheat, barley, and alfalfa were planted immediately after soil-applied and incorporated

[1]Research Assistant and Professor, Department of Plant Sciences, University of Arizona, Tucson, AZ 85721.

atrazine or simazine at 1 lb/A and NoTox at 2, 4, and 8 lb/A. Alfalfa was also treated with atrazine at 0.125, 0.25, and 0.5 lb/A with NoTox at 0.25, 0.5, and 1 lb/A with 4 days between application and planting. In all cases stands were reduced in the presence of herbicide regardless of the presence or rate of NoTox. Phytotoxicity of NoTox alone at high rates was observed in alfalfa and barley.

In summary, no treatment reduced emergence of seedlings. NoTox did not significantly reduce phytotoxicity of simazine or atrazine in the crops examined under the experimental conditions tested.

COMPETITION BETWEEN WHEAT (*TRITICUM TURGIDUM* L. DURUM GROUP CV. MEXICALI AND *T. AESTIVUM* L. CV. ANZA) AND WILD OATS (*AVENA FATUA* L.)

J. F. Henson and L. S. Jordan[1]

Abstract: Topgrowth and total nitrogen of Anza and Mexicali wheat and wild oats grown in pure stands were approximately the same at maturity when nutrients were supplied with a 1.5 mM nitrate Hoagland's solution. When the nitrate content of the solution was increased to 15 mM, topgrowth and total nitrogen of pure stands of Anza and wild oats increased about threefold, with a twofold increase for Mexicali. Both wheat genotypes, when supplied with the 15 mM nitrate solution and in a 1:1 wheat to wild oat ratio, had greater topgrowth and total nitrogen than would be expected from comparing the biomass and total nitrogen of pure stands. When wild oat populations were increased to a ratio of 5 wild oats to one wheat plant, both topgrowth and total nitrogen for each wheat genotype were severely reduced and differences between them disappeared. When the nitrate content of the nutrient solution was 15 mM, the approximate ratio of Anza to Mexicali for grain yield was 1.8, 1.5, and 1.0 in wild oat free conditions, in a wheat to wild oat ratio of 1:1, and 1:5 respectively.

[1]University of California, Riverside.

CHEMICAL AND CLIPPING EFFECTS ON LEAFY SPURGE (*EUPHORBIA ESULA* L.) ROOT DRY MATTER CONTENT

B. K. Landgraf and L. O. Baker[1]

Abstract: Leafy spurge is one of the most difficult perennial weeds to control. A well-established infestation requires two or more years of intensive tillage to deplete the root reserves to a level that they cannot reestablish topgrowth. One application of 2,4-D [(2,4-dichlorophenoxy) acetic acid] was reported to have no more effect on root reserves than a single tillage operation. This study was conducted to determine the effect of repeated clipping and chemical treatment of leafy spurge topgrowth on root dry matter content.

Clipping at an 18-day interval was more effective than shorter or longer intervals. Contact herbicides were more effective than 2,4-D

[1]Research Assistant and Asst. Professor, Plant and Soil Sicence Department, Montana State University, Bozeman, MT 59717.

because they did not stimulate bud dormancy. Leafy spurge regrowth was slower following application of 2,4-D; however, root dry matter production was not reduced. The reduction in root dry matter content was similar following clipping or chemical application. Leafy spurge roots were unable to regenerate new topgrowth when root dry matter content was reduced 88 to 90%.

EVALUATION OF REPETITIVE HERBICIDE TREATMENTS FOR LEAFY SPURGE CONTROL

R. E. Vore and H. P. Alley[1]

Abstract: Due to the habitat and persistent, perennial nature of leafy spurge (*Euphorbia esula* L.), this species has become a serious problem in the western United States and Canada. A field study was initiated May 25, 1978, near Devil's Tower, Wyoming, to evaluate efficacy of repetitive herbicide treatments. Evaluations were based on grass production and suppression of leafy spurge shoot and root growth.

Original treatment evaluations, 24 months after application, showed picloram (4-amino-3,5,6-trichloropicolinic acid) 2% beads and K salt at 2.0 lb ai/A maintained 95 and 96% top growth control, respectively. Retreatment with picloram (K salt) at 1.0 lb ai/A had the greatest capacity in improving top growth control of original treatments which included picloram (2% beads and K salt) at 0.5, 1.0 and 2.0 lb ai/A, picloram plus 2,4-D [(2,4-dichlorophenoxy)acetic acid] amine at 0.5 + 1.0, 1.0 + 2.0 and 2.0 + 4.0 lb ai/A, and dicamba (3,6-dichloro-*o*-anisic acid) at 4.0 and 8.0 lb ai/A. Initial root control evaluations were based on excavations of the primary root system to depths of 6 to 8 inches. Later excavations were made on the primary root system, which were found to be dead to a maximum depth of 16 inches. Most recent evaluations were made to determine reductions of the entire root system. Excavations in control plots revealed 936.5 root segments weighing 47.3 grams per cubic foot of soil. All original/retreatment combinations reduced root numbers and weight significantly (58 to 99% reduction). Average forage production measurements from two years data reveal an increase of 218 to 724 lb of air dry forage per acre resulting from herbicide treatments, as compared to the untreated area production.

[1]University of Wyoming, Plant Science Division, Laramie, WY 82701 (SA-1089)

ROLLER AND WICK APPLICATIONS OF HERBICIDES FOR LEAFY SPURGE (*EUPHORBIA ESULA* L.) CONTROL IN PASTURES

Rodney G. Lym and Calvin G. Messersmith[1]

Leafy spurge (*Euphorbia esula* L.) was discovered in North Dakota in 1909, and has spread statewide to infest over 600,000 acres. The infestation has increased over 100,000 acres since 1973. Leafy spurge is not a problem in cropland where regular cultivation controls the plant, but the

[1]Research Associate and Professor, respectively, North Dakota State University, Fargo, ND.

weed infests many acres of pasture and rangeland which reduces grazing capacity greatly. Leafy spurge reduces both forage production through direct weed competition and forage utilization by livestock. The weed contains a digestive irritant so most livestock, especially cattle, do not graze in infested areas to prevent accidental consumption of the purgative and emetic substance (1).

Picloram (4-amino-3,5,6-trichloropicolinic acid) at 2 lb ai/A applied from early June to mid-September will give over 90% control when evaluated the growing season after treatment. However, this effective treatment often is not economical because of the high picloram cost and the large acreage infested by leafy spurge.

Alternatives to broadcast herbicide application, including the roller and wick applicators, are being studied at North Dakota State University, to reduce the cost of leafy spurge control.

Materials and Methods

The roller applicator was compared to conventional broadcast application of picloram for leafy spurge control. The primary component of the roller applicator is an 8 inch diameter pipe covered with a 0.5 inch thick carpet. Herbicide is applied to the carpet from a storage tank via a plastic pipe that runs the length of the roller until the carpet is uniformly moistened. The roller rotates at approximately 50 rpm in a counter-clockwise direction as the applicator moves forward, thus lifting the weeds for good contact with the carpet. The roller height was adjusted so the upper half of most of the leafy spurge stems was treated.

A wick applicator also is being tested for leafy spurge control. The design differs from the more common rope-wick applicators in that the pipe is much smaller at 0.75 inch diameter and there is no rope. Instead 0.125 inch holes are drilled every 2 inches into one side of the pipe. These holes are covered by a strip of 0.25 inch thick foam rubber which in turn is covered by a canvas material. The system is sealed to prevent dripping. Herbicide is wicked onto the plant as the leafy spurge rubs against the canvas. The wick used here has two pipes 1 foot apart which allows the leafy spurge to nearly become upright after being wicked by the first pipe before being retreated by the second pipe.

Broadcast applications of picloram were applied with a backpack sprayer delivering 8.5 gpa at 35 psi. The ground speed of the roller and wick varied from 1 to 3 mph depending on the terrain of the experimental site. Solution concentration on the roller and in the wick was 1:7 (picloram: water, v:v), the same as 2 lb ai/A at 8 pga broadcast unless stated otherwise. Comparisons of control between broadcast and the roller application were in a randomized complete block design with four replications.

The first experiment, established on September 22, 1978, compared leafy spurge control with picloram when applied broadcast or with the roller applicator with and without a foam additive. The second experiment established on October 3, 1979, evaluated leafy spurge control with picloram when roller applied late in the season.

Estimates of the actual volume applied by the roller and wick applicators were made on areas of leafy spurge approximately 1 A in size with at least an 80% stand of leafy spurge throughout. The picloram:water ratio was 1:7.5 or 1:7 (v:v) with the roller and 1:3 (v:v) with the wick applicator, except dicamba (3,6-dichloro-*o*-anisic acid) was applied instead of picloram at one site.

A third experiment was established on June 16, 1980 to compare the leafy spurge control using various picloram:water ratios ranging from 1:1 to 1:15 (v:v) applied with a 5% crop oil additive. All treatments were compared to picloram applied broadcast at 1 and 2 lb ai/A. Six soil samples to an eight inch depth were taken from each plot 19 weeks after treatment. The soil samples were bioassayed using sunflower (*Helianthus annuus* L.) to determine the amount of picloram in the soil. Sunflower height, and fresh and dry weight were used to determine the picloram residual in the soil. The experimental design was completely random with three replications.

Results and Discussion

Leafy spurge control with picloram at 2 lb ai/A was similar when applied either broadcast or with the roller (Table 1). Roller application of picloram with the foam additive gave better control than without the additive, especially at 3 mph. However, up to 6% grass injury was noted when the foam was added. The leafy spurge control declined over the two year period, but the broadcast and roller treatments were similar. Control exceeded 80% when applied with the roller plus a foam additive and broadcast at 2 lb ai/A in late May, 1980. However, leafy spurge control declined at least 10% from May 1980 to late August 1980 to a range where retreatment probably would be recommended. The fact that roller and broadcast applied treatments showed similar control over 2 years may indicate that leafy spurge control with picloram is due to translocation within the plant soon after treatment and not the long soil residual of picloram.

Table 1. Leafy spurge control with picloram using roller applicator for treatments applied September 22, 1978 near Valley City, ND.

			Control (%)			
Type of application	Additive	Rate[a] (lb/A)	May 31, 1979	August 29, 1979	May 30, 1980	August 27, 1980
Broadcast	None	1	88	82	74	65
Broadcast	None	2	98	91	88	72
Roller - 1 mph	None	2	91	87	82	66
Roller - 3 mph	None	2	94	69	52	36
Roller - 1 mph	Foam	2	97	94	94	77
Roller - 3 mph	Foam	2	97	88	83	73
Control	----	-	0	0	0	0
LSD (0.05)			9	10	17	23

[a] Solution concentration on the roller was the same as 2 lb ai/A at 8.5 gpa broadcast.

Leafy spurge control was variable for treatments applied late in the season with the roller applicator (Table 2). Early observations in May, 1980 showed both treatment methods at nearly 100% control but only picloram broadcast at 2 lb ai/A gave good control by June 24, 1980. A possible explanation for the large decrease in control is that many of the leaves had senesced, the plants were nearly dormant, soil and air temperatures were low and a hard freeze occurred 6 days after treatment. Thus partial translocation of picloram into the root system probably accounted for control of only the upper-most buds, but the buds below this area probably emerged accounting for substantial new growth in June.

Table 2. Leafy spurge control with picloram using the roller applicator near Walcott, ND for treatments applied October 3, 1979.

Type of application	Rate[a] (lb/A)	Control in 1980 (%)	
		May 8	June 24
Broadcast	1	99	79
Broadcast	2	100	100
Roller - 1 mph	2	99	80
Roller - 2 mph	2	94	77
LSD (0.05)		6	27

[a]Solution concentration of the roller was the same as 2 lb ai/A at 8.5 gpa broadcast.

The wick applicator was utilized extensively in 1980, with solution concentrations of picloram:water ranging from 1:1 to 1:15 (v:v). Visual observations indicated that the aboveground leafy spurge vegetation was controlled but an accurate comparison of wick, roller, and broadcast application techniques must await evaluation in 1981 during the growing season after treatment.

Estimates of the amount of herbicide applied with the roller and wick applicators are shown in Table 3. The roller applicator applied 30 to 53%

Table 3. Estimates of amount of herbicide applied per acre on leafy spurge using roller and wick applicators at various sites in North Dakota.

Application method and location	Acres[a] treated	Gallons applied	Herbicide[b] and conc (v:v) (herb.:water)	Rate applied	
				lb/A[c]	% of broadcast rate [d]
Roller					
Valley City (1978)	0.78	3	Picloram (1:7.5)	0.89	44
Sheldon	0.82	2	Picloram (1:7)	0.6	30
Valley City (1980)	0.68	2.9	Dicamba (1:7)	2.14	53
Tolna	0.80	3	Picloram (1:7)	0.93	47
Minot	0.99	2.65	Picloram (1:7)	0.66	33
Wick					
Sheldon	1.65	1.09	Picloram (1:3)	0.33	17
Tolna	0.48	0.9	Picloram (1:3)	0.45	23
Minot	0.99	1	Picloram (1:3)	0.50	25

[a]Areas had 80% or greater infestation of leafy spurge.

[b]Picloram contained 2 lb ai/gal and dicamba contained 4 lb ai/gal.

[c] $\text{lb/A} = \frac{[\text{total solution volume applied (gal)}]\,[\text{herbicide ai (lb/gal)}]}{\text{Area (acres)}}$

[d]Broadcast rate with picloram was 2 lb ai/A, dicamba was 4 lb ai/A.

as much picloram and the wick applied from 17 to 25% as much herbicide as broadcast treatments at 2 lb ai/A. This represents a reduction in herbicide use of 50 to 70% with the roller and 75 to 80% with the wick applicator. Areas with lower leafy spurge densities per acre would use even smaller amounts of herbicide since only plants touched by the applicator are treated.

Preliminary observations indicated acceptable topgrowth control from all roller and wick treatments, regardless of the herbicide solution concentration. However, the soil bioassay did show differences in the amount of picloram in the soil. Picloram applied broadcast at 2 lb ai/A had a residual of 0.17 ppm and the application of 1:1 (v:v) was very similar with 0.19 ppm picloram residual (Table 4). The roller application of 1:1, 1:3,

Table 4. Estimates of the picloram residue in soil 19 weeks after application for treatments applied near Sheldon, ND, in 1980 by a sunflower bioassay.

Application method	Rate (lb/A)/conc. (v:v)	Picloram residue (ppm)
Broadcast	1	0.03
Broadcast	2	0.17
Roller	1:1	0.07
Roller	1:3	0.06
Roller	1:7	0.03
Roller	1:7 + 5% crop oil	0
Roller	1:11	0
Roller	1:15	0.05
Wick	1:1	0.19
Wick	1:3	0.04
Wick	1:3 + 5% crop oil	0.06
Wick	1:7	0
Wick	1:11	0
Wick	1:15	0.01
Untreated control	----	0

and 1:15 (v:v) and the wick application of 1:3 (v:v) and 1:3 plus 5% crop oil additive all had an equal or larger amount of picloram reamining in the soil than the broadcast treatment at 1 lb ai/A. The roller application at 1:7 plus an additive had no residual picloram but the 1:15 treatment had 0.05 ppm for an unknown reason. In general the picloram residual in the soil with each treatment follows the picloram solution concentration of the wick and roller applicator.

The roller application at 1:7 (v:v) had the same picloram residual as broadcast at 1 lb ai/A (Table 4) while this roller treatment givew leafy spurge control similar to picloram applied broadcast at 2 lb ai/A (Table 1). The wick application of 1:3 plus an additive had similar residual to the roller at 1:3 and the broadcast treatment at 1 lb ai/A and could be expected to give good leafy spurge control. The picloram probably is reaching the soil through several methods including washing from treated plants, release through decomposition of treated stems and roots, and exudation from the roots of treated plants directly into the soil.

These experiments indicate that the roller application is an effective method of applying picloram for leafy spurge control. Picloram applied with the roller at a solution concentration of 1:7 (v:v) provided similar leafy spurge control to picloram broadcast at 2 lb ai/A with much less picloram residual in the soil. The wick application holds promise and is being evaluated further. Both methods should substantially reduce the amount of herbicides used, thus reducing potential herbicide residue problems and costs for the landowner.

Literature Cited

1. Messersmith, C. G. 1979. The leafy spurge plant (*Euphorbia esula* L.) Proceedings. Leafy Spurge Symposium, Bismark. North Dakota Cooperative Extension Service, Fargo ND. p 1-7a.

ROPEWICK GLYPHOSATE APPLICATION

R. L. Miller, R. H. Lockerman, and C. R. Hunt[1]

Abstract: A 50% glyphosate [*N*-(phosphonomethyl)glycine] solution was applied to several perennial weed types in established pasture and native rangeland. Chemical and equipment efficiency was evaluated under conditions of variable terrain, plant growth habit, and growth stages. Glyphosate suppressed top growth of leafy spurge (*Euphorbia esula* L.) 75% during the flower stage in an established pasture. However, removal of central axis apical dominance resulted in a 32% increase in rhizomatous vegetative reproduction. Wild iris (*Iris missouriensis* Nutt.), elk thistle [*Cirsium foliosum* (Hook.) D.C.], and rubber rabbitbrush [*Chrysothamnus nauseosus* (Pall.) Britt.] were suppressed 100% ten weeks after application in seeded and native range. Differential rigidity among plant species caused chemical splashing around some plant species as the application bar passed. Crop injury around elk thistle and rubber rabbitbrush was approximately 17% ten weeks after application. Musk thistle (*Carduus nutans* L.) was supressed 90% in the flower bud stage. Some plants escaped injury due to the tractor tires breaking the plants close to the soil surface. Escapes in all plant species except leafy spurge were directly related to stem rigidity. Yellow toadflax (*Linaria vulgaris* Hill.) and needleleaf sedge (*Carex eleocharis* L.) were suppressed 100 and 78%, respectively, on native rangeland with no crop injury. Noncontrolled needleleaf sedge plants resulted from heavy stand densities which did not allow for good chemical coverage. Control and crop injury was also directly related to terrain.

[1]Research Tech. and Asst. Professor, Montana State University, and Senior Development Assoc., Monsanto Company, respectively.

INTEGRATED WEED CONTROL SYSTEMS ON SAGEBRUSH RANGELANDS

R. A. Evans and J. A. Young[1]

Abstract: Comprehensive large-scale studies are being conducted on establishment and evaluation of alternative weed-control systems on degraded rangelands in central Nevada by SEA/AR, U.S. Department of Agriculture in cooperation with the Nevada Agricultural Experiment Station. Weed control-seeding alternatives being evaluated are: (1) spraying 2,4-D [(2,4-dichlorophenoxy)acetic acid] for brush control and seeding crested wheatgrass (*Agropyron cristatum* (L) Beauv.) and grass-forb-shrub mixtures; (2) spraying 2,4-D for brush control and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] for downy brome (*Bromus tectorum* L.) control with seeding; (3) plowing for brush and weed control with seedling; (4) prescribed burning for brush and weed control with and without seeding; and (5) check. These alternative treatments will be subjected to and evaluated with the following cattle grazing treatments: (1) season-long grazing; (2) rest-rotation grazing treatments; and (3) non-grazing. The study consists of 14 - 40 acre plots enclosed separately with electric fencing.

Evaluations of weed control, seedling establishment and forage production, cattle production, wildlife and watershed responses, and economic benefits are being made in relation to the 14 weed control-seeding and grazing management alternatives.

At this time, base data has been collected on each facet of the study before treatment were applied, the weed control-seeding treatments have been established, and some have been evaluated for brush and weed control and seedling establishment of forage plants. Cattle grazing on the treatment areas will commence in the fall of 1981.

Results of this study will form the basis for recommendations of technologies of weed control and seeding and grazing management for the improvement of degraded sagebrush rangelands in the Intermountain region of the United States.

[1]U.S. Department of Agriculture, SEA/AR, University of Nevada, 920 Valley Road, Reno, NV 89512.

SELECTIVE CONTROL OF FOXTAIL BARLEY IN GRASS STANDS IN WESTERN WYOMING

Ralph Simnacher, Harold Alley, and Leslie Burrough[1]

Foxtail barley (*Hordeum jubatum*), a very common weedy species, occurs on dry and moist areas from sagebrush desert and the plains through the foothills to the mountain forest, and is particularly troublesome in the Central and Rocky Mountain regions.

The Wyoming Weed and Pest Law of 1973 gave us a definite list of weed species to control which does not include foxtail barley. Farmers and ranchers frequently requested a chemical control for foxtail barley, which in some cases had taken over had meadows and pastures reducing production drastically and causing injury to their livestock.

In 1977 it was noted in the Farson area that pronamide [3,5-dichloro (*N*-1,1-dimethyl-2-propynyl)benzamide] controlled foxtail barley in alfalfa

[1]Sweetwater County Weed and Pest Control, Farson, WY.

and many other grasses survived. The initial trial was at 1.5 lb ai/A. pronamide. Since then rates have debreased to as low as .25 lb ai/A. Vel 5026 was also tried in some of the 1977 trials. Other small trials using pronamide were conducted in 1978.

Experimental plots were established December 10, 1979, near Farson, Wyoming, and April 28, 1980, near Pinedale, Wyoming, on moist hay meadows and grass pasture to evaluate four herbicides. Three replications at varied rates of herbicides were applied to one square rod plots in a random manner with a backpack sprayer equipped with an 8004 nozzle applying 40 GPA at 20 psi. Soils were frozen to semi-frozen and plants were dormant at the time of application. Soil texture varied from clay loam, sandy loam, to loamy sand with an organic matter range of 0.7 to 1.8% and soil pH varied from 8.1 to 8.9. The temperature ranged from 28° to 38°F with wind velocities of 0 to 7 mph at time of application. Other grasses in the test area were quackgrass (*Agropyron repens*), smooth brome (*Bromus inermis*), common meadow foxtail (*Alopecurus pratensis*), garrison creeping meadow foxtail (*Alopecurus arundinacea*), redtop (*Agrostis alba*), and alkali sacton (*Sporobulus airoides*).

The experimental plots were evaluated August 21, 1980 (Table 1). Pronamide gave the most consistent results in both spring and fall trials. Spring trials with pronamide demonstrated from 82 to 100% control of foxtail barley. The lower rates, .25 lb ai/A to .75 lb ai/A, produced no damage to other grasses but at 1.0 lb ai/A there was approximately a 10% reduction in production. In the fall trial near Farson the 1.0 lb ai/A rate resulted in 30 to 40% reduction in the other grasses.

The fall and spring trials produced from 70 to 100% control of foxtail barley in all plots except with the lowest rates of metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one]. Metribuzin results were the most variable throughout the trials. Terbacil (3-*tert*-butyl-5-chloro-6-methyluracil) and hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4-(1*H*,3*H*)-dione] treatments resulted in good control of foxtail barley but were too severe on the other grasses.

An evaluation of the results of all trials in relationship to soil texture, organic matter, and soil pH indicated no pattern of variation that was significant.

Removal of foxtail barley with herbicides is only a temporary cure. Establishment of competitive species such as reed canary grass (*Phalaris arundinacea* L.) or garrison creeping meadow faxtail can domiante and crowd out faxtail barley in most high alkali areas. Irrigation management and drainage or wet areas should be practiced in conjunction with use of herbicides to get desirable grass establishment.

Table 1. Results of fall and spring applied herbicides for control of foxtail barley (*Hordeum jubatum* L.) in grass stands.

Chemical	Rate (lb ai/A)	Control (%)	Remarks[1]
Pronamide	0.25	82	Other grasses not injured
	0.5	98	Other grasses not injured
	0.75	99	Other grasses not injured
	1.0	100	Slight injury to other grasses
Metribuzin	0.25	13	Other grasses not injured
	0.5	60	Some other grasses suppressed
	0.75	93	*Sporobulus* removed, other grasses not injured
	1.0	94	*Sporobulus* removed, other grasses injured, *Alopecurus* not injured
Terbacil	0.5	90	Some injure to other grasses
	1.0	96	Removed other grasses
	1.5	98	Removed other grasses
Hexazinone	0.25	80	Variable injury noted
	0.5	93	Removed other grasses
	0.75	97	Removed other grasses
	1.0	99	Bare

[1]Other grasses included: *Sporobulus airoides, Agropygon repens, Bromus inermis, Alopecurus patensis, Alopecurus arundinacear,* and *Agrostis alba.*

STUDY OF THE COMPETITIVE EFFECT OF DWARF SPIKERUSH ON VARIOUS AQUATIC WEEDS[1]

R. R. Yeo and J. R. Thurston[2]

Dwarf spikerush [*Eleocharis coloradoensis* (Britt.) Gilly] is a short-growing aquatic plant that belongs to the sedge family, Cyperaceae, and is native to California. It usually grows to a height of only two inches in full sunlight. It forms very dense sodlike growths that will dislpace several kinds of rooted submersed aquatic plants in certain aquatic situations. In the Corning Canal near Red Bluff, California, it has displaced sago (*Potamogeton pectinatus* L.), slender, and curleyleaf pondweeds (*P. crispus* L.) and American and Nuttall's elodea. In California Exposition Lagoon in Sacramento, and in a small pond in Monterey, it has displaced leafy pondweed (*P. foliosus* Raf.). These are a few of the aquatic weeds and sites where dwarf spikerush has effectively controlled or prevented the influx of these aquatic weeds. An experiment was conducted to determine

[1]Contribution of the U.S. Dep. of Agric. in cooperation with the California Exp. Stn.; Mid-Pacific Region, Water and Power Res. Serv., D.S. Dep. of the Interior, and the California Dep. of Water Res.

[2]Botanist and Biologist, respectively, AR, SEA, USDA, Davis, CA 95616

some of the effects of dwarf spikerush on several important species of waterweeds growing in California.

In May, 1979, ninety 75-L plastic growth containers, each with a bottom surface of 0.21 m^2, were place outdoors under shade cloth providing 55 percent shade. Eight cm of Yolo clay loam soil were placed in each growth container for a growing substrate. The growth containers were filled with well water for two weeks to allow the soil to stabilize. The experimental design required dividing the 102 containers into eight groups of twelve for aquatic weed and dwarf spikerush treatments and one group of six for controls of dwarf spikerush. Each of the twelve growth containers with a group was planted with nine tubers, seedlings, or stem cuttings of one of the following aquatic weeds: American (*Potamogeton nodosus* Poir.), sago, or horned pondweed (*Zannichellia palustris* L.), American or Nuttall's elodea, hydrilla, Eurasian watermilfoil (*Myriophyllum spicatum* L.), and common coontail (*Ceratophyllum demersum* L.). After planting, the aquatic plants were allowed to establish and grow for four weeks. Dwarf spikerush tubers were then planted in six of the twelve containers that contained each kind of plant at a density of 1,296 tubers per 0.21 m^2. The control group of six growth containers was planted with only dwarf spikerush tubers, at the same density. Water was exchanged periodically to remove unwanted filamentous algae. The data measured and reported in this paper includes the average number of shoots and total plant dry weights per 0.21 m^2 of each aquatic weed growing with and without dwarf spikerush. The numbers of tubers of tuber-bearing species was also counted. The final data were collected at the end of the second growing season, October 1980. The data were analyzed and the statistical significance determined using Student's t-Test.

Table 1 shows the number of plant shoots, tubers and plant dry weights of the different aquatic weeds. With the exception of Eurasian watermilfoil, all of the values were less for the plants grown with dwarf spikerush. The number of shoots was reduced by 50 percent or more, dry weight was reduced at least 65 percent, and the number of tubers of tuber-bearing plants was reduced 53 percent or more.

American pondweed forms both floating and submersed leaves. When American pondweed plants were grown with dwarf spikerush, the petioles of many of the floating leaves were stunted, apparently due to the competition caused by the dwarf spikerush.

Several hydrilla tubers that had been formed in the growth containers with and without dwarf spikerush were examined histologically. No aberrations were found in sections of tubers grown with dwarf spikerush.

Common coontail plants did not grow satisfactorily in the growth chambers despite repeated efforts to replant them early in 1979. Data on this plant was not obtained.

Table 1. Effect of dwarf spikerush on the number of shoots and tubers and plant dry weights of several aquatic weeds.

Plant part measured	Number, plant parts Plants grown alone[1]	Number, plant parts Plants grown with dwarf spikerush	T-test[2]
	American pondweed		
Shoots[3]	121	38	4.9**
Entire plant[4]	35	9	6.8**
Tubers[3]	156	73	3.2**
	Sago pondweed		
Shoot	85	11	2.2[5]
Entire plant	31	11	2.8*
Tubers	740	286	3.1*
	Hydrilla		
Shoot	33	16	4.6**
Entire plant	69	17	7.8**
Tubers	76	36	3.6**
	Horned pondweed		
Shoot	645	34	3.7**
Entire plant	10	0.01	4.0**
	Nuttal's elodea		
Shoot	102	17	3.7**
Entire plant	54	7	5.8**
	American elodea		
Shoot	96	18	6.5**
Entire plant	45	9	5.3**
	Eurasian watermilfoil		
Shoot	20	19	NS[5]
Entire plant	50	40	NS[5]

[1]Mean values for six replicates.

[2]Student's t-Test; ** indicated significance at the 1% level and * indicates significance at the 5% level.

[3]Number counted in 0.21 m^2.

[4]Dry weight (g) of entire plants in 0.21 m^2.

[5]Treatments significant at the 10% level.

RESPONSE OF ACALA COTTON VARIETIES TO PREPLANT TRIFLURALIN OR LAYBY DIURON

J. H. Miller, C. H. Carter, R. H. Garber, and H. B. Cooper[1]

Abstract: For three years, four varieties of cotton (*Gossypium hirsutum* L.) were treated with either preplant-incorporated trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) at 0.84 kg/ha; layby diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] at 1.4 kg/ha; or with no herbicide. All plots were cultivated four times each season. Varieties used all three years were 'Acala SJ-3', 'Acala SJ-4', and 'Acala G8160' (a gossypol free variety). 'Acala SJ-3', used in the first year, was replaced by 'Acala SJ-5' in the second and third years. While the response from varieties varied, herbicide treatments did not influence cotton emergence, lint yield, or fiber properties including length, uniformity, strength, elongation, or fineness of any variety. Herbicide treatments did not influence the occurrence of foliar symptoms of Verticillium wilt (*Verticillium dahliae* Kleb.) although the varieties varied from one another.

Introduction

Herbicides have become an integral part of modern cotton production systems and it is doubtful whether the industry would survive without them. While large numbers of herbicides are used in cotton, few studies have dealt with cotton varietal responses to herbicides. In 1954, Normand (4) reported no varietal differences in cotton stand reductions caused by chlorpropham (isopropyl-*m*-chlorocarbanilate) or monuron [3-(*p*-chlorophenyl)-1,1-dimethylurea]. He suspected, however, that a varietal difference in stand reduction was associated with dinoseb (2-*sec*-butyl-4,6-dinitrophenol). Waddle, et al. (5) conducted a three year study using four varieties, 'Fox', 'Deltapine 15', 'Empire WR', and 'Arkot 2-1', planted on three dates and treated with preemergence chlorpropham, dinoseb, diuron, or no herbicide. They found the variety by herbicide interaction to be nonsignificant in each of the years, as well as in the combined data over years. However when dates were also considered, a significant interaction occurred in the combined data. The interaction was due to the deleterious effect of dinoseb on the late planted 'Arkot 2-1' variety in 1954. They reported this variety germinates poorly under stress of high temperatures and that dinoseb aggravated this condition in one season. They concluded that, given a normal planting season, these herbicides would not have a deleterious effect on most cotton varieties. Baker (1) compared two early maturing varieties, 'DES 21326-04' and 'Lockett 4789A', with 'Stoneville 213'. The varieties responded similarly to various herbicide combinations including dinitramine (N^4,N^4-diethyl-α,α,α-trifluoro-3,5-dinitrotoluene-2,4-diamine), fluometuron [1,1-dimethyl-3-(α,α,α-trifluoro-*m*-tolyl)urea], MSMA (monosodium methanearsonate), dinoseb, and prometryn [2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine]. Bourland, et al.(2) recorded lateral root development of seeds of 20 varieties of cotton subjected to 0 and 1 ppm concentrations of trifluralin in germination tests on paper. In this laboratory study, they found that the varieties 'McNair 235', 'Stoneville 603', 'PD 875', 'DES 56', 'Tamcot CAMD-E', 'Deltapine 26', 'Coker 315', and 'Deltapine 15' were more tolerant to trifluralin than the varieties 'Coker 304', 'DES 24', 'Stoneville 256', 'Tamcot SP37H', 'Deltapine 55', 'Stoneville 213' or 'Tamcot SP21S'.

The research reported here was undertaken to determine whether Acala

[1]Research Agronomist, Agronomist, Research Pathologist, and former Plant Breeder, AR, SEA, USDA, U.S. Cotton Research Station, Shafter, CA 93263

cotton varieties associated with production in the San Joaquin Valley of California would be deleteriously affected by trifluralin or diuron, two of the commonly used herbicides of the region.

Materials and Methods

The experiments were conducted for three years at Shafter, California on Wasco fine sandy loam (75% sand, 18% silt, 7% clay, and 0.5% organic matter). Each year four varieties of cotton were subjected to trifluralin at 0.84 kg/ha applied before the preplanting irrigation as a broadcast soil-incorporation treatment, to diuron at 1.4 kg/ha applied as a directed-broadcast spray at cotton layby, and to no herbicide. The trifluralin was applied in 370 L/ha of water and soil incorporated 7.5 cm deep the same day with a powered tiller. Beds were formed, and a furrow-irrigation was applied within 2 or 3 days after herbicide application. During the third week of June, the diuron, in 370 L/ha of water, was directed to the soil at the base of the cotton plant and soil-incorporated with a rolling cultivator. Furrow irrigation followed within 2 days. All plots were cultivated four times each season.

The varieties selected for study were all Acala varieties developed at the U.S. Cotton Research Station at Shafter, California. Each was selected for specific purposes. 'Acala SJ-2' is a high yielding variety in soil with low to moderate infestation of the Verticillium wilt fungus. 'Acala SJ-3', 'Acala SJ-4', and 'Acala SJ-5' are high yielding varieties in the presence of moderate to heavy Verticillium infestations, but will seldom yield as well as 'Acala SJ-2' in the absence of wilt disease. These three varieties also are usually shorter growing that 'Acala SJ-2'. 'Acala G8160' is a highly developed gossypol free (glandless) strain of cotton derived from 'Acala SJ-1'. This strain, referred to as a variety in this report, is similar to 'Acala SJ-2' in yield, growth, and wilt tolerance. All of these varieties produce high-quality strong fiber. 'Acala SJ-2', 'Acala SJ-4', and 'Acala G8160' were grown all three years. The variety 'Acala SJ-3' was deleted from the study after the first year and was replaced by 'Acala SJ-5'.

The experimental design was a split plot with herbicide treatments as whole plots. Subplots (varieties) were 4 m wide (4 rows) and 20 m long. Six replications were used.

Measurements of cotton stand, cotton yield, cotton fiber properties, and leaf symptoms of Verticillium wilt, were collected from plants in the center two rows of each subplot. The influence of treatment on cotton stand was determined by counting plants on two dates in 8 m miniplots in each subplot. The first count was made soon after plants began to emerge (10 days after planting); whereas, the second count was made about 20 days after planting. After cotton stand data were obtained, the cotton population was reduced by hand thinning to 6.5 plants/m of row. Wilt evaluations were made by counting diseased and healthy plants in 40 m of row in each subplot in September of each season. Cotton yields consisted of weights of the lint fraction of seed-cotton harvested by a spindle picker. After ginning, lint samples from each subplot were subjected to standardized fiber quality procedures. The fibergraph, the stelometer, and the fibronaire were used to determine the effect of treatment on fiber properties. Since the experimental area was essentially weed-free, weeds were not considered important in this research. Data were evaluated by using analysis of variance.

Results and Discussion

Cotton emergence, as measured by plant counts 10 days after planting, showed that varieties differed in their rate of emergence (Table 1). In the first year, 'Acala SJ-3' emerged slower than 'Acala SJ-2'. In the second year, 'Acala G8160' emerged slowest of the other four varieties, whereas, in the third year, 'Acala SJ-2' and 'Acala SJ-4 emerged less rapidly than 'Acala SJ-5' or 'Acala G8160'. Therefore no consistent pattern for early emergence was established for varieties during this study. Also, use of trifluralin did not significantly influence early emergence of any of these varieties. Data collected at about 20 days after planting showed that plant emergence was not significantly different among varieties and that trifluralin did not influence final cotton stand.

Table 1. Effect of herbicides on plant populations of cotton[a]

Acala variety	1975 Trifluralin	1975 None	1975 Avg	1976 Trifluralin	1976 None	1976 Ave.	1977 Triflur-alin	1977 None	1977 Avg
	Early stand (plants/m)								
	(4/26)[b]			(4/30)			(4/16)		
SJ-2	6.3	10.1	8.2a	12.9	13.4	13.1a	10.1	10.4	10.2b
SJ-3	5.7	5.2	5.5 b	--	--	--	--	--	--
SJ-4	6.3	7.2	6.8ab	12.6	11.3	11.9a	10.6	9.8	10.2b
SJ-5	--	--	--	11.2	11.7	11.5a	10.7	12.5	11.6a
G8160	6.5	7.2	6.9ab	9.4	8.3	8.8 b	11.3	11.5	11.4a
Avg.	6.2a	7.4a		11.5a	11.7a		10.7a	11.1a	
	Final stand (plants/m)								
	(5/9)[b]			(5/6)			(4/26)		
SJ-2	12.9	14.1	13.6a	16.8	16.3	16.5a	11.3	12.2	11.7a
SJ-3	13.4	12.7	13.1a	--	--	--	--	--	--
SJ-4	13.1	13.8	13.4a	17.9	15.5	16.7a	12.7	11.9	12.3a
SJ-5	--	--	--	16.7	16.7	16.7a	12.5	14.7	13.6a
G8160	13.9	16.3	15.1a	15.4	13.6	14.5a	12.7	12.1	12.4a
Avg.	13.4a	14.2a		16.7a	15.5a		12.3a	12.7a	

[a]Means in a line or column designated "average" within a season followed by the same letter are not different at the 5% level of probability.

[b]Date of sampling. Planting dates for 1975, 1976, and 1977 were 4/16, 4/20, and 4/8, respectively.

During this research, trifluralin never influenced cotton yield regardless of variety (Table 2). Diuron applied at layby did not alter cotton yield in the last two seasons, but during the first season, yields of 'Acala SJ-3' and 'Acala SJ-4' were reduced. The reason for this reduction is not clear. These two varieties are usually somewhat shorter growing that 'Acala SJ-2' or 'Acala G8160'. Being shorter, it is possible that a greater percentage of the foliage was contacted by the directed-postemergence diuron spray, thus affecting yield. 'Acala SJ-3' was not used in succeeding seasons, however, examination of the 'Acala SJ-4' data in subsequent years does not support this concept. In fact, 'Acala SJ-4' treated with diuron in the last two seasons, although not significantly different, tended to yield more than 'Acala SJ-4' plants receiving no herbicide or treated with trifluralin. Among varieties, 'Acala G8160' yielded significantly less than other varieties in the first season and significantly less than 'Acala SJ-5' or 'Acala SJ-2' in the second season. During the third season, there were no significant differences in yields among the varieties.

The effect of herbicides and varieties on fiber properties is reported in Table 3. While fiber properties varied with variety, the herbicide treatments did not affect fiber length (2.5% span length), fiber uniformity (uniformity index), fiber strength (T_1), or fiber elongation (E_1). Micronaire readings, independent of variety, were influenced by herbicide treatments in 1975 and 1976. In these cases, micronaire readings were lower for cotton from untreated plots compared to cotton from plots receiving trifluralin or diuron. However, none of the micronaire readings varied from normal standards sufficiently to penalize the fiber with regard to market value. Reduced micronaire is usually associated with immature fiber. Fiber strength readings (T_1), while not significantly different, tended to indicate slightly weaker fiber from the untreated plots, thus supporting the micronaire data. We do not believe that competition from the few weeds present in this study could account for immature fibers of cotton grown on the untreated plots.

The incidence of Verticillium wilt (Table 4), as measured by the percentage of plants displaying leaf symptoms, was not influenced by herbicide treatments. As expected, leaf symptoms indicated 'Acala SJ-2' and 'Acala G8160' had more wilt than the other varieties The lack of Verticillium wilt response to applications of trifluralin or diuron agrees with an earlier report by Miller, et al. (3).

This research indicates that cotton varieties associated with current cotton production in the San Joaquin Valley of California respond in a similar manner to trifluralin and diuron and under normal use are not likely to be damaged by these herbicides. While different varieties were used, the results of this research are in general agreement with findings of Baker (1) and Waddle, et al. (5).

Literature Cited

1. Baker, R. S. 1977. Response to various levels of herbicide use among cotton varieties selected for early maturity. Proc. Beltwide Cotton Prod. Res. Conferences, 179-80.

2. Bourland, F. M., S. Mesri, and B. White. 1981. Differential tolerance of cotton cultivars to trifluralin. Proc. Beltwide Cotton Prod. Res. Conferences. Jan. 6, New Orleans, LA. (In press).

3. Miller, J. H., C. H. Carter, R. H. Garber, and J. E. DeVay. 1979. Weed and disease responses to herbicides in single- and double-row cotton (*Gossypium hirsutum*). Weed Sci. 27:444-449.

Table 2. Effect of herbicides on yield of cotton.[a]

Acala Variety	1975[b] Triflur-alin	1975 Diuron	1975 None	1975 Avg.	1976 Triflur-alin	1976 Diuron	1976 None	1976 Avg.	1977 Triflur-alin	1977 Diuron	1977 None	1977 Avg.
		(kg/ha)				(kg/ha)				(kg/ha)		
SJ-2	1280	1350	1290	1310 b	1240	1230	1250	1240ab	1550	1430	1440	1480a
SJ-3	1330	1210*	1380	1310 b	--	--	--	--	--	--	--	--
SJ-4	1460	1220*	1530	1400a	1200	1260	1150	1200 bc	1430	1480	1360	1430a
SJ-5	--	--	--	--	1290	1270	1300	1290a	1480	1540	1500	1510a
G8160	1260	1150	1210	1210 c	1110	1210	1170	1160 c	1480	1380	1430	1430a
Avg.	1330a	1230a	1360a		1210a	1240a	1220a		1480a	1460a	1430a	

Lint Yield

[a]Means in a line or a column designated "average" within a season followed by the same letter are not different at the 5% level of probability.

[b]The herbicide by variety interaction in 1975 was significant at the 5% level of probability. Means (marked by an asterisk) of the varieties SJ-3 and SJ-4 were reduced by diuron. Yields were rounded to the nearest ten kilograms.

Table 3. Effect of herbicide treatment and variety on lint fiber properties[a]

Herbicide[b] (main plots)	2.5% Span Length (mm) 1975	1976	1977	Uniformity Index (%) 1975	1976	1977	Strength Index (T_1) (mN/tex) 1975	1976	1977	Elongation (E_1) (%) 1975	1976	1977	Micronaire (units) 1975	1976	1977
None	287a	290a	290a	45.6a	46.0a	46.5a	235a	221a	222a	9.19a	8.19a	8.52a	3.75 b	3.69 b	3.94a
Trifluralin	287a	290a	290a	45.5a	46.0a	46.3a	243a	226a	224a	8.34a	7.95a	8.43a	3.94a	3.82a	4.03a
Diuron	284a	290a	290a	45.9a	45.8a	46.0a	247a	226a	225a	8.57a	7.84a	8.56a	4.01a	3.73ab	4.03a
Acala Variety[b] (subplots)															
SJ-2	287a	292a	292a	44.3 b	45.7a	46.1a	240 b	220 b	216 b	8.71ab	7.94ab	8.77a	3.53 d	3.53 b	3.88 b
SJ-3	282 b	--	--	46.8a	--	--	244ab	-	--	8.88a	--	--	4.22a	--	--
SJ-4	287a	290a	287 b	46.5a	46.1a	46.5a	247a	227ab	230a	8.31 b	8.04ab	8.22 c	4.04 b	3.77a	4.01ab
SJ-5	--	290a	287 b	--	45.7a	45.9a	--	229a	230a	--	7.74 b	8.32 bc	--	3.83a	4.12a
G8160	287a	290a	292a	45.0 b	46.3a	46.7a	241 b	220 b	218 b	8.89a	8.23a	8.71ab	3.80 c	3.84a	3.99ab

[a]Data sharing a common subscript for herbicides or varieties within a season are not different at the 5% level of probability.

[b]The hericide by variety interaction was not significant at the 5% levle of probability in any season.

Table 4. Influence of herbicide and cotton variety on occurrence of Verticillium wilt (*Verticillium dahliae*).[a]

	Percentage of plants with foliar symptoms											
	1975				1976				1977			
Acala Variety	Trifluralin	Diuron	None	Avg.	Trifluralin	Diuron	None	Avg.	Trifluralin	Diuron	None	Avg.
	(%)				(%)				(%)			
SJ-2	8.8	10.0	11.7	10.2a	4.9	5.1	3.5	4.5a	7.2	12.0	15.3	11.5a
SJ-3	8.5	6.4	6.9	7.3 bc	--	--	--	--	--	--	--	--
SJ-4	6.4	4.2	6.5	5.7 c	2.0	2.5	2.7	2.4 b	4.8	6.3	3.5	4.9 b
SJ-5	--	--	--	--	2.4	2.5	2.1	2.3 b	0.7	1.0	1.2	0.9 c
G8160	8.6	7.8	12.8	9.7ab	5.4	4.3	3.2	4.3a	7.0	14.0	10.5	10.5a
Avg.	8.1a	7.1a	9.5a		3.7a	3.6a	2.9a		4.9a	8.3a	7.6a	

[a]Means in a column or line within a season followed by the same letter are not different at the 5% level of probability.

4. Normand, W. C. 1954. A study of the interaction of cotton varieties and pre-emergence herbicides. Proc. South. Weed Conf., 129-133.

5. Waddle, B. A., C. Hughes, M. N. Christiansen, and R. E. Frans. 1957. The response of selected cotton varieties to pre-emergence herbicides. Weeds 5:243-249.

EPTC ALFALFA SEED TREATMENTS

D. W. Cudney, C. E. Bell, L. S. Jordan, H. Walden, R. Russell, and J. Kastler[1]

Abstract: Nondormant desert alfalfa was tested with two rates of EPTC (*S*-ethyl dipropylthiocarbamate) seed treatment compared to a standard preplant soi-incorporated EPTC treatment at two locations in southern California. Weed control was comparable to preplant treatments, and alfalfa phytotoxicity was within an acceptable range of normal rates of application.

[1]Cooperative Ext. Weed Scientist, Coop. Ext. Farm Advisor, Professor of Horticulture, Graduate Res. Asst., Staff Res. Assoc., and Coop. Ext. Intern, University of California.

SELECTIVE POSTEMERGENCE CONTROL OF QUACKGRASS IN SUGAR BEETS AND POTATOES

R. H. Callihan and P. W. Leino[1]

Abstract: RO 13-8895 and BAS 9052 OH {2-[1-(ethoxyimino)-butyl]-5-[2-(ethylthio)-propyl-1]-3-hydroxy-2-cyclohexene-1-one} were applied to four separate groups of experimental plots to determine their efficacy in control of quackgrass (*Agropyron repens*) and to determine the tolerance of potatoes (*Solanum toberosum* L. var. Russet Burbank) and sugar beets (*Beta vulgaris*) to these chemicals.

Efficacy was determined by visual assessments of quackgrass stand in the field and by collection of treated quackgrass rhizomes from the field. These rhizomes were placed on moist media, sprouted in a growth chamber, and counted.

In sugar beets, RO 13-8895 controlled up to 90% of the quackgrass at its highest rate (1.5 lb/A); whereas, BAS 9052 OH controlled 95% of the quackgrass at its highest rate (2.5 lb/A). With the increase of herbicide efficacy and dose, the yield of sugar beet roots was increased.

Field observations of increased control of quackgrass foliage were directly related to observation of increased inhibition of sprouting of quackgrass rhizomes collected from the treated sugar beet plots. At the one and two lb/A rates of RO 13-8895, no sprouting occurred in treated quackgrass rhizomes collected from the potato field. Inhibition of sprouting increased with increase in dose with both chemicals.

No symptoms of either herbicide were found on potato plants. Sugar beets showed necrotic spot lesions at the one lb/A rate of R) 13-8895 and at the .75 lb/A rate lesions were detected on some sugar beet plants. However, yield of sugar beet roots was not affected. Potato yield also showed no dose-related differences to either herbicide.

[1]University of Idaho.

HERBICIDES REDUCE HAND LABOR REQUIREMENTS IN SUGAR BEETS

Harold P. Alley and Neil E. Humburg[1]

Abstract: The lack of effective and predictable weed control in sugar beets has long been stated as being the limiting factor in complete mechanization for the production of this crop. Contractual labor has been accused of being undependable, lazy, and not working fields where herbicides have not been utilized.

Hand labor requirements to thin and weed sugar beets have been recorded for five years by the University of Wyoming sugar beet research team. Data accumulated during this period afford a good indication of why the above mentioned accusations are commonplace. Only 1980 data from three cooperators will be reported in this paper.

Large demonstration weed control plots were established on cooperators' fields utilizing planting, preplant, and postemergence herbicide application equipment developed by the Agricultural Engineering Department. The herbicides and/or combinations were selected from those cleared for grower use. Sugar beet seed was planted at the rate of 2 to 3 seeds per foot. Labor requirements to hand weed and thin the sugar beet demonstration plots were recorded for each treatment. Hand labor required in this study was figured at $3.00 per hour. This was necessary to compare effectiveness of the various herbicide treatments and to assess the economics. Hand labor requirements in 1980 show that untreated sugar beet plots required from 21.6 to 39.1 hours per acre as compared to 4.3 to 12 hours per acre where the two most commonly utilized preplant herbicides, cycloate (*S*-ethyl *N*-ethylthiocyclohexanecarbamate) and ethofumesate [(±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate], were used. A further reduction in hand labor requirement of from 2.3 to 4 hours per acre was common where both the preplant and postemergence complementary treatments were used.

Hand labor costs to thin and weed the untreated plots averaged from $64.80 to $117.30 per acre as compared to $12.90 to $36.00 where only preplant treatments were applied. A low of from $6.30 to $11.10 per acre was realized where both preplant and postemergence treatments were utilized.

Two assumptions can be drawn from the labor studies: (1) Sugar beet growers should pay more to the hand laborer than the contract calls for to weed untreated beet fields, and (2) The use of herbicides can reduce hand labor requirements and return from $12.00 to $71.00 per acre to growers over all application, herbicide, and labor costs, if dependable labor can be hired for $3.00 per hour.

[1]University of Wyoming, Plant Science Division, Laramie, WY 82071 (SA-1088)

FEASIBILITY STUDIES FOR MINIMUM-TILL CULTURE OF SUGARBEETS IN CALIFORNIA

Robert F. Norris[1]

Abstract: The sugarbeet plant does not compete well against weeds. All current weed management programs require combinations of weed control techniques, and rely on cultivation for weed control between the crop rows. Recently developed, and experimental, herbicides offer improved weed con-

[1]Botany Department, University of California, Davis, CA 95616.

trol and could eliminate the need for cultivation. Experiments have been conducted to determine the feasibility of growing sugarbeets in the central valley of California without cultivation during the growing season. Standard soil preparation procedures were followed, beds spaced 30 inches on center were prepared, and a single row of subarbeets was precision (2.0 inch spacing) planted on the top of each bed. Herbicides were sprayed as bands along the top of the bed, or were applied on a broadcast basis. The plots were irrigated with sprinklers until the sugarbeets had emerged, after which time furrow irrigation was used. The beets were not thinned and no cultivation or hoeing was conducted on the top of the beds. The plots treated with broadcast herbicides were never cultivated; those with band herbicide applications were cultivated as needed to control the weeds. Several broadcast-applied herbicide combination treatments gave yields that were equal to those from plots that were band treated and cultivated. Both types of herbicide treated plots produced yields that were the same as those derived from hand weeded controls. Herbicides tested in these experiments included pyrazon [5-amino-4-chloro-2-phenyl-3(2*H*)-pyridazinone], diethatyl [*N*-(chloroacetyl)-*N*-(2,6-diethylphenyl)glycine], ethofumesate [(±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate], cycloate (*S*-ethyl *N*-ethylthiocyclohexanecarbamate), diclofop-methyl {2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid}, phenmedipham (methyl *m*-hydroxycarbanilate *m*-methylcarbanilate), and BAS-9052. The experiments demonstrated that sugarbeets can be grown without cultivation in the spring and summer in the Sacramento Valley. This has the potential for reducing the energy needed to grow the crop. It also has implications for disease management, as one of the paths of entry of the soft rot bacteria into the sugarbeet plant is via wounds created by cultivator damage; no cultivation would eliminate these entry sites for the bacteria. The commercial acceptability of reduced tillage in sugarbeets will depend on availability of adequate herbicides, costs of fuel for tractors versus costs of herbicides, and on the weed flora present in the field.

RO 13-8895, A SECELTIVE POSTEMERGENCE HERBICIDE FOR GRASS CONTROL

R. W. Bagley, G. L. Benson, A. R. De Mur, and H. D. Woofter[1]

Abstract: Ro 13-8895 {acetone-*O*-[D-2-[*p*-[α,α,α-trifluoro-*p*-tolyl)-oxy] phenyl]propionyl]oxime} has been widely evaluated as an emulsifiable concentrate formulation in postemergence sprays with promising results against annual grasses such as barnyardgrass (*Echinochloa crusgalli*), wild oats (*Avena fatua*), foxtails (*Setaria* spp.), shattercane (*Sorghum bicolor*), and wild proso millet (*Panicum miliaceum*), and perennials such as quackgrass (*Agropyron repens*), bermudagrass (*Cynodon dactylon*), and rhizome johnsongrass (*Sorghum halepense*). Excellent selectivity has been observed in all trials on soybeans, cotton, sugar beets, alfalfa, rapeseed, potatoes, safflower, sunflower, vegetables, other broadleaf crops, and certain monocot crops: onions and asparagus. Wheat, oats, and barley are not tolerant. Corn and sorghym are particularly susceptible. Broadlead weeds and sedges (*Cyperus* spp.) are not controlled by Ro 13-8895.

Ro 13-8895 exhibits slow, systemic action on grasses. Chlorosis and tip dieback can normally be observed within 5 to 7 days, but full effects

[1]Maag Agrochemicals Research and Development, HLR Sciences, Inc., Vero Beach, FL 32960.

may not be evident for 14 to 21 days. Herbicidal effectiveness may be reduced when grass growth is affected by lack of moisture, low air temperatures, or other stress conditions. Stage of grass growth may influence foliar uptake and effectiveness of Ro 13-8895, especially in perennial grasses where translocation to the underground parts is essential to inhibit the sprouting of rhizomes. Non-ionic surfactants and certain other spray adjuvants enhance postemergence activity on grasses without injuring broadleaf plants.

Combinations of Ro 13-8895 and broadleaf herbicides have provided outstanding control of both grass and broadleaf weeds. However, in some cases a higher rate of Ro 13-8895 is required in tank-mixed combinations than when applied alone in postemergence spray treatments. The use of this new grass herbicide in conjunction with other herbicides for broadleaf weed control merits further investigation.

IMPLICATION OF DEFERRING INCORPORATION ON THE HERBICIDAL ACTIVITY OF SELECTED DINITROANILINES

Wayne King and J. O. Evans[1]

The dinitroaniline herbicides are a family of compounds used in the preemergence control of annual grasses and many broadleaf weeds. In general, these herbicides must be mixed or incorporated into the soil soon after application to reduce volatilization and photodecomposition and to place the chemical in the proximity of the germinating weed seeds. This incorporation can be a problem to growers not only because of high fuel costs, but also because of the inconvenience of incorporating the compounds within several hours of application. It is often difficult to keep up to a commercial sprayer with a disk or field cultivator.

Tribluralin (α,α,α-trifluoro-2,6-*N*,*N*-dipropyl-*p*-toluidine) and oryzalin (3,5-dinitro-N^4,N^4-dipropylsulfanilamide) are two herbicides of the dinitroaniline family and represent quite different ends of the range this family of compounds has in regard to volatility and water solubility. Trifluralin is quite volatile and has a very low solubility in water. Oryzalin is very involatile and is much more soluble in water than trifluralin. Label directions for trifluralin require one soil mixing operation within 24 hours of application to prevent loss of the compound, and another at some later time to insure uniform mixing of the herbicide into the soil. Oryzalin, because of its low volitility, need not be incorporated into the soil but does need about 1.3 cm of moisture to move it into the weed germination zone.

This study shows the effects of incorporating these two herbicides with time intervals of up to one week after application. A 50:50 mixture of tribluralin and oryzalin was also used in this study. This mixture is formulated by Eli Lilly and Company as EL 5219.

Materials and Methods

Plots were established near Durant, Oklahoma in June, 1980 on a loam soil of 0.9% organic matter. Trifluralin, oryzalin, and EL 5219 were each applied at the rate of 0.84 kg/ha. Applications were made 7 days, 5 days,

[1]Plant Science Department, Utah State University, Logan, UT 84322.

3 days, 1 day, and immediately prior to incorporation. Nonincorporated surface applied treatments were also made following the incorporation procedure and served as controls together with plots receiving no herbicide. Application equipment was a tractor-mounted compressed air-plot sprayer. Plot size measured 5.5 m x 15.2 m. Layout was in a randomized block design with three replications. The entire plot area was seeded with the annual grass foxtail millet [*Setaria italica* (L.) Beauv.] just prior to incorporation. Incorporation was done with a tandom disk running 13 cm deep 11 km per hour. The entire plot area was disked twice, the second time at right angles to the first. A spike-tooth harrow was pulled behind the disk the second time over to make an acceptable seed bed. Following disking and prior to the surface herbicide applications, cotton and soybeans were planted in 0.91 m rows, two rows of cotton alternating with two rows of soybeans. Activity of the herbicide treatments was determined by counts of the millet in a 14 square meter area in the center of each plot two months following treatment.

A similar trial was conducted at Farmington, Utah in September and October 1980 on a sandy loam soil of 1.1% organic matter. Time intervals between herbicide application and incorporation were the same as those used in Oklahoma; herbicide rates were lower: .56 kg/ha of each of the compounds was used rather than .84. Treatments were applied using a compressed air bicycle-type sprayer. Plots measured 4.3 m x 9.1 m and were in randomized block design, four replications. No crops were planted with the exception of Nugains wheat which served as a sensitive grass species along with the common weed green foxtail (*Setaria faberi* Herrm.). These two species were applied to the plots with a hand-operated cyclone seeder just prior to the two disking operations which mixed the herbicide and planted the seed. The plots were then sprinkle irrigated and received 3 cm of water. Counts of wheat and green foxtail 19 days following incorporation were used to determine herbicidal activity.

Results and Discussion

Figure 1 shows the percent control of foxtail millet in Oklahoma by each of the compounds. All incorporated treatments gave excellent control with the exception of trifluralin at 7 days. This drop in control was probably due to the high surface moisture of the soil at the time the trifluralin was applied. Moist soil increases the volatilization of trifluralin. By time for the 5-day application, the surface was somewhat drier and we saw more activity. Oryzalin shows no response to the moisture variation. Control by EL 5219 was down a little at 7 days, but not enough to be significantly different from the other incorporation times. One interesting thing was the high amount of weed control, 79%, exhibited by trifluralin when not incorporated.

Table 1 shows the average count of millet per plot. With a 7-day interval between application and incorporation, trifluralin was different from its other incorporated treatments, but not from the control or the nonincorporated treatment. In reference to the oryzalin column, it should be noted that this trial received no moisture at all until 30 days after treatments were completed. This would be expected to lower control in the nonincorporated oryzalin treatment, but it showed good control. There was a trend toward less activity, but it was not significant. There was a difference with the nonincorporated EL 5219 from both the control and the incorporated treatments. There was no apparent explanation why there was greater difference in this treatment as compared to either trifluralin or oryzalin alone.

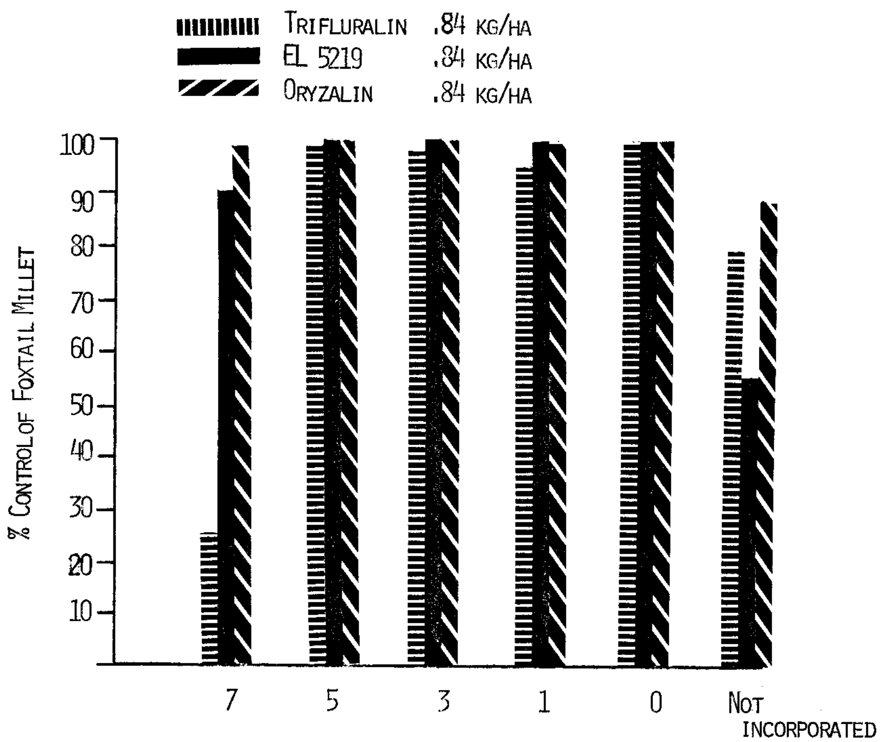


Figure 1. DAYS BETWEEN APPLICATION AND INCORPORATION

Table 1. Millet counts per $14m^2$ at Durant, Oklahoma

Days between application and incorporation	Trifluralin .84 kg/ha	EL 5219 .84 kg/ha	Oryzalin .84 kg/ha
7	14.0ab*	2.0 c	0.3 b
5	0.3 c	0.0 c	0.0 b
3	0.3 c	0.0 c	0.0 b
1	1.0 c	0.0 c	0.0 b
0	0.0 c	0.0 c	0.0 b
Not incorporated	4.0 bc	8.3 b	2.0 b
Control	18.7a	18.7a	18.7a

*Numbers in a column followed by the same letter are not significantly different at the 5% level.

The data show very good control in all the incorporated treatments except the 7 day trifluralin treatment. This isn't to say there was no other loss of the compounds over the time intervals involved, but rather that what loss there was was not sufficient to reduce control of the highly sensitive millet at the rates the herbicides were applied.

Figure 2 shows percent control of wheat at Farmington, Utah where lower chemical rates were used. This graph reveals an ascending curve for trifluralin as the time intervals before incorporation are decreased. Trifluralin control had the widest variation of the three compounds in this graph with a total variation of 34%--from 46 up to 80% control. EL 5219 gave consistent control at all time intervals, varying only about 10%. Oryzalin controls showed little influence from the length of time between application and soil mixing. The greatest control in the nonincorporated treatments was with oryzalin.

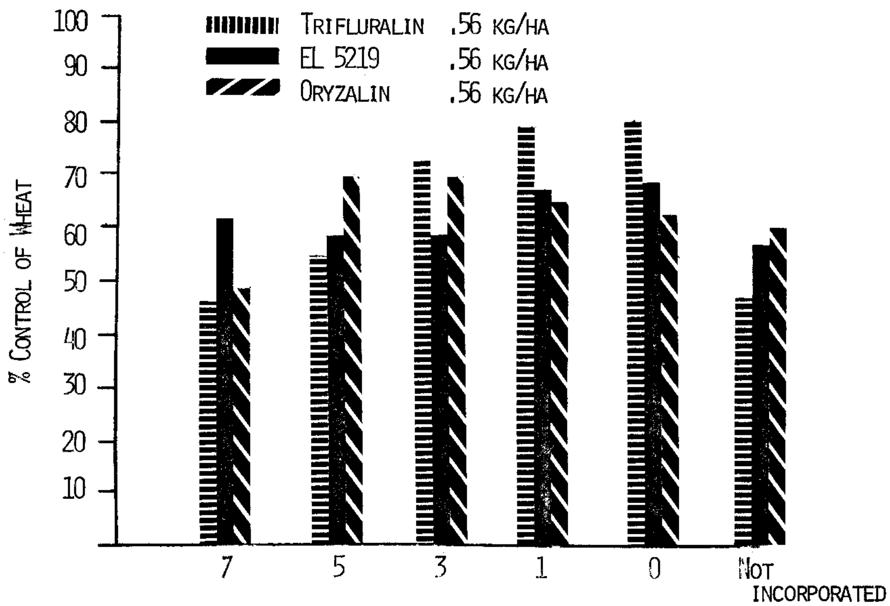


Figure 2.

Figure 3, the percent control of green foxtail, shows that the best control for each compound is 1 day or immediately prior to incorporation. In each of these treatment times, trifluralin gave approximately equal or better control of this grass than the other compounds. Again this indicates good weed control from even the nonincorporated treatment of trifluralin. EL 4219 showed progressively better control with shorter incorporation delays, but most of the differences were not significant. Oryzalin, being

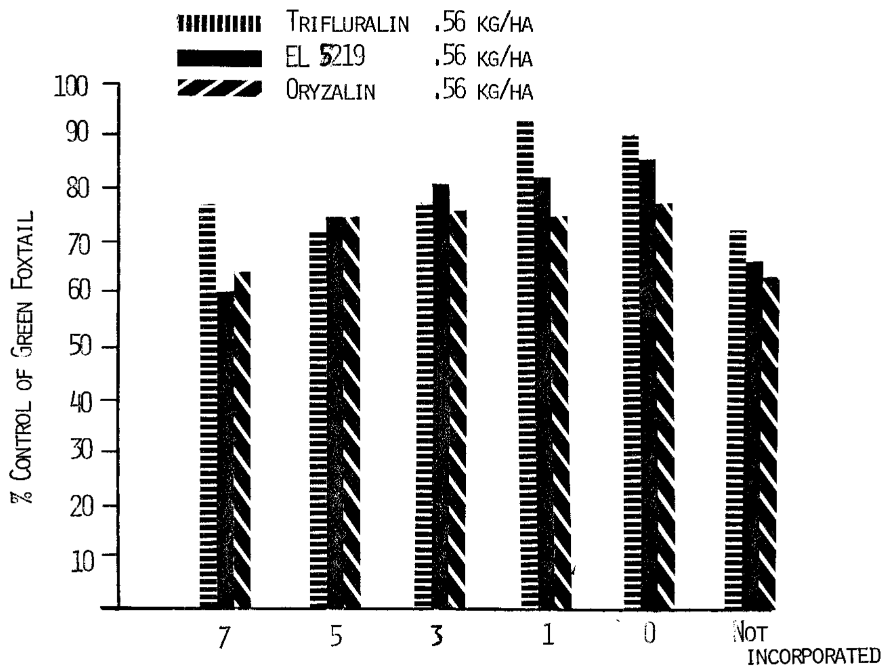


Figure 3. DAYS BETWEEN APPLICATION AND INCORPORATION

slightly less effective on green foxtail, was not influenced significantly by the interval of time between application and soil mixing although soil mixing does appear to improve its activity.

Actual foxtail counts at Farmington for all herbicide treatments were significantly different from the control as shown in Table 2. For each compound there was no significant difference between the nonincorporated and the 7-day treatments, and in each case these two treatments have significantly greater numbers of plants than the 1-day and immediately incorporated treatments. In each case there was no real difference between the 1-day and immediate incorporation. This table indicates significant loss of activity with a 7-day delay of incorporation.

Summary

Delaying incorporation of trifluralin by one week can, in certain instances, reduce weed control by 75%. Usually no significant reduction of weed control occurs if incorporation of trifluralin is delayed for 24 hours. Incorporation may be delayed three to five days with minimal loss of weed control. Even when not incorporated, trifluralin may provide up to 79% control of very susceptable species under dry conditions.

Oryzalin, though usually applied without incorporation, can be significantly more effective if thoroughly incorporated into the soil within

five days of application. When both trifluralin and oryzalin are mixed together into the proposed new formulation, activity is reduced if incorporation is delayed. In one study, incorporation of this mixture was delayed five days with no significant reduction in weed control; however, reduction in weed control with delays less than five days were detectable.

Table 2. Effect of delayed incorporation of dinitroanaline herbicides on numbers of green foxtail plants.

Days between application and incorporation	Foxtail plants per 3m^2, Farmington, Utah		
	Trifluralin .56 kg/ha	EL 5219 .56 kg/ha	Oryzalin .56 kg/ha
7	28.8 b*	49.0 b	45.3 bc
5	36.5 b	32.8 cd	32.5 d
3	28.8 b	25.8 d	32.8 cd
1	10.5 c	22.8 d	31.0 d
0	12.8 c	18.8 d	28.5 d
Not incorporated	36.0 b	44.0 bc	46.3 b
Control	124.6a	124.6a	124.6a

*Numbers in a column followed by the same letter are not significantly different at the 5% level.

INFLUENCE OF VARIOUS HORMONAL HERBICIDES ON THE EFFICACY OF DICLOFOP, DIFENZOQUAT, AND BARBAN FOR WILD OAT CONTROL

W. J. Schumacher, D. C. Thill, G. A. Lee, and R. H. Callihan[1]

Abstract: Wild oat (*Avena fatua* L.) continues to be a threat to many of the crop production areas of the Pacific Northwest. The ability of the wild oat to reproduce quickly and adapt readily to a wide range of environmental conditions, has made this annual grassy weed one of Idaho's most serious weed threats. Research had shown that wild oat can be controlled effectively with diclofop {2-[4-(2',4'-dichlorophenoxy)-phenoxy]propanate}, difenzoquat (1,2-dimethyl-3,5-diphenyl-1*H*-pyrazolium methyl sulfate), and barban (4-chloro-2-butynyl *m*-chlorocarbanilate). In the need to conserve fuel and time, these compounds have been applied as tank mixtures with various hormonal-type herbicides for broadleaf weed control, which at time has resulted in inadequate wild oat control. A greenhouse study was initiated to evaluate wild oat control when diclofop, difenzoquat, and barban were tank mixed with 2,4-D amine [(2,4-dichlorophenoxy)acetic acid], 2,4-D ester, bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), MCPA (2-methyl-4-chlorophenoxyacetic acid), and dicamba (3,6-dichloro-*o*-anisic acid). The growth of wild oat plants responded differently to the various tank mixtures. Wild oat control was decreased significantly when diclofop was tank mixed with MCPA or dicamba. All tank mixes with diclofop resulted in a slower "burn-

[1]Department of Plant and Soil Science, University of Idaho, Moscow, Idaho 83843.

down" of wild oat plants compared to diclofop alone. Wild oat control was significantly increased when barban was tank mixed with dicamba. Wild oat control was not influenced by the addition of the hormonal-type herbicides to difenzoquat compared to difenzoquat alone.

WILD OAT (*AVENA FATUA* L.) CONTROL WITH TRIALLATE-IMPREGNATED FERTILIZER

J. R. Dickerson, P. L. Rardon, and P. K. Fay[1]

Abstract: Wild oat is the most troublesome weed of small grain producers in Montana. Triallate [*S*-(2,3,3-trichloroallyl)diisopropylthiocarbonate] has been used effectively for wild oat control in the state since 1962. Fertilizer impregnation with herbicides is a proven practice in many agricultural situations; however, the application of triallate-impregnated fertilizer is not a common practice in Montana. The rising cost of fuel has created new interest in fuel-saving techniques. The application of triallate-impregnated fertilizer would save fuel since a producer could combine fertilizer and herbicide application in a single operation. The efficacy of triallate-impregnated fertilizers for wild oat control was compared to conventional liquid and granular formulations in several tests in 1979 and 1980.

Triallate-impregnated fertilizer provided better wild oat control than the granular formulations of triallate when applied in the spring at lower herbicide rates. The control of wild oats was not affected by the rate of the impregnated fertilizer used. Impregnated fertilizer stimulated a twofold increase in wild oat germination therefore fertilizer could shorten the dormancy period of the soil reserve of wild oat seeds.

Tests were established to compare triallate-impregnated ammonium nitrate and urea. There were no differences in wild oat control with fertilizer. The efficacy of fall and spring applications of impregnated fertilizer and granules was compared. Fall application provided superior wild oat control.

Impregnated fertilizer offers better wild oat control, increased accuracy of application, and decreased time of application when compared to granules. In addition, there is no need for specialized application equipment for fertilizer application.

[1]Montana Agricultural Experiment Station, Bozeman, MT 59717.

GLYPHOSATE AS A MANAGEMENT TOOL IN REDUCED TILLAGE SMALL GRAIN PRODUCTION

R. P. Schneider[1]

As energy costs continue to increase, the use of the isopropylamine (IPA) salt of glyphosate [*N*-(phosphono)methyl glycine] as a management tool in small grain production has increased. Past use of residual herbicide compounds coupled with carryover problems and unsatisfactory weed control have reduced producer acceptance of chemical tillage. IPA glyphosate

[1]Area Product Development Supervisor, Monsanto Agricultural Products Company, Denver, CO 80231

alleviates the concern for carryover while optimizing annual weed control.

Materials and Methods

Field studies were conducted in the central Great Plains to evaluate the performance of IPA glyphosate on volunteer wheat (*Triticum aestivum*), downy brome (*Bromus tectorum*) and kochia (*Kochia scoparia*) in reduced tillage systems. Rates of IPA glyphosate ranged from 380 g/ha to 1120 g/ha (0.01 to 0.38 lb ae/A) and volumes of carrier from 9.3 L/ha to 93.5 L/ha (1-10 gpa). Treatment comparisons for aerial and ground application were also made.

Results and Discussion

Efficacy of IPA glyphosate on volunteer wheat and downy brome was excellent, and the addition of dicamba (3,6-dichloro-*o*-anisic acid) gave long term control of kochia (Table 1). The data presented positions labelled rates of IPA glyphosate as the product of choice for spring and summer weed contol in reduced tillage. As fuel availability decreases and fuel costs increase, producer demands for lower economic inputs for weed control increase. The use of reduced rates of IPA glyphosate gives the small grain producer optimum weed control, while reducing evergy input costs.

Table 1. Control of volunteer wheat, downy brome, and kochia with IPA glyphosate.

		Control (%)					
	Rate (lb ae/A) or	Wheat		Downy brome DAT		Kochia	
Treatment	(lb ai/A)	12	26	12	26	12	26
Glyphosate	0.38	80	100	90	90	50	70
Glyphosate + X-77	0.38 0.50% v/v	80	100	90	90	60	70
Glyphosate + X-77 dicamba	0.38 0.50% v/v 0.25	80	100	90	90	85	97

Moisture data from the study areas demonstrated the importance of concise soil sampling procedures and uniform trial locations. At several locations soil-plant available water was not increased even though weed control was excellent. Other locations indicated that weed control with chemicals increased available soil water as compared to tillage. Given the number of variables involved, specific small plot areas are required for representative samples and statistically accurate data. Soil water information comparing tillage to chemical fallow should include both soil-plant available water and the percent change in soil water as a function of treatment.

Reduced rates, 280 g/ha (0.01 lb ae/A) have proven to be very effective especially at volumes less than 47 L/ha (5 gpa). Efficacy on volunteer wheat has ranged from 90-99%. The application of 280 g/ha IPA glyphosate plus 280 g/ha dicamba (0.125 lb ai/A) has given 92-100% kochia and redroot pigweed (*Amaranthus retroflexus* L.) control.

Volume studies conducted during the 1980 fallow season indicated that aerial applications of glyphosate, 28 L/ha (3 gpa) may be 2-5% more efficatious than ground applications, 93.5 L/ha (10 gpa) at equal rates. The difference was thought to be a function of carrier volume. When ground application volumes were reduced, 9.3 to 47 L/ha (1-5 gpa) efficacy was equal regardless of application method.

Further research efforts by university and industry researchers with reduced rates of IPA glyphosate can provide the modern small grain producer with a complete management system to lower input costs while increasing productivity.

DOWNY BROMEGRASS CONTROL IN WINTER WHEAT

B. R. Seder and P. K. Fay[1]

Abstract: Downy bromegrass (*Bromus tectorum*) ranked as the second most troublesome weed in Motana in 1979, a dramatic increase from the year before when it ranked 8th. It is a major problem in winter wheat. Downy brome is especially troublesome following wet springs since viable seed is often produced before summer fallow tillage begins. The seed had little dormancy so most seeds germinate in the fall of the year of production.

Historically, downy bromegrass was easily controlled by tillage if winter wheat seeding was delayed until fall rains occurred. The situation is changing as a result of an increase in recropping and a decrease in summer fallow tillage because of fuel prices. There is increased interest among producers for herbicides which control downy bromegrass.

Field experiments were established to compare the efficacy of triallate [*S*-(2,3,3-trichloroallyl)diisopropylthiocarbamate], trifluralin (α,α,α-trifluoro-2-6-dinitro-*N*,*N*-dipropyl-*p*-toluidine), profluralin [*N*-(cyclopropylmethyl)-α,α,α-trifluoro-2,6-dinitro-*N*-propyl-*p*-toluidine], and diclofop methyl {2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid}. Triallate provided the most effective control. Diclofop was most effective when it was incorporated once after application. One of the most effective treatments was incorporation without herbicide. Two incorporations reduced the number of downy bromegrass plants from 16.9 to 5.4 plants per .08 m^2.

Downy bromegrass is very susceptible to glyphosate [*N*-(phosphonomethyl) glycine]. Glyphosate applied in the spring as a substitute for summer fallow tillage provided excellent control of downy bromegrass at the low rate of 0.1 kg/ha regardless of growth stage. The use of glyphosate for all applications prior to seeding winter wheat is an inexpensive effective means of preplant control of downy bromegrass.

[1]Field Assistant and Assistant Professor, Plant and Soil Science Department, Montana State University, Bozeman, MT 59717.

DPX-5648 - A NEW HERBICIDE FOR CONTROL OF JOHNSONGRASS AND MANY OTHER WEEDS

R. H. Harding, C. B. Chumley, G. E. Cook, and F. A. Holmes[1]

Abstract: DPX-5648 (aminosulfonylbenzoic acid, methyl ester) is a new, highly active sulfonylurea herbicide that controls many important broadleaf and grass weeds both preemergence and postemergence. It is particularly active on johnsongrass, giving season-long control of seedling or rhizomatous plants. Tolerance is exhibited by alfalfa, sugarcane, and certain desirable perennial grasses. Some commercial pine species are tolerant at rates that control many weeds and some vines. DPX-5648 has potential for use in reduced tillage fallow systems where rates below 1/4 oz ai/A have provided excellent weed control. Other uses for DPX-5648 under investigation include sugarcane ripening and application with the rope wick technique. Mechanistic studies have shown that DPX-5648 stops plant cell division, resulting in rapid growth inhibition and eventual plant death.

Introduction

DPX-5648 is a new highly active herbicide for both pre- and postemergence control of a large number of perennial and annual broadleaves and grasses. DPX-5648 has potential for weed control in certain field and tree crops, chemical fallow, and noncropland situations. Johnsongrass has shown susceptibility in seedling and rhizomatous growth stages. Water soluble salts have been highly active in rope wick applications. DPX-5648 has activity as a plant growth regulator.

Toxicology

DPX-5648 has low acute oral toxicity to rats. Its LD_{50} for fasted male and female rats is greater than 5,000 mg/kg. Exposure of the rabbit eye to the solid chemical produced very mild to minimal conjunctival irritation with no other effects. DPX-5648 produced mild to no skin irritation when applied to shaved, intact guinea pig skin at fifty percent concentration in an inert carrier. No irritation was produced at five percent concentration. No sensitization was produced at either concentration. DPX-5648 was not mutagenic when tested in the Salmonella/microsome assay using the Ames procedure.

Three-month feeding studies in male and female rats have been conducted with DPX-5648 at dietary levels of 0, 100, 1,000, and 5,000 ppm. There were no compound related gross or microscopic pathological findings.

Greenhouse Test

Biological activity of DPX-5648 was discovered in greenhouse tests where it controlled a number of annual grasses and broadleaves. Results from a special postemergence test demonstrate the high potency of this compound. Treatment was made two weeks after planting. Results were recorded two weeks later. The 5 g/ha rate corresponds to approximately 1/200 lb/A.

Field Results

This activity was confirmed in subsequent field tests. Results demonstrated the broad spectrum activity of DPX-5648 at very low rates. The results were from a postemergence application of 15 g/ha or approximately one-quarter ounce per acre in a typical museum test vs. untreated check.

In a test on well-established hard-to-kill weed species such as poison

[1]Biochem Department, E. I. duPont de Nemours & Company, Inc., Menlo Park, CA

ivy, golden rod, dewberry, and honeysuckle one kg/ha provided greater than 95 percent weed control. Broomsedge was the surviving species.

DPX-5648 is readily translocated and kills both the above and below ground parts of the plant. Primary site of action is in the root and shoot meristems. Growth stops soon after application and usually represents the first symptom of herbicidal activity. While preemergence treatments do not normally inhibit seed germination, subsequent seedling growth of sensitive species is quickly inhibited. We have had extensive evaluation of DPX-5648 on johnsongrass andconsistently saw good control--this being representative of the season-long results.

A wide range of annual and perennial weed species has been controlled with DPX-5648 in noncrop trials established in 1979 and 1980. DPX-5648 at rates of 1 to 2 oz ai/A controls both broadleaf and grass species. Selectivity to some species such as crested wheat grass has been observed at rates as low as 2 oz ai/A.

Many states are now interested in leaving desirable grass species on road shoulders, but want to control the broadleaf weeds. DPX-5648 roadside trials in Idaho controlled broadleaf weeds and many grasses, whereas crested wheatgrass was only stunted. Stunted grasses will mean less trips with a mower.

Loblolly pine has shown good tolerance to DPX-5648. More work is needed on other conifer species to determine tolerances because differences were noted in preliminary tests. If additional commercial pine species are tolerant to effective rates, DPX-5648 may prove useful in forestry weed control. A number of trials are in progress on the West Coast to determine conifer selectivity.

DPX-5648 has been tested as a fallow treatment in eastern Oregon and eastern Washington for two years. In 1979, DPX-5648 was applied at rates of 1/4, 1/2, and 1 oz ai/A in late October or early November and gave complete control of downy brome and volunteer wheat by May 1, 1980. These fields were tilled at that time and planted to wheat in August of 1980.

In September of 1980, DPX-5648 was applied to fallow at rates of 1/8, 1/4, and 1/2 oz ai/A and by February 1, 1981, both downy brome and volunteer wheat were completely controlled.

The addition of 0.1 to 0.2% of certain surfactants improves the activity of DPX-5648 on some species. Russian thistle 12-14 inches high was treated with DPX-5648 at rates of 1/8, 1/4, and 1/2 oz ai/A with and without surfactant. Three weeks later all of the Russian thistle in plots treated with DPX-5648 and surfactant were dead, whereas none of the Russian thistle was controlled in plots treated with DPX-5648 and no surfactant.

Currently studies are being conducted at rates as low as 1/16 oz ai/A. Once the lowest rate needed for control of downy brome and volunteer wheat are found, recropping studies can be conducted.

Salts of DPX-5648 applied with a rope wick applicator have given promising results. DPX-5648's high activity and ability to translocate in plants make it ideal for rope wick application. Concentrations of a few thousand ppm have given total control of johnsongrass. Potential crop injury from such treatments requires additional testing before crop uses could be recommended.

To summarize, DPX-5648 is a highly active, broad-spectrum herbicide for the control of broadleaves and grasses, especially johnsongrass. It has potential for industrial sites and rights-of-way in addition to certain selective or specialized uses in chemical fallow, farestry, and rope wick application. Other possible used are weed control in alfalfa and as a plant growth regulator for sugar enhancement in sugarcane.

AN ANALYSIS OF THE ANTAGONISM BETWEEN DICLOFOP-METHYL AND SELECTED SMALL GRAIN HERBICIDES

J. O. Evans and R. W. Gunnell[1]

Abstract: The phytotoxic activity of diclofop-methyl {2-[4-(2,4-dichlorophenoxy)phenoxy]propanoic acid} is greatly impaired by pretreating susceptible grass species with certain herbicides immediately prior to diclofop-methyl application or by spraying sensitive grass species with tank mixtures of these compounds. Several pretreatment variables are important in determining the magnitude of the interaction and whether the economic benefit of spraying grassy weeds with diclofop-methyl is significantly reduced. The antagonistic interaction is not observed with all small grain herbicides nor is it expressed in precisely the same manner. The basis of this interaction appears to be multifaceted since the expression is observed in a variety of ways and at differing stages of plant development.

[1]Plant Science Department, Utah State University, Logan, UT 84322.

FACTORS INFLUENCING TRIFLURALIN PHYTOTOXICITY TO POTATOES

C. H. Huston, L. K. Hiller, and R. E. Thornton[1]

Abstract: Field and growth chamber studies indicated that preplant incorporated applications of trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) resulted in injury during the early growth stages of potatoes (*Solanum tuberosum* L. cv. Russet Burbank). Injury was influenced by soil temperature, seed piece placement, and herbicide rate.

Trifluralin injury was typified by delayed emergence, retarded growth, decreased root development, swelling, cracking and brittleness of stems, and a delay in stolon initiation.

Increases in trifluralin rate, applied at 0, 0.44, 0.58, and 0.87 kg/ha and incorporated to a depth of 8 cm, were accompanied by corresponding increases in plant injury. Soil temperatures of 10°C in both the growth chamber and field studies resulted in the most severe damage while temperatures of 21°C resulted in only very slight injury, even at the higher herbicide rates. Soil temperatures of 15°C resulted in damage intermediate in severity. At 10°C potatoes planted at a depth of 8 cm were more severly injured than those planted at 18 cm. This effect was diminished with higher soil temperatures.

Potatoes eventually outgrew the injury symptoms and no significant differences in plant growth or total yield were present at the end of the growing season.

Preplant incorporated applications of 3.5 kg/ha of EPTC (*S*-ethyl dipropylthiocarbamate) alone or in combination with trifluralin did not contribute to the phytotoxicity of trifluralin.

[1]Graduate Research Assistant, Associate Professor, and Extension Horticulturist, respectively, Department of Horticulture and Landscape Architecture, Washington State University, Pullman, WA 99164.

SONALAN EFFICACY AND CROP TOLERANCE WHEN APPLIED PREPLANT INCORPORATED TO EDIBLE BEANS IN THE PACIFIC NORTHWEST - EUP RESEARCH

William T. Cobb[1]

On April 18, 1980, Eli Lilly and Company was granted an experimental use permit for ethalfluralin [*N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine] for weed control in seed and podded vegetables and peanuts. The permit allowed for the use of 1,343 gallons nationwide of ethalfluralin; of this amount, a total of 233 gallons was allocated for use in Washington, Oregon, and Idaho. The primary emphasis of the experimental use permit in the Pacific Northwest was on dry, lima, and snapbeans. The permit was obtained too late to be of much utility in pea and lentil areas in 1980. Work with ethalfluralin on peas and lentils is being conducted this spring and application will be completed by the termination date of the experimental use permit.

Materials and Methods

Application of ethalfluralin under the experimental use permit was conducted using a wide variety of application equipment. Several applications were made using a specially designed plot sprayer obtained from Rear's Manufacturing Company in Eugene, Oregon. A number of plots were applied using commercial application equipment, such as a Big A or Tryco floater, and were actually established by commercial applicators. Grower equipment was utilized whenever possible to establish experimental use permit trials. Generally, grower-type equipment consisted of a tractor equipped with one or more spray tanks with a spray boom mounted at the leading edge of the incorporation equipment or belly-mounted under the tractor.

For the most part, ethalfluralin was applied in a water carrier; however, in each state one or more trials were carried out using liquid fertilizer as a carrier or with ethalfluralin impregnated on dry fertilizer. In several trials, ethalfluralin was also tank-mixed with EPTC (*S*-ethyl dipropylthiocarbamate).

Incorporation equipment used in these trials was even more varied than the type of application equipment used. In a number of trials, disc harrows were used. In some instances power-driven equipment such as a rotovator or Lely-Roterra-type implements were used. Field cultivators, such as the Ace Triple K, were very popular as incorporation tools in the Magic and Treasure Valleys of Idaho. In all cases, the ethalfluralin was soil incorporated twice; sometimes using two passes of the same equipment, sometimes using combinations of implements such as a field cultivator followed by a flex-tine or spike-tooth harrow.

Rates of ethalfluralin used in the dry bean trials varied with the soil type, the particular crop, and the anticipated weed spectrum. In coarse textured soils for the control of annual weeds such as lambsquarters (*Chenopodium album* L.), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], and redroot pigweed (*Amaranthus retroflexus* L.): 0.56 to 0.75 lb ai/A; medium soils: 0.75 to 0.94 lb ai/A; and for fine textured soils: 1.12 to 1.31 lb ai/A. For nightshade (*Solanum* spp.) control in coarse textured soils: 1.12 to 1.31 lb ai/A; medium soils: 1.31 to 1.5 lb ai/A;.and for fine textured soils: 1.5 to 1.88 lb ai/A.

A total of 35 trials was conducted in the three-state area of the

[1]Plant Science Representative, Lilly Research Laboratories, Kennewich, WA 99336.

Pacific Northwest. This breaks down to a total of 22 trials in Idaho, 8 trials in Oregon, and 5 trials in Washington. By bean type or variety the breakdown is as follows: dry beans (red, white, pink, pinto, black turtle, and red kidney): 27 trials; lima beans: 2 trials; and snapbeans (both green and for seed): 6 trials. By soil type, 11 trials were conducted on coarse textured soils (i.e., sand, loamy sand, or sandy loam); 21 trials were conducted on medium textured soils (loams, silt loams, or silts); and 3 trials were conducted on fine textured soils (silty clay loams, sandy clay loams, etc.). Most of the trials were evaluated for weed control, crop injury, and crop stand three times during the season (early, mid-season, and late). Yield data was obtained from 15 of the trials. In all cases, harvest was via commercial-type equipment.

Results

Dry bean varieties show excellent tolerance to ethalfluralin. Lima beans appear to be only slightly less tolerant to ethalfluralin than dry beans. Snapbean tolerance to the nightshade-control rates of ethalfluralin seems to be variety-dependent, with some varieties showing excellent tolerance and others showing varying degrees of tolerance ranging from only slightly susceptible to very suscuptible to injury from ethalfluralin.

The lower or annual weed control rate of ethalfluralin, adjusted for soil type, provided 88 to 98 percent control of the following weed species: barnyardgrass, common lambsquarters, Kochia (*Kochia scoparia*), green foxtail (*Setaria viridis*), and redroot pigweed. The higher rate or nightshade control rate of ethalfluralin provided 92 percent control of hairy nightshade (*Solanum sarachoides*). The 2X or double rate of ethalfluralin provided 99 percent hairy nightshade control. Trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) and EPTC tank-mix combinations gave 90 percent hairy nightshade control, and the trifluralin-alachlor [2-chloro-2',6'-diethyl-*N*-(methoxymethyl)acetanilide] tank-mix gave 73 percent hairy nightshade control. These results are based on multiple observations from 15 trials which contained hairy nightshade populations sufficiently uniform to rate.

Ethalfluralin at the higher rate range also provided excellent control of several other weed species, including but not limited to: cutleaf nightshade (*Solanum triflorum*), witchgrass (*Panicum capillare*), Russian thistle (*Salsola kali*), and tumble pigweed (*Amaranthus albus*). In most cases these weed species were only present in a limited number of trials. Common mallow (*Malva neglecta*) was found at a number of trial sites, particularly many of those located in Malheur County of Oregon and the Treasure and Magic Valleys of Idaho; ethalfluralin provided only marginal control of this particular weed species.

As stated earlier, yields were determined from 15 different trials. In the majority of cases, ethalfluralin or ethalfluralin + EPTC treatments on dry beans yielded as well if not better than the trifluralin + EPTC reference treatments. Since the treatment size in these various trials was very large in comparison to the untreated controls and since these trials were harvested with commercial equipment, yields from untreated controls were obtained in only a few trials. Hence yield figures are expressed as a comparison to the reference herbicide treatment rather than to an untreated control.

Conclusions

Based upon results obtained from this experimental use permit, previously reported Lilly and Elanco small-plot research and previously reported university-USDA research results, it appears that ethalfluralin is a very effective material for the control of hairy nightshade and numerous other annual weed pests in commercially grown dry and lima beans in the Pacific Northwest. Ethalfluralin also shows excellent crop tolerance to dry and lima beans.

Eli Lilly and Company has received a one-year extension of the existing experimental use permit effective April, 1981. A request for an experimental use permit for ethalfluralin surface applied on cucurbits, preemergence to the crop and weeds has also been filed with the EPA.

CARROT YIELD RESPONSE TO WEED COMPETITION

C. E. Bell and D. W. Cudney[1]

Abstract: Carrot yield response to various weed pressures and control practices was analyzed in a field study. The trial compared the competitive ability of carrots against a native weed population of several species. Early competition was from common purslane (*Portulaca oleracea*), later competiton was from nettleleaf goosefoot (*Chenopodium murale*), little mallow (*Malva parviflora*), london rocket, (*Sisymbrium irio*), and volunteer cereals. Eight herbicide treatments and an untreated control were used. Trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluine) was applied preplant incorporated at .75 lb ai/A. Three treatments were applied preemergence; bensulide [*O*,*O*-diisopropyl phosphorodithioate *S*-ester with *N*-(2-mercaptoethyl)benzenesulfonamide] at 6 lb a.i., nitrofen (2,4-dichlorophenyl *p*-nitrophenyl ether) at 4 lb a.i., and chloroxuron {3[*p*-(*p*-chlorophenoxy)phenyl]-1,1-dimethylurea} at 3 lb ai/A. Four treatments were made postemergence to the carrots; linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] at 1 lb a.i., nitrofen at 4 lb a.i., stoddard solvent (carrot oil) at 50 gal/A, and stoddard solvent plus linuron at 50 gallons plus 1 lb a.i. respectively. Postemergence applications were made at the appropriate stage of growth of carrots and weeds according to label directions. Weed control ranged from 99.6% with chloroxuron to 10% for linuron. Carrot yield for any treatment was roughly in the same proportion as the percent weed control, indicating a very direct relationship of yield to weed control. It was apparent that competition from weeds was particularly critical during the early life of the crop.

[1]Farm Advisor, El Centro, and Extension Weed Specialist, Riverside, Univ. of California Cooperative Extension.

Table 1. Carrot yield compared to weed control.

Treatment	Yield (lbs)	% Weed control	Marketable roots (%)
Chloroxuron	29.95 a[1]	99.6	44.5
Nitrofen	25.48 ab	97.9	49.8
Bensulide	22.23 bc	95	40.4
Trifluralin	19.35 c	90	35.4
Nitrofen (post)	16.38 c	84.4	27.0
Linuron	11.1 d	10.0	29.3
Stoddard solvent + linuron	9.73 de	66.3	25.8
Stoddard solvent	7.7 de	67.5	10.4
Untreated control	6.58 de	0	14.9

[1]Means followed by the same letter are not significantly different at the .01 level.

RECENT ADVANCES IN WEED CONTROL FOR LENTILS IN SASKATCHEWAN

Brian N. Drew[1]

Initial introductions of lentils during the late 1960's as a commercial field crop for Saskatchewan failed as a direct result of extreme weed competition. It was immediately obvious that successfully limiting weed competition represented the most important step to ensuring profitable lentil production. Because this crop is relatively short and lacks the ability to form a dense canopy even under ideal growing conditions, most of the common annual grass and broadleaved weed species can compete effectively with lentils at any time throughout the growing season. However, competitive effects are particularly significant during establishment of the lentils and during periods when low soil moisture limits growth. Lentils should not be grown on land where perennial weeds are known to be a problem. Volunteer grains and oilseeds can become serious weed problems when stubble cropping, particularly following a dry autumn. Studies conducted by the Crop Development Centre indicate that seed yield losses caused by infestations of both grass (Table 1) and broadleaved weeds generally range from 25% to 95% of potential lentil yield. These losses are generally greater than for other field crops, particularly under low weed densities. Weeds also interfere with harvest operations, reduce sample quality and increase transportation and cleaning costs.

Cultural weed control generally produces highly variable results, with the level of weed control achieved primarily dependent upon environmental conditions and stage of weed growth. Postemergent harrowing crosswise to the direction of seeding within two weeks after emergence of the lentils when the plants are less than 10 cm in height has proven relatively ineffective as a means of controlling any weeds except for germinating broadleaf seedlings and frequently proved impractical, spread diseases, and

[1]Weed Control Specialist, Crop Development Centre, University of Saskatchewan, Saskatoon, Saskatchewan, S7N 0W0.

Table 1. Effect of natural wild oat densities on lentil seed yield (average of tests conducted at the Crop Development Centre during 1974-1976).

Wild oat density (plants/m^2)	Lentil yield (kg/ha)
0	1824
8	1167
18	741
33	306
76	133
118	38

caused excessive crop damage. In contrast, one or two preemergent harrowing operations following seeding should be considered a standard practice for firming and grooming the seedbed and improving the kill of winter annuals only partailly uprooted by seeding and tillage operations. Appropriate weed control during summerfallow years, careful selection of a clean seedbed, inclusion of a shallow tillage operation in problem areas prior to seeding, and use of clean seed are important procedures to consider when planning lentil production.

Chemical weed control must be considered an integral factor in profitable lentil production, with the choice to grow lentils including a commitment to effective use of herbicides. The four herbicides currently registered for weed control in lentils (Table 2) include barban (4-chloro-2-butynyl *m*-chlorocarbanilate), diclofop methyl {2-[4-(2,4-dichlorophenoxy) phenoxy] propanoic acid}, dinoseb (2-*sec*-butyl-4,6-dinitrophenol), and metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)-one].

Table 2. Herbicides registered for weed control in lentils effective March 1, 1981.

Herbicide	Rate (kg/ha)	Application type	Weed (s) controlled
Barban	0.35	postemergence	wild oats
Diclofop	0.70	postemergence	wild oats, green foxtail, yellow foxtail, barnyard grass, Persian darnel
Dinoseb amine	0.80-1.54	postemergence	stinkweed, wild mustard, volunteer rapeseed
Metribuzin	0.21	Postemergence	ball mustard, wild mustard, stinkweed, volunteer rapeseed, hemp nettle, chickweed, corn spurry, tartary buckwheat, smartweed, lambsquarters .

Although insufficient data are available to date, experiments have indicated that metribuzin, triallate [*S*-(2,3,3-trichloroallyl)diisopropyl-thiocarbamate], fall-applied trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine), spring-applied triallate plus trifluralin, ethalfluralin [*N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(triflurormethyl)benzenamine], sethoxydim (POAST), fluazifop-butyl (FUSILADE), and diquat [6,7-dihydrodipyrido(1,2α:2',1'-*c*)pyrazinediium ion] show promise as treatments for control of a variety of specific weed problems. Caution must be exercised in using any of these non-registered compounds since the liability and responsibility fall completely upon the grower in the event of crop damage or inadequate weed control until such time as these herbicides become registered for use in lentils. Potential lentil producers are requested to annually obtain information on the current status of herbicide recommendations and weed control procedures prior to the spray season.

Although these postemergence chemicals control a number of the common weeds, the scope of weed species controlled is limited so producers must check carefully to ensure control is possible of specific weed problems anticipated on an individual farm basis. Note that elimination of only some weed species permits less competitive weeds to dominate the weed spectrum and, in turn, effectively outcompete the seedling lentils. For example, elimination of wild mustard (*Brassica kaber*) and wild oats (*Avena fatua*) allows such weeds as green foxtail (*Setaria viridis*), redroot pigweed (*Amaranthus retroflexus*), and cow cockle (*Vaccaria segetalis*) to flurish is this short, open crop. Products are not presently registered which provide adequate control of perennial grasses, thistles, and volunteer cereals. A grower must develop a long-term, integrated approach to weed control by effectively manipulating rotations and herbicides (particularly in spring cereals where a wide range of chemicals is available) in order to reduce weed populations during other parts of the cropping sequence. Use of lentils to extend cropping periods, or when stubble cropping may necessitate sacrificing small areas of the crop to permit spot treatment using glyphosate [*N*-(phosphonomethyl)glycine] in areas of dense thistle stands. Avoiding drift from phenoxies such as MCPA{[(4-chloro-*o*-tolyl)oxy] acetic acid} and [(2,4-dichlorophenoxy)acetic acid] is critical since lentils are very sensitive to these products. Thorough product knowledge and accurate application are essential for maximizing herbicide benefit. This is only possible through careful observation of detailed instructions included on the label describing specific procedures and safety precautions. Therefore the extension of information becomes as critical a step in the research process as the experimentation itself. To this end an advisory service (including grower information brochures, winter herbicide information meetings, summer field tours and personal consultation) has been established to update the lentil producers.

STUDIES IN THE ACTIVATION OF PREEMERGENCE HERBICIDES WITH OVERHEAD IRRIGATION

A. H. Lange, J. R. Schlesselman, and W. Bendixen[1]

Abstract: The timely and accurate application of irrigation water is the key to optimum results with preemergence herbicides. Because of today's energy problems and increased use of sprinkler irrigation, more attention is turning to the incorporation of preemergence herbicides by sprinklers. The exploratory studies using a specially designed experimental irrigation simulator were conducted during the past ten years. Some generalizations about herbicides and herbicide activation in a few Califonria soils are made. A great deal more work of this type is recommended in order to clarify: (1) the importance of initial irrigation on activation of specific herbicides in specific soil types; (2) the amounts of vertical movement with different amounts of water initially and with subsequent irrigation; (3) the form of movement whether in suspension or solution; (4) the effect of amount and timing on residual activity; and (5) other aspects of herbicide activity in agricultural soils.

[1]Cooperative Extension Service, University of California.

COMBINATIONS WITH OXADIAZON FOR WEED CONTROL IN NURSERY CONTAINERS

G. F. Ryan[1]

Abstract: Common groundsel (*Senecio vulgaris* L.) was controlled 80 to 100% in most cases by combinations of oryzalin (3,5-dinitro-N^4,N^4-dipropylsulfanilimide) or napropamide [2-(α-naphthoxy)-*N*,*N*-diethylpropionamide] with oxadiazon [2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one]. Barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] was controlled 92 to 98% for 8 weeks and 80 to 99% for 16 weeks by two applications of oxadiazon plus oryzalin or napropamide. Napropamide, oryzalin, or DCPA (dimethyl tetrachloroterephthalate) was required with oxadiazon for control of mouseear chickweed (*Cerastium arvense* L.). Only oryzalin controlled common chickweed [*Stellaria media* (L) Vill.] and birdseye pearlwort (*Sagina procumbens* L.).

Growth of cotoneaster (*Cotoneaster dammeri* 'Lowfast') and three cultivars of azalea (*Rhododendron* X), as measured by shoot fresh weight, was reduced 12 to 20% by oxadiazon plus napropamide or oxadiazon plus oryzalin applied twice at a rate of 4.5 kg/ha for each chemical, with an 8-week interval between applications. Oryzalin alone applied twice at 4.5 kg/ha reduced fresh weight of azalea 'Hinodegiri' 46% in one experiment and 'Rosebud' 14% in another case.

In other experiments, two applications of oxadiazon at 4.5 kg/ha plus napropamide at 4.5 or 6.7 kg/ha or oryzalin at 4.5 kg/ha with an 8-week interval did not significatly affect growth of azalea 'Hinodegiri', Japanese pieris (*Pieris japonica*), Japanese holly (*Ilex crenata* 'Howardii'), cotoneaster (*C. dammeri* 'Lowfast'), or euonymus (*Euonymus fortunei* 'Emerald Cushion').

Two applications of oryzalin at 4.5, 9.0, or 18.0 kg/ha with a 3-month

[1]Washington State University, Western Washington Research and Extension Center, Puyallup, WS 98371.

interval did not significantly affect fresh weight of azalea 'Rosebud', Japanese privet (*Ligustrum japonicum*), euonymus, Japanese holly, or creeping juniper (*Juniperus horizontalis* 'Wiltonii').

Introduction

Oxadiazon applied in granular form controls many kinds of annual grass and broadleaf weeds in nursery containers without injury to a wide range of woody ornamental plants. It is especially useful because it controls bittercress (*Cardamine* sp.), which has been one of the important weed problems in container nurseries. However, not all annual weeds are controlled at satisfactory levels. Among the species not controlled are common chickweed, mouseear chickweed, and birdseye pearlwort. The latter weed has become a problem during the past two or three years during which oxadiazon has been widely accepted for nursery container use.

Various herbicides have been tested in combination with oxadiazon. Three applications of a combination of trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*,dipropyl-*p*-toluidine) at 5.6 kg/ha or alachlor [2-chloro-2',6'-diethyl-*N*-(methoxymethyl)acetanilide] at 8.4 kg/ha with oxadiazon at 2.2 kg/ha were not phytotoxic to four ornamental species (3).

Combinations of oryzalin or oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene] with oxadiazon applied in October, January, and May controlled common groundsel through August (1). As the rate of each herbicide in the combinations was increased from 2.2 to 4.5 kg/ha, dry weights of shoots and roots of *Buxus microphylla* tended to decrease, but were not significantly less than the hand-weeded checks (1).

When napropamide was applied with oxadiazon, control of common groundsel remained at 80 to 90% after 14 weeks, compared with less than 50% control from either herbicide applied separately at the same rate (2).

In several experiments from 1976 to 1979, combinations of oxadiazon with napropamide or oryzalin were compared with other treatments for weed control in nursery containers, with emphasis on bittercress, common groundsel, and barnyardgrass. Results with those combinations or the three herbicides applied separately are reported here. In 1980, the emphasis was on which herbicides could be used to supplement oxadiazon for control of the two chickweed species and birdseye pearlwort.

Materials and Methods

Weed control evaluations. Herbicides were applied to 3.8 L tapered matel containers filled with a growing medium of bark (Douglas fir and hemlock), sphagnum peat, and sand (6:1:1) ratio. Before herbicide application the containers were seeded with the kinds of weeds to be studied. A separate set of containers was seeded with each kind of weed. They were reseeded at 8-week intervals except in 1977 when 4-week intervals were used. Weed seedlings were removed from the untreated containers before each reseeding. Wettable powder formulations of the herbicides were applied with a compressed air back-pack three nozzle boom sprayer at 234 L/ha. Granular formulations were applied with shaker bottles. Herbicide application was followed immediately with approximately 1 cm of sprinkler irrigation. Treatments were replicated four times on four or five containers of each weed species per treatment in randomized complete block design. Weed seedlings were counted at 4- or 8-week intervals and the results were expressed as percent control compared with the total weed count in the untreated containers.

Growth of nursery plants. To determine the effects of the treatments on appearance and growth of various kinds of ornamental plants, the same treatments that were evaluated for weed control were applied to nursery plants that had been transplanted into containers 4 to 13 days prior to treatment. The containers and growing medium were the same as for the weed control evaluation. These containers were weed-free initially and the few weeds that appeared during the season were removed as soon as observed. At the end of the season the plant tops were cut at the soil surface and weighed, and the results were expressed as percent of the untreated plants.

Results

Weed control. Common groundsel control in 1976 from the oxadiazon plusnapropamide combination was about 80% at the end of 8 weeks, and it was maintained at this level by re-treatment (Table 1). A single application of oxadiazon plys napropamide controlled barnyardgrass 90% for 16 weeks, compared with 62% for napropamide alone.

In 1978, neither oryzalin nor napropamide applied separately controlled common groundsel, but in combination with oxadiazon the control was 98 to 100% for 8 weeks and was maintained at 95 to 99% by a second application (Table 2). The higher rates of oxadiazon and napropamide used in 1978 may account for better control than in 1976. Control of barnyardgrass was 92 to 96% from the oxadiazon plus oryzalin combination compared with 67 to 74% from oryzalin alone at the end of 8 weeks and the combination maintained 91% control after a second application.

Table 2. Weed control from oryzalin and napropamide separately and in combination with oxadiazon, 1978.

Herbicide	Rate[1] (kg/ha)	Control (%)[2] Common groundsel, weeks after initial application 8	16	Barnyardgrass 8	16
Oxadiazon 2G	4.5				
+ oryzalin 5G	4.5	98 a	84 ab	92 a	58 de
Oxadiazon 2G	4.5				
+ napropamide 5G	4.5	99 a	64 bcd	95 a	57 de
Oryzalin 5G	4.5	71 b	48 cd	67 c	48 e
Napropamide 5G	4.5	38 c	44 d	95 a	56 de
Oxadiazon 2G	4.5 + 4.5				
+ oryzalin 5G	4.5 + 4.5	100 a	99 a	96 a	91 a
Oxadiazon 2G	4.5 + 4.5				
+ napropamide 5G	4.5 + 4.5	100 a	95 a	96 a	80 ab
Oryzalin 2G	4.5 + 4.5	84 ab	74 abc	74 bc	65 cd
Napropamide 5G	4.5 + 4.5	65 b	44 d	86 ab	76 bc

[1]The re-treatments were 8 weeks after the initial application.

[2]Means within a column followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

Table 1. Control of common groundsel and barnyardgrass in nursery containers, 1976.

Herbicide	Rate[1] (kg/ha)	Common groundsel control (%)[2] Weeks after first application 4	8	16	24	Barnyardgrass control (%)[2] Weeks after first application 4	8	16	20	24
Oxadiazon 2G + napropamide 5G	2.2 3.4	85 a	82 a	51 b	-	95 a	98 a	90 a	49 b	-
Oxadiazon 2G + napropamide 5G	2.2 + 2.2 + 2.2 3.4 + 3.4 + 3.4	85 a	79 a	81 a	84	92 a	95 a	99 a	99 a	99 a
Napropamide 5G	3.4	14 b	-	-	-	83 a	83 ab	62 b	26 c	-
Napropamide 5G	3.4 + 3.4 + 3.4	-	-	-	-	73 a	70 b	86 a	86 a	90 a

[1] Re-treatments were at 8-week intervals.

[2] Means within a column followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

The oxadiazon plus napropamide combination did not show a significant advantage over oxzdiazon alone in 1979 or 1980 (Table 3). As in previous years, control of groundsel in 1980 from the combination with oxadiazon was superior to control from oryzalin or napropamide alone (Table 3). However as in 1976, control of common groundsel by the combinations in 1979 and 1980 was not over 91% (Tables 1 and 3).

Oxadiazon plus napropamide at 2.2, 3.4, or 4.5 kg/ha of each chemical and oxadiazon plus oryzalin at 3.4 ot 4.5 kg/ha of each chemical controlled mouseear chickweed 99.5 to 100% when evaluated on the basis of seedlings growing past the 4-leaf stage (Table 4). Oxadiazon alone gave not more than 70% control on this basis. The combination with oryzalin was more effective in preventing seedling emergence that the combination with napropamide.

Oryzalin controlled common chickweed 99.8% and birdseye pearlwort 100% (Table 5). Napropamide and DCPA partially controlled common chickweed but failed to control pearlwort. Combinations with oxadiazon were not included in this experiment.

Table 3. Common groundsel control from oxadiazon, napropamide, and oryzalin, separately and in combinations, 1979 and 1980.

		Control (%)[1]			
		1979		1980	
		Weeks after treatment			
Herbicide	Rate (kg/ha)	4	8	8	16
Oxadiazon 2G	4.5				
+ napropamide 50WP	4.5	91 a	57 a	80 a	53 b
Oxadiazon 2G	4.5				
+ oryzalin 5G	4.5	-	-	86 a	51 b
Oxadiazon 2G	4.5	90 a	65 a	78 a	55 b
Napropamide 50WP	4.5	-	-	44 b	-
Oryzalin 5G	4.5	-	-	46 b	-

[1]Means within a column followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

Effects on growth of nursery stock. Napropamide at 3.4 or 6.7 kg/ha plus oxadiazon at 2.2 or 4.5 kg/ha did not significantly affect fresh weight of shoots of azalea 'Hinodegiri', Japanese pieris, or cotoneaster (Table 6). However, three applications of oryzalin 75WP at 4.5 kg/ha reduced the fresh weight of azalea 'Hinodegiri' 46%. Fresh weight of Japanese pieris plants treated with oryzalin 75WP at 4.5 kg/ha was significantly less than for plants treated with napropamide 8G at 3.4 or 6.7 kg/ha. Three applications of oryzalin at 9 kg/ha had an even more severe effect on these two species. None of the treatments significantly affected fresh weight of cotoneaster.

In 1977, two applications of oxadiazon at 4.5 or 9.0 kg/ha, or oryzalin at 4.5, 9.0, or 18.0 kg/ha, with a 3-month interval between applications, did not significantly affect fresh weight of azalea 'Rosebud', Japanese

Table 4. Mouseear chickweed control from oxadiazon separately and in combination with napropamide or oryzalin, 1980.

		Control (%)[1]			
		Emerged		Past 2-leaf stage	Past 4-leaf stage
		Weeks after treatment			
Herbicide	Rate (kg/ha)	4	8	8	12
Oxadiazon 2G	4.5	58 b	22 b	70 b	-
Oxadiazon 2G					
+ napropamide 50WP	2.2	50 b	0 c	87 a	99.5 a
Oxadiazon 2G	3.4				
+ napropamide 50WP	3.4	56 b	4 bc	94 a	99.9 a
Oxadiazon 2G	4.5				
+ napropamide 50WP	4.5	78 ab	15 bc	94 a	99.8 a
Oxadiazon 2G	3.4				
+ oryzalin 5G	3.4	96 a	74 a	98 a	99.9 a
Oxadiazon 2G	4.5				
+ oryzalin 5G	4.5	96 a	78 a	99 a	100.0 a

[1]Means within a column followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

Table 5. Control of common chickweed and birdseye pearlwort, 1980.

		Control (%)[1]				
		Common chickweed		Birdseye pearlwort		
		Emerged	Taller than 1.3 cm	Emerged	Taller than 1.3 cm	
		Weeks after treatment		Weeks after treatment		
Herbicide	Rate (kg/ha)	4	8	4	8	16
Oxadiazon 2G	4.5	13 c	-	10 c	-	-
Napropamide 10G	4.5	75 b	87.0 b	20 c	-	-
Oryzalin 5G	4.5	97 a	99.8 a	73 a	98	100
DCPA 5G	13.4	90 ab	82.5 b	44 b	-	-

[1]Means within a column followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

Table 6. Herbicide effects on growth of container nursery plants, 1976

Herbicide	Rate[1] (kg/ha)	Fresh weight of shoots as percent of untreated plants[2]		
		Azalea Hinodegiri	Japanese pieris	Cotoneaster Lowfast
Untreated	-	100 a	100 bc	100 a
Oxadiazon 2G + napropamide 8G	2.2 3.4	91 ab	102 abc	96 a
Oxadiazon 2G + napropamide 8G	4.5 6.7	83 abc	99 c	99 a
Napropamide 8G	3.4	96 ab	116 a	98 a
Napropamide 8G	6.7	94 ab	115 ab	89 a
Oryzalin 75WP	4.5	54 d	88 cd	94 a
Oryzalin 75WP	9.0	25 e	76 d	94 a

[1]Three application were made at these rates with 8-week intervals.

[2]Means followed by the same letter are not significant different at the 5% level, Duncan's multiple range test.

Table 7. Fresh weight of nursery container plants treated with oxadiazon or oryzalin, 1977.

Herbicide	Rate[1] (kg/ha)	Fresh weight of shoots as percent of weeded check plants[2]				
		Azalea Rosebud	Japanese privet	Euonymous Emerald Cushion	Japanese holly Howardii	Juniper Wiltonii
Weeded check	-	100	100	100	100	100
Oxadiazon 2G	4.5	115	93	82	96	111
Oxadiazon 2G	9.0	102	89	71	92	112
Oryzalin 5G	4.5	107	101	89	99	114
Oryzalin 5G	9.0	95	105	88	90	110
Oryzalin 5G	18.0	94	75	78	94	114

[1]Two applications were made at these rates with a 3-month interval.

[2]No significant differences within columns.

privet, euonymus, Japanese holly, or creeping juniper (Table 7).

Two applications of napropamide at 4.5 kg/ha with an 8-week interval in 1978 did not affect significantly the fresh weight of azaleas 'Hinodegiri' and 'Rosebud', but the napropamide plus oxadiazon combination did reduce fresh weight of these cultivars 14 to 17% (Table 8). Two applications

Table 8. Herbicide effects on growth of container nursery plants, 1978.

Herbicide	Rate[1] (kg/ha)	Fresh weight of shoots as percent of untreated plants[2]				
		Azalea Hinodegiri	Azalea Rosebud	Cotoneaster Lowfast	Japanese holly Howardii	Euonymus Emerald Cushion
Untreated	-	100 a	100 a	100 ab	100 b	100 a
Oxadiazon 2G	4.5					
+ Napropamide 5G	4.5	83 b	86 b	95 ab	114 a	110 a
Oxadiazon 2G	4.5					
+ oryzalin 5G	4.5	93 ab	83 b	91 b	97 b	113 a
Napropamide 5G	4.5	95 a	92 ab	102 a	105 ab	110 a
Oryzalin 2G	4.5	102 a	86 b	100 ab	108 ab	102 a

[1] Two applications were made at these rates with an 8-week interval.

[2] Means within a column followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

of oryzalin at 4.5 kg/ha alone or with oxadiazon reduced fresh weight of azalea 'Rosebud' 14 to 17%. Fresh weight of cotoneaster, Japanese holly, or euonymus was not affected by any treatment.

Two applications of the oxadiazon plus napropamide combination at 4.5 kg/ha of each chemical significantly reduced the fresh weight of cotoneaster and the height of azalea 'Caroline Gable' in 1979 (Table 9). The means for the azalea, pieris, and cotoneaster show a 10% reduction in fresh weight from oxadiazon, and a 14% reduction from the combination treatment. If the oxadiazon granules are not thoroughly washed off the foliage by irrigation or rainfall, injury to soft leaves may occur. No obvious injury was observed, but the first irrigation after application may not have been adequate and there could have been enough injury from one or both applications to reduce photosynthetic activity and thereby reduce growth.

The oxadiazon plys oryzalin combination at either the 3.4 or 4.5 kg/ha rate of each chemical reduced fresh weight of azalea 'Caroline Gable' 16 to 20% in 1980, and the combination of oxadiazon at 4.5 kg/ha plus DCPA at 13.4 kg/ha reduced it 17% (Table 10). This cultivar was not significantly affected by the oxadiazon plus napropamid combination, and none of the treatments affected growth of Japanese pieris, cotoneaster, or Japanese holly.

Table 10. Herbicide effects on growth of container nursery plants, 1980

Herbicide	Rate[1] (kg/ha)	Fresh weight of shoots as percent of untreated plants[2]			
		Azalea Caroline Gable	Japanese pieris	Cotoneaster Lowfast	Japanese holly Howardii
Untreated	-	100 a	100 bc	100 a	100 a
Oxadiazon 2G	4.5	88 ab	110 abc	91 a	101 a
Oxadiazon 2G + napropamide 10G	3.4 3.4	87 ab	115 ab	97 a	105 a
Oxadiazon 2G + napropamide 10G	4.5 4.5	95 ab	125 a	98 a	103 a
Oxadiazon 2G + oryzalin 5G	3.4 3.4	80 b	104 bc	95 a	110 a
Oxadiazon 2G + oryzalin 5G	4.5 4.5	84 b	95 c	91 a	109 a
Oxadiazon 2G + DCPA 5G	3.4 9.0	88 ab	120 ab	89 a	103 a
Oxadiazon 2G + DCPA 5G	4.5 13.4	83 b	103 bc	93 a	108 a

[1]Two applications were made at these rates with an 8-week interval.

[2]Means within columns followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

Table 9. Effects of oxadiazon separately and in combination with napropamide on plant growth, 1979.

Herbicide	Rate[1] (kg/ha)	Percent of untreated plants[2]: Azalea Caroline Gable	Azalea Caroline Gable	Japanese pieris	Cotoneaster Lowfast	Mean	Japanese holly Howardii
		Height	Fresh weight of shoots				
Untreated	-	100 a	100 a	100 a	100 a	100 a	100 a
Oxadiazon 2G	4.5	95 ab	87 a	93 a	91 ab	90 b	104 a
Oxadiazon 2G	4.5						
+ napropamide 50WP	4.5	90 b	85 a	85 a	88 b	86 b	83 a

[1] Two herbicide applications at these rates with an 8-week interval.

[2] Means within columns followed by the same letter are not significantly different at the 5% level, Duncan's multiple range test.

Oryzalin was the only herbicide that appeared to be effective as a supplement to oxydiazon for control of both of the chickweed species and birdseye pearlwort. Under the conditions of these experiments, application of oryzalin should not be repeated at shorter than 3-month intervals if reduction of growth is to be avoided. In all experiments in which a second herbicide application was made 8 weeks after the initial treatment, the fresh weight of an azalea cultivar was reduced significantly by oryzalin applied separately or in combination with oxadiazon. When the interval was 3 months between applications, oryzalin did not significantly affect growth of any cultivar (Table 7).

Two applications of napropamide separately at 6-week intervals (2) or in combination with oxadiazon at 8-week intervals (Table 6) did not significantly affect growth of azalea 'Caroline Gable'. However, in 1978 and 1979, two applications of the napropamide plus oxadiazon combination repeated at 8-week intervals did reduce growth of azaleas. If this combination is used on azaleas, the interval between applications probably should be longer than 8 weeks.

The growth reducing effects reported here were in comparison with essentially weed-free untreated plants, a condition that usually would not occur in a nursery. The experiments were conducted in this way to compare the direct effects of herbicide treatment on nursery plants without the complication of effects from weed competition. Growth reductions of 10 to 20% determined on this basis may be acceptable to nurserymen if the herbicides provide a high level of weed control at costs that are reasonable compared with other methods of control.

Literature Cited

1. Humphrey, W. A., C. L. Elmore, and T. W. Mock. 1977. Long-term weed control in container-grown plants. Flower and Nursery Rpt. (May-June): 6.

2. Ryan, G. F. 1976. Control of bittercress, common groundsel, and barnyardgrass in two nursery container media. Proc. West. Soc. Weed Sci. 29:156-168.

3. Weatherspoon, D. M. and W. L. Currey. 1976. Repeated applications of Treflan, Lasso, and Ronstar applied separately and in combination on container ornamentals. Proc. SNA Res. Conf. 125-218.

ANNUAL WEED CONTROL IN TREES AND VINES WITH GLYPHOSATE

T. E. Dutt[1]

Abstract: Annual weed control studies with glyphosate [*N*-(phosphonomethyl) glycine] were conducted during the winter months in vineyards and orchards throughout California. The commercial formulation of the isopropylamine (IPA) salt of glyphosate provided excellent postemergence control of numerous annual grass and broadleaf species when applied at rates of 0.38 to 0.75 lb ae/A. It was beneficial to combine IPA glyphosate with additional nonionic surfactant at 0.5% (v/v) in many of the trials. Tank mixes of IPA glyphosate with simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine], napropamide [2-(α-naphthoxy)-*N*,*N*-diethylpropionamide], diuron [3-(3,4-dichloro-

[1]Development Assoc., Monsanto Agric. Products Co., Fresno, CA 93710.

phenyl)-1,1-dimethylurea], oryzalin (3,5-dinitro-N^4,N^4-dipropylsulfanilamide), and oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene] for residual weed control were also evaluated. Tank mixes of IPA glyphosate with residual herbicides provided improved length of control, as compared to IPA glyphosate of the residual herbicides alone.

LEAFY SPURGE PROGRAM IN WYOMING: ACTION AND REGULATORY PHASE

George F. Hittle[1]

Action Phase

Organization. In 1973 the Wyoming Weed and Pest Council adopted a logo titled "The Wheel of Weed & Pest Control" (Edwin H. Amend, Associate Director, Cooperative Extension, North Dakota State University, Fargo).

Axle: Legal basis. The Wyoming Legislature provided a legal basis allowing for the formation of weed and pest control districts.

Bearing surface: Education. Education and research allow for progress. Dr. Alley and his associate have pledged continuing leadership in education and research programs at the University. They are under financed, but somehow manage to get the job accomplished.

Hub: Technology. University, industry, etc. must keep us abreast of technological changes.

Spokes: Agencies and organizations. Weed and pest districts, research organizations, industry, University, Department of Agriculture, and last but not least agricultural organizations all have a part to play in the effectiveness of the weed and pest control movement. Each agency and organization must carry a fair share of the total load.

Rim: Program and social environment. Supervisors, know your job, and take well deserved pride in achievements of the past. Prepare for the future. Jobs are changing. No longer does weed and pest control consist of dispensing of chemical; know the purpose of existence of your job, of the district. Understand relationship between regulations and education. Does the program fit today's social conditions? Why does the program exist?

Tire: Service. This is what holds the program together. It is the external portions of the weed and pest district which make contact with the public. Keep your finger on the local situation.

Locking nut: Organizational structure. The organization must fit local and social requirements.

Entire wheel: The purpose of the wheel of weed and pest control is to control weeds and pests. Avoid useless internal controversy. Fight weeds and pests, not each other.

Coordination is tying in all components mentioned in the wheel: Research, education, industry, weed districts, state and federal agencies. The purpose of coordination is to formulate a successful, coordinated system of weed management programs through public and private agencies and progressive landowners. Implementation or expansion of the program will depend upon the acceptance by landowners, managers, and interested organizations. Demand for and support of the control measures is necessary for a coordinated system.

Before initiating a large-scale weed system such as leafy spurge, it

---

[1]Weed & Pest Coordinator, Wyoming Department of Agriculture, Cheyenne, WY.

is imperative that we had the knowledge required, recognizing the organizations and funds were needed to get the job completed. Attemps to initiate the program without the aforementioned ingredients should be avoided since failure would only diminish chances for future adoption and success. Emphasis will be placed on leafy spurge (*Euphorbia esula*), recognizing that any noxious weed can be placed in the system.

To develop a coordinated system for leafy spurge, several factors had to be considered: 1. Recognition of the problems, which includes surveys, plant behavior, and priority of control. 2. Knowledge required for implementing a control program, which includes preventative measures, physical control methods, biological control, herbicide control methods, and management.

Before discussing the regulatory phase, let me give you some advice Dr Amend, a former professor at the University, gave us.

Tell what you are selling. Believe in the program you are selling. Know who you are selling your program to and they know who you are. Know how to reach your audience. Utilize the news media. Be enthusiastic and honest.

We have people who meet these qualifications: Our educators, supervisors, district board members, among some!

Regulatory Phase

The regulatory phase is divided into several categories: Organization, Funding, Implementation, Monitoring program, and Penalty.

A. Organization. The leafy spurge program is a special act under the Wyoming Weed & Pest Control Act.

1. Wyoming Department of Agriculture coordinates the various activities between federal, state, and district programs under the Leafy Spurge Act.

2. The actual treatment program is under the direction of the weed and pest control district board of directors. The weed and pest supervisors are the workhorses for the program.

3. State and district evaluation committees are established to review the district's programs annually. These committees consist of representatives from the University of Wyoming, Weed & Pest Council, Department of Agriculture, Public Land Office, Governor's Office, and weed and pest districts.

4. The University of Wyoming, Plant Science Division, through the excellent leadership of Dr. Harold Alley and his staff provides us with education and research programs that in my opinion are the number one priority. Though not funded by the program, they should have been. Without them we could not and would not operate.

B. Funding: Private, district, and state.

1. Landowners contribute 20% of the cost of the treatment program, but not to exceed a total of $60.00 per acre.

2. District contributes 80$ of the cost of the treatment program. Districts are authorized to levy up to an additional one mill to fund its contribution.

3. State (WDA) contributes the balance which cannot be funded by the districts. The total cost on State land is paid for by Public Land Offices.

C. Implementation; which is the heart of the program and is carried out by the district. They are a very important part of the wheel.

1. Their program is designed to contain and control approximately 35,000 acres of leafy spurge in a six-year time period, without jeopardi-

zing their responsibilities and normal programs already in effect under the Wyoming Weed & Pest Control Act.

2. The districts have to organize and obtain landowner agreements prior to initiating a program on the landowner's property.

3. Application is being completed by private, commercial, district, and federal applicators. Many application methods are being utilized such as hand, vehicular, and aerial methods.

4. Herbicides being used are limited to three compounds at the present time.

D. Monitoring Program. Many precautionary measures have to be undertaken in a program of this magnitude under the Weed and Pest Control Act and the Leafy Spurge Program. One of the measures that has been taken is setting up a herbicide monitoring program which involves collection of soils, water, and sediment samples which are analyzed for herbicide contamination and residues.

The monitoring program was set up to:

1. Protect the weed program in the State of Wyoming.

2. Assure ourselves and the public we can safely apply herbicides and not contaminate our waterways.

3. Protect the environment.

4. Protect the herbicides and be assured they well be available in the future.

5. Meet DEQ and Federal water quality standards.

6. Study soil residues of various compounds.

The reasons are many, and I have only outlined a few that are of high priotity. The monitoring program is being completed in cooperation with the U.S. Geological Survey, Wyoming Weed and Pest Control Districts, the Wyoming Department of Agriculture, and the University of Wyoming.

E. Penalty. Any landowner who refuses to perform remedial requirements to control leafy spurge is subject to a civil penalty not to exceed one hundred dollars ($100.00) per day, but not to exceed a total penalty of five thousand dollars ($5,000.00) per year.

Summary

1. Program cost is expensive, but expensive compared to what? I'm not going into the cost figures; however, we do publish a report that goes into details.

2. The program effectiveness is projected at 75% to 90% which means 10% to 25% of the original acreage will have to be treated each year after the program ends (this estimate would include new infestations, regrowth, new seedlings, etc.). Research studies by the University of Wyoming indicates program effectiveness is higher than projected.

3. Progress appears to be on target with some adjustments being made. We are at the half-way mark of the program.

4. Problems encountered. Adopting rule and regulations that would allow the districts to carry out the program based on three phases of operations in setting up the program.

a. District carrying out the program under provisions of Weed and Pest Control Act of 1978 using only the additional mill levy (which is referred to as the first mill levy).

b. District carrying out the program under the Leafy Spurge Control Act of 1978 using only the additional mill levy (referred to as the second mill).

c. District carrying out the intent of the program using the additional mill levy plus receiving funds appropriated by state legislatures.

d. Some states that border Wyoming who are not developing and carrying out effective programs.

e. Leafy spurge root growth.

5. Anticipated problems: non-cooperation by landowners, lack of continued state funding would be very detrimental to the program and all weed control programs.

In conclusion, it appears we do have the capabilities and we are carrying out an effective program in cooperation with the agencies and organizations involved in the leafy spurge program.

In closing, remember tomorrow, March 19, 1981, has been proclaimed as National Agriculture Day where people all across the United States will take time to recognize the story of what agriculture means to America.

"Agriculture: It's your heartbeat, America!"

LEAFY SPURGE PROGRAM IN WYOMING: EDUCATION AND RESEARCH PHASE

Harold P. Alley[1]

As one mosquito said to another while they were viewing the prancing pulchritude of a nudist colony, "I just don't know where to begin."

It is easy to accept an invitation over the telephone to discuss the educational and research phase of the leafy spurge (*Euphorbia esula*) program in Wyoming but somewhat different when it comes time to prepare a presentation which may be of interest to the group you are to address, and more difficult when you realize it is your peers you are addressing. I may have an advantage in that I have been either in research and/or extension activities at the University of Wyoming for 25 years and have had the opportunity to work with and assist in the development of the leafy spurge program.

I also realize that we do not have any special educational gimmicks in Wyoming, we have the same problems, people, organizations, educational techniques as other states. I would also be the last to insinuate that what was done in Wyoming would work in any other state.

What I say here today may be challenged by other research and extension personnel and that my tunnel vision is such that this quotation may come to mind:

"People who think they 'know it all' are extremely irritating to those of us who do." (Clark)

The leafy spurge program was not developed over night nor by one or two individuals or organizations. It did not even come about in the last 3 or 4 years. We have to be aware of the programs which led up to where we are now.

We have to have a foundation, a solid foundation upon which to build. I would like to use the building of a pyramid--using its large cornerstones along with the time and effort expanded in its construction to outline the educational programs leading to where we now are in the Wyoming leafy spurge program.

We could start with the first educational activities which originated in the formation of the State Weed Conference in 1937. The first Weed Control Conference was organized two years before Idaho and some 12 years

---

[1]Professor of Weed Science and Extension Weed Specialist, University of Wyoming, Laramie WY.

before California, Washington, and Montana. Leaders during this early period realized the need for educational programs and programs which were not only educational but assistance programs through organization of Weed and Pest districts.

I think we have to reminisce, look back to those early times and the dedicated individuals, many times not reimbursed for their endeavors, who scratched and clawed for educational programs, materials, and data. It is very easy to become discouraged and take the easy way out in this profession of Weed Science, not being dedicated to your convictions. Can you imagine being put in their place, the limited or non-existent technology available, the herbicides they had, difficulties in communications, transportation, equipment, etc., etc. All I have to do is realize what these pioneers had to work with and I become a more dedicated person. They did not sit back and wait for a miracle to happen; they made use of what they had available.

The organization of the Wyoming Weed and Pest Control Act of 1973 has played a major role in the educational process. Until 1973 Wyoming had a maximum of 11 organized districts, some only partial counties with supervisors employed only during the summer months and no capital to work with. I do not need to inform this group that most of the districts were non-functional. It wasn't until 1973 that Wyoming had an active state-wide program.

Considerable educational effort was necessary to formulate a state-wide Weed and Pest district which included all lands within the boundaries including federal, state, private, and municipally owned lands. I think it says something for education when a state of only 2.6 million acres of cultivated land in a state of 62.4 million acres could organize a state-wide district. Those responsible for the education had to face and convince woolgrowers, stockgrowers, public land control officials, governing bodies of municipalities, farmers and ranchers, and legislators with every facet of representation attempting to convince them of the merits and needs for a state-wide program. No one individual nor organization could accomplish what was done. The enlistment of agricultural leaders, extension, research, Weed and Pest supervisors, State Department of Agriculture and many others were essential.

The Weed and Pest supervisors have played a major role in the educational process and will be instrumental in maintaining present programs and development of new ones. The greatest improvement in the entire program has been the educational programs for the supervisors. They are the contacts within the districts, they are in contact with the people every day. We have supervisors running in education from high school to those with a M.S. degree. All must be certified. If they have not had the training in college they are required to complete correspondence courses in Weed Science and Entomology which were prepared specifically for them. They are also required to attend educational meetings prepared for them. The supervisors have been a major force in legislative activity, sometimes spending weeks at Cheyenne when the legislature is in session.

The State Department of Agriculture is the regulatory arm but we have been fortunate to have the close relationship of this group--the Commissioner of Agriculture, Board of Agriculture and the Weed and Pest Coordinator. They must understand and support the programs being developed.

If I had to single out one individual to be the catalyst and leader, one who has the major responsibility of the organization, program development, solicitation of support, it would be the Weed and Pest Coordinator. If a state does not have the type individual who can bring all loose ends together, they are in all probability, not going to have a functional program.

With approximately 50% of the land in Wyoming controlled by public agencies it is essential to have their support--support which includes financial assistance. We have always been critical of these agencies, policies dictated from Washington, not understanding our problems. Educational trips to Washington, D.C. which has brought about cooperation and some capital would not have possible without expenditure of time and monies by our state organization.

The farmers and ranchers, leaders from this group is very important from the educational aspect. They seem to have more influence on legislators and other agriculturists than any other people. These individuals have to be problem oriented, understand the problem and be willing to back programs through their efforts.

Research and extension on the University level is relied upon to supply the educational force. Wyoming has no more personnel or tools available than most other states. Research has to develop the necessary tools and programs for education. Extension has to take these programs to the clientele. Experience is important but we must believe in our own distiny and high calling that they demand our wholehearted allegiance.

All of the previously mentioned organizations and individuals were necessary and essential in the adoption of the Leafy Spurge Control Act of 1978.

Educational meetings, bulletins, radio, fact sheets have been concernd with the seriousness of leafy spurge and the necessity for 25 years of my tenure and no doubt years prior to my time. Until state legislators, ag. appropriation committee members, agricultural leaders, community leaders, the press and others were taken into the field, viewed the magnitude of Wyoming's problem as compared to what it was 15 to 20 years ago and compared to neighboring states' problem the program progressed very slowly.

In summary of the Education Phase I would conclude that all the educational media at our disposal is not as effective as "eye to eye" contact and viewing the problem first hand in the field.

The weed program, especially leafy spurge, was given its greatest boost during the Governor's Resource Management Tour when the leafy spurge problem was viewed by the press. People on that tour were shocked and much good publicity has been received since that tour.

The $2.65 million appropriated for leafy spurge control in Wyoming is a lot of money. But let's put it into perspective. Let's tell it like it is. On the Governor's Tour we had the opportunity to view thousands of acres of leafy spurge infested rangeland just prior to the groups visit to mine reclamation sites. This gave us an opportunity to show the thousands of acres of rangeland put out of production as compared to the few hundred acres of mined land where millions of dollars had been spent on Environmental Impact Assessments, the state and federal monies spent to reclaim these small acres as compared to what they were viewing.

The infestation of 35,000 acres of leafy spurge in Wyoming as compared to 600,000 in North Dakota, 543,000 in Montana, 105,000 in Nebraska, 60,000 in South Dakota, give us a real selling point. If we had done something 15 years ago, the costs would have been minimal. Do we sit back and wait another 15 years until we, too, have 600,000 acres infested? It was time for action and we were fortunate that our legislature had the initiative, foresight and fortitude to start the fight.

Research Phase

I don't deem it necessary to reinvent the wheel before we can initiate control programs. We do not have all the answers and we never will. It may be very shocking to those in research to conduct a literature review. The phenoxy herbicides were introduced after World War II, picolinic acid in 1964, dicamba (3,6-dichloro-*o*-anisic acid) soon after. The immense amount of research reports, station bulletins, weed control guides are all in agreement whether they were prepared in 1948, 1964, or 1980.

Anyone who has conducted leafy spurge research understands its regenerative potentials. How much research had been done on the root system?

Ninty-nine percent of the research on all perennial weeds have been concerned only with vegetative top growth control. Excavations to study the underground root system is time consuming and laborious. I think all of us should dedicate ourselves to these type of studies. Wyoming's major contribution is the study of repetitive treatments, depth of root kill, longevity of control and economics of control.

Immediately following the initiation of the Wyoming Leafy Spurge Control Program in 1978, the leafy spurge symposia were held in Bismark, North dakota and Billings, Montana in 1979. Many committees were formed. But without monies to conduct research very little has been accomplished.

Project proposals have been submitted to the Old West Commission since 1976 whem Wyoming initiated the first proposal. The latest proposal from the states of Nebraska, North Dakota, South Dakota, Montana, and Wyoming is apparently going to be funded for one year at approximately $123,000. As a direct response from the two previously mentioned symposia the North Dakota State University committed $100,000 for additional research on perennial weed control during the 1979-1981 biennium. The 1979 Montana Legislature apprpriated $138,000 to support biological control programs for the biennium including $63,000 for a greenhouse to propagate and screen insects. There is also an indication that the U.S. Department of Agriculture is requesting $300,000 for high priority research in fiscal year 1982.

It may be of interest to the group to view a partial list of the research contemplated by the five states in the Old West Commission area if the financing becomes available: 1) roller, wick, and controlled droplet application; 2) total management systems - fertilizer, mowing-burning; 3) annual herbicide treatments; 4) treatment combinations; 5) forage yields; 6) economic benefits; 7) repetitive treatments; 8) root control studies; 9) ground water contamination; 10) plant growth regulators; 11) competitive grasses; 12) biological control; 13) new herbicides; 14) translocation; 15) physiological; 16) biotypes; 17) ecology; 18) allelopathy; 19) sheep grazing; and 20) hydrocarbon content.

Many of these research projects are of necessity to more fully understand the leafy spurge plant. Any research project creates problems that require more research. We will probably never reach the point that control of any perennial weed is an easy task. It is my feeling that we have to utilize what is available at this time and not wait until the answers to the avobe mentioned studies are completed.

COMMON CRUPINA: EDUCATION AND PUBLIC AWARENESS

Donald C. Thill[1]

Common crupina (*Crupina vulgaris* Cass.) was recently intruduced into the United States from the Mediterranean region of Europe. The species was first reported in 1968 near Grangeville, Idaho. A survey conducted in

[1]Department of Plant and Soil Sciences, University of Idaho, Moscow, Idaho 83843.

1980 indicates that common crupina now infests approximately 9,000 hectares of rangeland in Clearwater, Idaho, and Lewis counties of northern Idaho. The only other known infestation of this annual rangeland weed occurs on approximately 1 hectare of pasture land in northern California. Crupina is a member of the Compositae family, and a close relative to spotted and diffuse knapweed (*Centaurea maculosa* and *C. diffusa*, respectively) and yellow starthistle (*C. solstitialis*).

In 1980 the University of Idaho, in cooperation with the Idaho Department of Agriculture and the Animal Plant Health Inspection Service (APHIS), initiated an estensive field testing program to determine the eradication feasibility of common crupina. APHIS provides federal funding, leadership and coordination, implements any quarantines of infested areas, and regulates and enforces the Federal Noxious Weed Act. The Idaho Department of Agriculture is responsible for statewide coordination, and implementation and regulation of any potential eradication program. The University of Idaho is involved with detection and survey of the problem, biology and control research, eradication recommendations, and education and public awareness.

In an effort to educate and inform the public of this new threat to the continued productivity of western rangelands, the University of Idaho research and extension personnel have utilized several information media. This includes the publication of a Current Information Series (CIS) bulletin (No. 542), and a CIS videotape (No. 121) on the distribution, biology, and control of common crupina. Both have been extensively distributed throughout Idaho and the other 10 western states. Timely news releases have been made in local and regional newspapers and on radio and television in northern Idaho. In addition, presentations dealing with the biology, control, and eradication feasibility have been made at various local, regional, and national meetings. A combination of the above efforts will continue in an effort to keep the public informed of new findings related to the eventual control or eradication of common crupina.

SURVEY OF WILD OAT IN WYOMING BARLEY AND WHEAT

N. E. Humburg and H. P. Alley[1]

Wild oat (*Avena fatua* L.) has been present in Wyoming for many years; however, in recent years the magnitude of severity in individual fields and geographic extent have increased rapidly. A survey of Wyoming barley and wheat fields was conducted in late July and early August of 1979. At this time of year wild oat panicles were evident above headed barley and wheat.

Five regions were included in the survey: 1) the far-western, mountain-valley fields near Afton, 2) irrigated fields near Riverton and Lander in north-central Wyoming, 3) irrigated fields west of the Big Horn Mountains of north-central Wyoming near Powell, Cody, Lovell, Basin, Worland, and Thermopolis, 4) irrigated and dryland fields near Sheridan, east of the Big Horn Mountains, and 5) dryland fields in the vicinity of Sundance in northeastern Wyoming. All regions included in the survey are basically mountain valleys, where field sizes generally are small and irregular in configuration. Winter wheat is produced primarily in the southeastern part of Wyoming under dryland wheat-fallow-wheat rotation. The quarter-million acres

[1]Plant Science Division, University of Wyoming, Laramie, Wyoming 82071.

of wheat in this part of the state is essentially free of wild oat.

Barley, much grown for malting pruposes, was the predominant small grain crop. Eighty-four barley fields, for a total of 3,680 acres of 109,000 in the region, were included in the survey. Half of the regional spring wheat, 350 acres, was surveyed. Winter wheat fields encompassing 740 acres were surveyed; most of the 5,500 acres in regions where wild oat is present was near Sheridan.

Procedure

The survey procedure involved in-field inspection, mapping and panicle counts using a quadrat. The form used made record of the county, field number, date, crop, crop condition, dryland or irrigated, site description, map, field size, and wild oat infestation by percentage according to visual evaluation. Wild oat density as mapped was verified by three quadrat counts per density category. Densities of wild oat were expressed as extreme, dense, moderate, and sparse for more than 270, 110 to 270, 20 to 110, and less than 20 panicles per m^2 respectively. Supplementary information concerning a field was noted, e.g., whether or not the field was cultivated after planting and identification of other weed species. The farm operator was contacted in order to obtain field history. If a chemical was used to control wild oat, the herbicide and rate of application were recorded. Further, an evaluation of the succuss of the treatment was obtained. The method of application and previous use of wild oat herbicides were recorded. Crops grown in 1976, 1977, and 1978 were indicated. The year of first-known wild oat appearance and the origin of the infestation were questions asked of the operator.

Results and Discussion

The principal information received from the survey was the location and degree of severity of wild oat infestations. Virtaully every barley and wheat field in the surveyed regions had some degree of wild oat infestation. There were a few fields where no wild oat was present; these usually were new fields where introduction of wild oat had not been allowed.

Most barley in Wyoming is produced under irrigation. Irrigated barley fields were located primarily in northwestern and west-central Wyoming. Based on the unit of the quadrat, not the full field, seven percent of Wyoming's irrigated barley acreage had an extremely dense infestation of wild oat, six percent was dense, 12 percent moderate, and 21 percent sparse. Over half the area had no wild oat. Barley growth was suppressed where wild oat was dense or extremely dense. Sparse or moderate infestations appeared to cause relatively little direct yield reduction in properly irrigated and fertilized fields. The most severe general infestations occurred in the far western part of the state, near Afton.

Dryland or non-irrigated barley is produced in the northeastern and far western parts of Wyoming. The percentage of area with extreme density of wild oat was much greater than that for irrigated barley. Extremely dense, dense, moderate, and sparse infestations occurred on 40, 17, 7, and 20 percent of dryland barley acreage, respectively. Sixteen percent, based on the quadrat unit, had no wild oat. Contaminated fields were rarely planted to other than small grains and there were no reports of herbicide use.

Dryland winter wheat grown in the vicinity of Sheridan is produced primarily under a small grain-fallow-small grain rotation system. The percentage of area for dense and estremely dense wild oat in winter wheat was essentially zero. One percent was categorized as moderate and six percent as sparse. The area determined to be free from wild oat was 93 percent.

Few fields were without wild oats, although in some it was resptricted to edges of fields. Reduced densities of wild oat in wheat were attributed to the fallow production system, use of herbicides and some crop rotation, particularly with alfalfa.

Use of herbicides for controlling wild oat was primarily on irrigated barley in the Cody-Powell region of northwestern Wyoming. Most herbicide application was by commercial concerns. Barley fields with low-density infestations generally were those where there were successful herbicide treatments, a history of herbicide use and/or crop rotation with sugarbeets, dry beans or alfalfa. Where wild oat was a major problem in barley and wheat fields in other regions of Wyoming, the characteristic pattern was year-after-year planting of small grains with herbicide use being a rarity.

The source of infestation was usually not known by farmers when wild oat had been present in a field for more than 20 years. However, known sources generally were the result of recent purchase of crop seed, namely malting barley which was contaminated with wild oat. The introduction of wild oat into many fields was by way of irrigation ditches.

Summary

In the barley and wheat growing regions of Wyoming where wild oat is commonplace, few fields were free of this weed. The densities of wild oat, from one field to another and among the regions, varied greatly depending upon the cultural system employed. There are herbicides available for controlling wild oat; yet results of this survey indicated that few growers were using herbicial control methods. The introduction of wild oat into Wyoming fields has been primarily by way of contaminated crop seed. Unfortunately, the sale of crop seed containing wild oat continues because laws do not prohibit its presence.

UTAH 1980 EXOTIC NOXIOUS WEED SURVEY

R. L. Chase[1]

An exotic noxious weed survey, funded by the Animal and Plant Health Inspection Service (APHIS), was conducted in Utah during the summer of 1980. The purpose of the survey was to locate, identify, and map newer weed species that pose a threat to Utah agriculture. Weed Science personnel, county agents, county weed supervisores, and district agricultural inspectors teamed up to survey the entire state. Twenty-one weeds were surveyed and mapped.

Attached is a list of the 21 weeds and the numbers of counties of the 29 in the state where each weed species was found.

Barbwire Russian thistle (*Salsola paulsenii*) is fast becoming established in the state. It appears to be moving in from Arizona and Nevada. This plant is about as rough as the name "barbwire" implies. Even in the early stage the spines are very sharp. The plant is much coarser and greener than regular Russian thistle (*S. kali* L. var. *tenuifolia* Tausch). It is not easy to identify unless both species are growing together so one can make a comparison.

Black henbane (*Hyoscyamous niger* L.), a poisonous member of the Solanaceae family, was found in six counties in the northern part of the state.

[1]Plant Science Department, Utah State University, Logan, UT 84322.

It is especially prevalent in Rich county where it has become a serious roadside weed problem.

Buffalobur (*Solanum rostratum* Dunal), although found in nine counties, is a serious prblem in only one. Just a few plants were found in each of the other eight counties. This is one plant we will attempt to eradicate from most counties.

Common crupina (*Crupina vulgaris* Cass.) was not found in the state.

Dalmation toadflax (*Linaria dalmatica* (L.) Mill.) is a problem in three counties and given the conditions where it is growing it would be extremely difficult to do anything but contain the infestation.

Dyers woad (*Isatis tinctoria* L.) is an annual or biennial mustard which is spreading from Northern Utah into Idaho and Wyoming. In the springtime it can be seen in such numbers that continuous masses of yellow extend over many acres. In the late summer the seed pods turn black. Woad is easily spread, and single plants have been spotted in the southern part of the state. We are attempting to contain this plant.

Giant whitetop (*Lepidium latifolium*) is on Utah's State Noxious Weed List. It is a perennial, tall-growing whitetop and difficult to control. There are several counties which have major infestations of this weed.

Goatsrue (*Galega officinallis* L.) is an introduced forage legune that has escaped and become a serious weed problem in Cache county. A small infestation has also been identified in Farmington, Davis county, probably as a result of moving ornamental plants from the University in Logan to the experiment farm in Farmington. At present a federal-county-university funded eradication program is being conducted on this weed.

The distribution and size of infestation of jointed goatgrass (*Triticum cylindricum*) is much larger than we had expected. It is a winter annual that is spreading in the winter wheat areas of the state. This grass poses a serious threat to our winter wheat farmers.

Leafy spurge (*Euphorbia esula* L.) is one of our eleven noxious weeds. It is located only in the northern part of the state, is difficult to control, but with a good control program can be contained to present areas. There are no large infestations.

Musk thistle (*Carduus thoermeri* Weinman), first reported in the state around 1966, has now spread throughout the state to 22 of the 29 counties. Nine counties have major infestations. Musk is one of Utah's eleven noxious weeds.

Watermilfoil (*Mycophyllum exalbescens* Fern.) is an aquatic weed found in reservoirs and slow moving rivers.

Western whorled mildweed (*Asclepis subverticillata* (Gray) Vail) is a perennial poisonous to livestock. It is found mainly in pastures, along roadsides and in waste areas in the southern portion of the state.

Silverleaf nightshade (*Solanum elaeagnifolium* Cav.), or horsenettle, is a spiny, perennial member of the Solanaceae family. Only Washington county has a serious infestation and the weed has been put on that county's noxious weed list.

Spotted (*Centaurea maculosa* Lam.) and squarrose knapweeds (*C. squarrosa* Roth) are not serious problems at present. The spotted knapweed acreage is probably less that five acres. Squarrose knapweed is largely in one area spread along a highway for approximately 15 miles.

A small infestation of telegraphplant (*Heterotheca grandiflora* Nutt.) was found in Washington county near the Arizona border.

Velvetleaf (*Abutilon theophrasti* Medic.) was found in only three counties and will be carefully monitored and controlled over a period of several years to make sure it does not spread.

Yellow nutsedge (*Cyperus esculentus* L.) is difficult to control. It is common in gardens in southern Utah in Washington and Kane counties. Nutsedge is also seriously interfering in crops in several other counties where high populations of the weed make farming difficult.

Yellow starthistle (*Centaurea solstitialis* L.) is an annual, easily controlled in the seedling stage, but menacing when mature. There are several relatively small infestations throughout the state.

Water hemlock [*Cicuta douglasii* (DC.) C.&R.], an extremely poisonous plant both to humans and cattle, was found in 19 counties. It infests irrigation ditches, streambanks, and wet meadows.

Infestation sites for each weed were marked on county maps. A written description was also prepared describing the weed survey in each county. Information on each county included the surveyors, date of survey, contacts made, types of stops, species found, areas of infestation, and any comments that were applicable. This information will be available to county weed control people.

State maps for each weed in the survey have been marked indicating counties with minor, intermediate, or major infestations. The survey information will be updated from time to time and will help guide future emphasis on weed control efforts throughout the state.

Table 1. Exotic noxious weeds of Utah, 1980.

Common name (s)	Scientific name	Counties infested*
Barbwire Russian thistle	*Salsola paulensii*	6
Black henbane	*Hyoscyamus niger*	6
Buffalobur	*Solanum rostratum*	9
Common crupina	*Crupina vulgaris*	0
Dalmation toadflax	*Linaria dalmatica*	5
Dyers Woad	*Isatis tinctoria*	9
Giant whitetop or Broad-leaf peppergrass	*Lepidium latifolium*	13
Goatsrue	*Galega officinalis*	2
Jointed goatgrass	*Triticum cylindricum*	16
Leafy spurge	*Euphorbia esula*	11
Musk thistle	*Carduus thoermeri*	22
Watermilfoil	*Myriophyllum exalbescens*	6
Poison milkweed or Whorled milkweed	*Asclepias subverticillata*	5
Silverleaf nightshade	*Solanum elaeagnifolium*	3
Spotted knapweed	*Centaurea maculosa*	3
Squarrose knapweed	*Centaurea virgata* var. *squarrosa*	4
Telegraphplant	*Heterotheca grandiflora*	1
Velvetleaf	*Abutilon theophrasti*	3
Yellow nutsedge	*Cyperus esculentus*	6
Yellow starthistle	*Centaurea solstitialis*	5
Water hemlock	*Cicuta douglasii*	19

*There are 29 counties in Utah

THE DISTRIBUTION AND DENSITY OF *CIRSIUM ARVENSE* (L.) SCOP., IN NORWAY IN 1980 VS. 1969

Lambert Erickson[1]

To call *Cirsium arvense* "Canada thistle" in Europe would be sheer ignorance if not unmitigated heresy, or to demonstrate oneself as another ignorant "ugly American". Remember this species was known to them for centuries prior to its introduction to the North American continent. Furthermore, the father of modern taxonomy, the great Swede, Karl Von Linnaeus named it "aker thistel" and "aker" means field.

As I scanned the 1980 Western Society of Weed Science Research Progress Report I found only four references to the species that could indicate that the problem has been largely solved, and that the problem that prevailed and that the survey (1) which we compiled in the early 1960's, showing over 2.5 million acres of *C. arvense* in the Columbia Basin prevails no more. Two of these reports complained that much previous data on Canada thistle control were taken too soon after treatment and a third said, "The acreage infested with Canada thistle is steadily rising despite considerable effort in recent years to control it."

Why call this species Canada thistle? Its point of origin appears to have been in horthern Europe. It would guess in France where it grows almost as vigorously as it does in the Upper Snake River area of Idaho. So, why not call it French thistle? How and where did it first enter North America? That remains unknown. Was it Leif Ericsson, or Columbus, or the Jamestown settlers, or the Pilgrims, or was it the Franciscan Priests from Europe who brought many field crop seeds and tried to "agriculturalize" the Canadian Indians? We do know the results of General Burgoyne's cavalry and artillery move from Quebec to Saratoga to be defeated by General Gates in 1777. History records it as probably the world's greatest "land battle". Many would agree with that terminology, for that once upon a time "trail" of thistle from Quebec to Saratoga, now extends in greater width and has become the "land battle" westward to the Pacific Coast.

In August 1969 when I arrived in Norway, pursuing a Fulbright Fellowship Grant there in Weed Science, I was fascinated by the relative absence of *C. arvense* along the roadsides, in pastures, and its almost total absence in cereal grain fields. This was in sharp contrast to the density of this species in the Pascific Northwest States of the United States.

In consultations with the scientists in the Norwegian Plant Protection Institute, Department of Weed Biology, I learned that the species had been more prevalent some decades earlier but the discovery, development, and extensive use of the phenoxyacetic acid herbicides especially 2,4-D [(2,4-dichlorophenoxy)acetic acid] and MCPA {[(4-chloro-*o*-tolyl)oxy]acetic acid} had significantly reduced its incidence in the interval between 1945 and 1969.

The author, however, suspected that other factors relating to the environmental conditions or the susceptibility of the prevailing biotypes to the phenoxys were major factors in this species reduction. 2,4-D and MCPA were also the major herbicides used in the United States. Although MCPA was the dominating phenoxy herbicide in Norway vs. 2,4-D in America.

---

[1]Emeritus Professor of Weed Science and Agronomy, University of Idaho, Moscow, ID 83843.

The climate was obviously different. In North America this aggressive perennial thistle dominates between latitudes 49° ± 5°N. Whereas, Norway is a long and narrow country extending from 58° to 71° N. lattitude. It was very discernable in 1969 that altitude was a dominating factor in its distribution. Its ecological limits appeared to be from 0 to approximately 200 meters above sea level (0 to 600 feet) in southern Norway, and 0 to 10 meters in northern Norway. In longitude it prevails from the southern coast to beyond 69° N. latitude, in the vicinity of Tromso.

In 1969 root clones were collected at approximately 100 km (60 mile) intervals from southern to northern Norway to determine their biological variations and their variations in herbicidal resistance. None of the clones were biologically or taxonomically pure. All were crosses involving morphological characteristics of three previously identified taxonomic strains e.g., Horridium, Mire, and Vestitum (3).

Scientiest K. Lund-Hoie of the Department of Weed Biology led the investigation in determining the response of the eight most vigorous clones to amitrole (3-amino-*s*-triazole) and amitrole^{14}C, with respect to both toxicity and translocation quantities and pathways. A few copies of that paper (2) are still available from either author.

In 1969-70 we discussed my returning in about 10 years for a follow up survey to determine if the strains involved in the study, collected from southern to northern Norway in 1969, would reveal tenacity in relation to the Amitrole^{14}C study results.

It became possible to travel to Norway in the summer of 1980 and to largely repeat the survey of 1969. The results were unexpected, depressing, and almost terrifying. There was no time available to determine what varieties prevailed. The data revealed a 10-fold increase along highway E-6 (European 6) extending from the town of As (south of Oslo) to Harstad, more than 1600 kilometers northward. Furthermore, my observations in 1969 indicating that *C. arvense* probably could not compete in grain fields were totally shattered. The observations regarding elevations and longitudes however remained intact.

Disappointedly, *C. arvense* is not an uncommon entity in the grain fields of southern Norway today. I can only conclude that conscientious chemical and cultural control efforts between 1945 and 1969 had brought excellent control and that relaxation of that effort had changed that scene.

In final conclusion, we are in desperate times. Funds for weed control will be reduced, some have vanished. One county in Idaho to my knowledge has already closed its weed program. We, nationally, perhaps can temporarily afford that yield loss. Importing nations cannot.

Literature Cited

1. Columbia Basin Interagency Committee Report. 1965.

2. Erickson, L. C. and K. Lund-Hoie. 1974. Canada thistle distribution and varieties in Norway and their reactions to ^{14}C-amitrole. Research in Horwegian Agriculture. Vol. 25.

3. Wimmer, F. and Grabowshi. 1829 Flora silesias vratislavie 3:82:92. From: Dimmer, F. 1927. Canada thistle, *Circium arvense*, field thistle, creeping thistle. Ohio Agr. Exp. Sta. Bul. 414. 45 pp..

PESTICIDES - THE PUBLIC IMAGE

R. L. Zimdahl and P. K. Martin[1]

Abstract: On balance, the information easily available to the public is strongly weighted against pesticides. People are unaware of the role and benefits of pesticides and because of this lack risk in magnified. Most agrichemical companies rely on the National Agricultural Chemicals Association to handle the pesticide public relations programs relative to benefits and risks. Pesticide advocates and antagonists emphasize the superiority of their arguments. Pesticide advocates typically play defense and leave the offense to those who object to pesticide use. This is not a winning strategy, and it may not be a strategy designed for endurance. It is time to build credibility by developing and facing issues, responsibly dealing with arguments perceived to be emotional, and most importantly disregarding the crusader of truth image.

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

PUBLIC CONCERNS ABOUT 2,4-D

Wendell R. Mullison[1]

While the use of chemicals for weed control goes back to ancient times (121), the modern use of chemicals as weed killers or herbicides started in Germany about 1850. The first chemicals used were lime and salt. Progress was very slow until 2,4-D [(2,4-dichlorophenoxy)acetic acid] was found.

The discovery of the herbicidal properties of 2,4-D during World War II arose independently in England and the United States at approximately the same time. The exact time, place, and who was the first to discover and realize that 2,4-D was an excellent herbicide is lost in the uncertainty caused by war time secrecy which disrupted normal scientific publication of research work. E. J. Kraus was one of the first people to have the idea in this country and W. G. Templeman, W. A. Saxton, and R. E. Slade were amongst the first in England. The first publication (83) that mentioned the use of 2,4-D as a herbicide was by J. W. Mitchell and C. L. Hamner in 1944. This was quickly followed by another paper (48) by Hamner and Tukey, also published in 1944, reporting on the herbicidal effect of 2,4-D and 2,4,5-T[(2,4,5-trichlorophenoxy)acetic acid] on bindweed. This historical information is not presented to give a history of 2,4-D, but to emphasize the fact that it has been known, used, and studied for 37 years.

The idea of specific or selective herbicides as weed control tools and the tremendous effectiveness of 2,4-D appealed to the imagination of agricultural scientists. Its time had come because hand labor was becoming increasingly scarce and expensive. The need to increase crop yields and to conserve energy lost in cultivation has further increased the value of 2,4-D as an agricultural tool to control weeds. Bovey and Young (24) consider

[1]Retired after 12 years of agricultural research, development, and registration at The Dow Chemical Company. He is now a consultant on agricultural pesticides, particularly herbicides.

the discovery of 2,4-D the greatest single advance in weed control and one of the most significant in agriculture.

Major Uses and Mode of Action

The major uses of 2,4-D are to control broad-leaved weeds in crops. 2,4-D is widely used to control broad-leaved weeds in cereal crops, particularly wheat, corn, oats, rye, and barley and the cane crops sugarcane and sorghum. It is also used to control dandelions and other broad-leaved weeds in lawns, rangelands, and pastures. 2,4-D is effective on some woody plants such as willow, sumac, and sagebrush, it is used to control some water or aquatic weed problems like Eurasion watermilfoil (*Myriophyllum spicatum* L.) and water hyacinth [*Eichornia crassipes* (Mart.) Solms]. Noxious vegetation that can pose health and safety problems may also be controlled.

The mode of action of 2,4-D has been extensively studied since its discovery. However, 37 years later, the specific way it acts is still not completely clear. Plant auxins are naturally-occurring compounds that control plant growth. Chemicals that have this property are called plant growth regulators. The synthetic plant growth regulator 2,4-D is known to act like a very powerful plant auxin, causing old cells to become rejuvenated and to over-stimulate young cells, preventing normal differentiation and maturation. Top growth ceases or is retarded, and growth in girth is over-stimulated. The cells in the plant food transporting tissue (the phloem) are often crushed or plugged thus interfering with food transport. 2,4-D is also known to affect general physiological processes of plants such as enzyme activity, respiration, nuclei metabolism, and protein synthesis (15). To simplify and summarize this complex process, 2,4-D interferes with the normal physiological and growth activities of plants so drastically that this interference causes death of susceptible plants.

Mammalian Toxicology of 2,4-D

Acute Oral Toxicity. 2,4-D is low to moderate in acute toxicity. The toxicity of pesticides is normally quoted in terms of the amount administered in a single oral dose that will kill 50% of the population of the test animals. This lethal dosage is called the LD_{50}. Table 1 gives the single LD_{50} values for 2,4-D in a number of animals.

Table 1. Single oral LD_{50} values for 2,4-D

Animal	LD_{50} (mg/kg)	Reference
Mice	368	Rowe and Hymas (106)
Rats	375*	Rowe and Humas
Dogs	100	Rowe and Hymas
Guinea pigs	469	Rowe and Hymas
Chickens	541	Rowe and Hymas
Rabbits	800	Spector (117)
Mule deer	400-800	Tucker and Crabtree.(123)

*Assuming an average adult would react the same way as these rats, if 0.92 oz. of 2,4-D was eaten at one time the individual would have a 50% chance of dying. Again based on rat data, this would also be true if this individual ate 2.47 oz. of aspirin.

2,4-D is usually formulated using salts or esters. Normally dosages are based on the 2,4-D acid content in these formulations. The various esters and salts of 2,4-D have approximately the same toxicity as the 2,4-D acid. If anything, the acid appears to be slightly more toxic. General symptoms of acute toxicity of 2,4-D in animals are: excessive thirst, lack of appetite, weight loss, inability to coordinate muscle movements, tremors, posterior paralysis, rapid breathing, and salivation (46, 132).

One of the early experiments (27) on the physiological effects of 2,4-D in animals identified temporary muscular spasms particularly in the hind limbs with subsequent lack of muscular coordination. It was also noted that the effect was the same whether 2,4-D was administered under the skin, into the abdominal cavity, or intravenously into the blood stream. Repeated injections (1/3 to 1/5 of the LD_{50} daily for three weeks to three months) did not produce chronic symtoms nor did they affect processes of animal reproduction and development.

Another group of scientists (42) working with rats was able to produce muscular stiffening after injection of 2,4-D into the abdomen at doses of 100-250 mg/kg. Injections of 2 mg 2,4-D directly into the blood stream supplying the target muscle in the experiment produced general muscular rigidity in rats in two minutes.

Exposure of livestock. One of the earliest studies (84) of possible toxic effects on animals from eating vegetation treated with 2,4-D was conducted with sheep and milk cows. Approximately 2.7 lb/A of 2,4-D were applied to two pastures. This is well in excess of the 1 lb/A 2,4-D often used to control broadleaf weeds in pastures. Sheep were grazed on one pasture for 12 days following spraying; milk cows, previously fasted for 12 hours, were grazed on the other for 48 days. In addition, a lactating cow was given 5.5 g of 2,4-D (approximately 10 mg/kg/day) daily for 106 days. During the last 38 days her milk was fed to a young calf. This feeding started three days after birth. The sheep showed no ill effects from grazing on the treated pasture. The milk cattle grazing on the treated pasture also showed no signs of ill effects; post mortem examinations at the end of the treatment showed no abnormal condition. The 2,4-D fed to the lactating cow produced no apparent effect on the flavor or odor of the milk. The calf fed this milk developed and grew normally and appeared in good health and vigor. Using a biological assay method 2,4-D was found in the blood serum of the cow fed 2,4-D but not in the blood serum of the calf fed her milk.

Eye toxicity. As a dry powder 2,4-D is only slightly irritating to the conjunctival membranes of the eye but salts, ester, and concentrated solutions are much more irritating with potential of causing appreciable injury to the eye (46, 105).

Skin toxicity. The acute dermal LD_{50} is given as 1.500 mg/kg (125) for rats and 1,400 mg/ka for rabitts (46). To determine subchronic dermal toxicity the following experiment was done with rabbits (60). Commercial formulations of the dimethylamine salt of 2,4-D, the isooctyl ester, and the butyl esters of 2,4-D were used. Gauze patches saturated with 15 ml of oil or water solutions containing 0.313% or 0.626% 2,4-D acid equivalent were applied to shaved abraded skin of the rabbits. New patches with the same dosage were applied daily and kept on the shaved skin of the rabbits for seven hours five days a week for three weeks. Assuming complete absorption this would be approximatel a daily dosage of 37 and 235 mg/kg. The authors say these exposure conditions are quite exaggerated, being two to five times more than would be expected in home or field use of 2,4-D.

There were no significant adverse effects on body weights, survival, blood values, clinical chemistry values, and organ/body weight ratios. No significant microscopic structural changes were observed in the nervous system or other representative tissues and organs. Local inflammatory skin reactions occurred in all treatments including the controls, especially those with the formulations diluted with oil. Other skin absorption studies (1) have also been conducted with 2,4-D on the shaved skin of albino white rabbits. The butyl ester and the diethanolamine salt of 2,4-D showed no toxic symptoms up to the highest rate tested, i.e., 3980 mg/kg. For the bytoxy ethanol ester of 2,4-D the skin absorption LD_{50} for rabbits was calculated to be 3980 mg/kg.

Inhalation toxicity. The inhalation toxicity of 2,4-D is considered to be minimal or only slightly toxic (125). This value is not accurately known but the Threshold Limit Values (TLV = defined as airborne concentrations of substances and represent conditions under which it is believed nearly all workers can be repeatedly exposed without adverse effects) have been established by the American Conference of Governmental Industrial Hygienists (8) as follows:

1. The airborne TLV time weighted average for a normal eight-hour workday or 40-hour workweek to which workers may be repeatedly exposed without adverse effects is 10 mg/m^3 of air.
2. The TLV short term exposure limit for the maximum concentration to which workers can be exposed for a continuous time period up to 15 minutes is 20 mg/m^3 (with a limit of four such exposures daily and the daily time weighted TLV value not being exceeded, and at least a 60 minute interval between exposures).

Chronic toxicity. In a preliminary test (111) dogs infected with a disease caused by a fungus were given the sodium salt of 2,4-D at rates of 1.17, 2.6, and 3.2 mg/kg. The treatments were by injection both intravenously and into the abdomen for 32 to 37 days. There was no evidence of chronic toxicity.

In another test with dogs (46) 2,4-D fed by capsulte at dose levels of 2, 5, and 10 mg/kg/day for five days per week for 13 weeks produced no adverse effects. However, 20 mg/kg/day produced muscular weakness, gastrointestinal disturbances, bleeding gums, and death in three out of four dogs. It is interesting to note that the one dog surviving the high dose level showed no signs of toxicity.

The USDA (94) conducted a study on the effect of multiple dosing of cattle, sheep, and chickens with an amine salt and an ester of 2,4-D to determine when poisoning would occur. Poisoning was defined as any observable sign of abnormal function or behavior. The mildest form of poisoning was considered to be lack of appetite. Cattle dosed with 50 mg/kg of 2,4-D administered orally showed no apparent ill effects after 112 daily doses; sheep showed no effect after oral doses of 100 mg/kg for 481 daily doses the exception of one sheep that lost weight after eight doses but regained it during the other 473 doses. Chickens given a liquid oral dose of 100 mg/kg daily for 10 days showed a 36% weight gain versus a 38% weight gain for the controls which is no significant difference. At higher dosage rates all these species showed various deleterious effects but the experiment indicated these animals would experience substantial exposure by accidental spray drift or eating treated vegetation without ill effects.

Rats (106) were fed 5, 15, 50, 150, and 500 mg/kg/day of 2,4-D in their diet for 113 days. These rats did not tolerate the 150 and 500 mg/kg/day dose levels so these dosages were discontinued. The rats given 50 mg/kg/day suffered slight adverse effects shown by depressed growth, excessive mortality and increased weights of the livers. The no-effect dose level was 15 mg/kg/day.

Long-term chronic feeding studies were conducted in Sweden (21) with chickens. Day old chickens were given 2,4-D at 1,000 parts per million (ppm) in the drinking water until maturity. In spite of this rather high dose level of 2,4-D, their weight gain, age at sexual maturity, the onset of egg production, and the number of animals dying from disease did not differ between the treated and untreated controls. The only result of this treatment was that the number of eggs produced and their weight was reduced for the treated birds. Analysis indicated one to two ppm of 2,4-D were found in the egg yolks and traces in the egg whites. With the exception of the kidneys that were larger and weighed more in the treated birds, there was no significant difference between the organ weights of the control chickens and the ones treated with this high dose level of 2,4-D.

The Canadian National Research Council (90) published an extensive report on the phenoxy herbicides and had this to say about repeated oral dosing of 2,4-D:

> "However, it appears that cattle and sheep can tolerate doses of various formulations of 2,4-D and 2,4,5-T, and MCPA up to 100 mg/kg of bodyweight for periods of ten days, and up to more than one year in some cases without mortality or gross symptoms of poisoning."

Carcinogenicity. A specific strain or breed of rats (Osborne-Mendel) was used in a two-year feeding study conducted by scientists in the Bureau of Science, Food and Drug Administration (49). The dose levels of 2,4-D in the diet were approximately 0.0, 0.25, 1.25, 7.0, 30.0, and 60 mg/kg/day. There was no tissue or organ damage to the rats at any of these levels attributed to 2,4-D. Tumors, both malignant and benign, were found distributed at random throughout all the control and treated groups in this study and were of the type normally found in this strain of rats. Since a clear dose response relationship was not present in this study, the authors appopriately concluded that their results indicate that 2,4-D is not carcinogenic. The same authors (49) also conducted a two-year feeding study on dogs fed diets containing 0, 10, 50, 100, and 500 ppm 2,4-D. This is equivalent to approximately 0, 2.5, 12.5, 25, and 125 mg/kg/day of 2,4-D. No adverse effects including cancer attributable to the 2,4-D were seen in the dogs fed these diets for two years.

The rat and dog data from the preceeding study (49) have been reviewed by others at a Swedish Conference (46) on chlorinated phenoxy acids. They cite the 1971 Joint Meeting of the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) Expert Committee on Pesticide Residues in Geneva (43) who concluded:

> "A two-year feeding experiment is available in two species, the rat and dog as well as a number of multi-generation reproduction studies. Despite certain statistical calculations on tumor incidence in rats fed 2,4-D for up to two years, consideration of all the data from the two-year feeding study does not support the view that 2,4-D is carcinogenic in these species."

Although the Swedish Conference and the FAO/WHO Expert Committee concurred with the conclusion of the original authors, the rat portion of this study has been criticized particularly by M. Reuber (103). His evaluation and a following critique is provided in the section "Some Opposing Views on 2,4-D" stated near the end of this report.

A Russian study (14) used the amine salt of 2,4-D in lifetime feeding studies on rats and mice. Another experiment was performed on mice where dermal applications of 2,4-D were made. There was no significant increase of tumors between the treated and the control groups in any of these studies. The dosage in the feeding studies was "0.1 of the LD_{50}" and "2 drops per week per animal of a 10% solution" of 2,4-D amine used in the mice dermal test.

At the National Cancer Institute (NCI) two strains of mice were used in a 18-month feeding study with 2,4-D acid (56). Groups of 18 male and 18 female mice of each strain were used. Animals in one series were given a daily dose by stomach tube of 46.4 mg/kg starting seven days after birth and continuing up to the 28th day. These animals were then fed a diet containing 149 ppm of 2,4-D until the experiment was terminated which was after 18 months. The other series was on the same time schedule, but the first dose level was 100 mg/kg and then the mice were fed a diet containing 323 ppm of 2,4-D. There was no significant incidence of tumors in any of these groups among the treated animals compared to the controls. Similar results were obtained when the mice were treated with the isopropyl, n-butyl or isooctyl esters of 2,4-D. The daily dose rate for these three 2,4-D esters was 46.4 mg/kg for days 7-28 and then the mice were given diets containing 111, 149, and 130 ppm respectively until the end of the experiment at 18 months. Again no significant differences were observed between the incidence of tumors in the treated animals compared to the control groups. The authors considered both the acid and the esters to be non-tumorigenic compounds. These studies demonstrate that the potential chronic toxicity is low and also support and strengthen the conclusion of the Joing FAO/WHO Expert Committee cited previously.

Birth Defects in Animals

Fetotoxicity, Embryotoxicity and teratogenicity. There is a variation in the way these three words have been used in the literature. The following are definitions as used in this review.

Embryotoxicity is the result in an embryo caused by some effect during the period that embryonic tissue differentiation and organogenesis occurs. In its most severe form this results in death of the embryo.

Teratogenicity, of the other hand, is a special case of embryotoxicity resulting in an imperfectly formed or abnormally formed major body organ or structure. This results from the effect on the developing embryo at the time the organs and various physical structures are being formed. Interference by chemicals or anything else with development at this time results in a major malformation; for example, a cleft palate, or hydrocephalus.

Fetotoxicity is a toxic or degenerative effect on tissues and organs that have already been formed by the fetus. Fetotoxicity is typically a non-specific effect similar to toxic effects which may be induced after birth. For example, the effect might be a lower than normal birth weight, a slower than normal development, delayed hardening of the bones, or death.

These distinctions are important because there is only a short period of time during organogenesis when the stage of development is such that teratogenic effects are likely to occur. Time of exposure is very important and should be noted in experimental work. In the human (101), the most critical days for teratogenic responses are between the 25th and 35th days of pregnancy and the period of greatest susceptibility is from the third week through the third month of pregnancy. If the embryo survives an embryotoxicity effect, many times it can subsequently develop into a normal individual. However, teratogenic effects last for the lifetime if the organism survives. Unfortunately, these two terms have frequently been used synonymously yet it is important to realize the difference.

Teratological experiments. Sheep (20) that were given two grams of

2,4-D (approximately 40 mg/kg) via stomach tube daily for 30, 60, and 90 days following breeding showed no birth defects in the lambs. There were no clinical signs of poisoning of the ewes during these feeding periods. In addition, there were no histopathological lesions found in any of the internal organs of the ewes or lambs.

A teratology study (110) evaluating 2,4-D acid, the propylene glycol butyl ether esters of 2,4-D and the isooctyl ester was conducted using rats of the Sprague-Dawley strain. Daily doses on days six through fifteen of pregnancy (the most critical days of gestation for teratologic effects with rats) were administered via stomach tube. Dose levels up to the maximum tolerated dosage of 87.5 mg/kg/day of 2,4-D acid or the equivalents of the esters were given. 2,4-D acid did not affect fertility, gestation, viability or survival of the newborn. The esters of 2,4-D had no effect on fertility and gestation but the highest dosage level (87.5 mg/kg/day) decreased litter size and the survival rate of the newborn to the end of weaning. However, the growth and development of the survivors at this high dosage was not affected. Teratogenic effects were not seen at any dose level. It was concluded that the no-effect dose level was 25 mg/kg/day of 2,4-D acid or the equivalent figure for the propylene glycol butyl ether esters and the isooctyl ester of 2,4-D

A Russian teratology study (13) on rats given a high dose level of 2,4-D, 50% of the LD_{50} dosage (assuming their LD_{50} value was the same as that cited in our literature this would be approximately 188 mg/kg), administered once during certain of the critical days of pregnancy resulted in decreased body weight and increased the rate of intrauterine deaths. It was also noted that there was some bleeding in the abdominal cavity of the fetuses and the normal cavities in the brain were enlarged. While these are toxoc symptoms, no teratological effects were noted. Chronic studies at the dosage of 0.5 mg/kg/day throughout the period of pregnancy reduced size and weight of the fetuses. Hemorrhages were found in some of the abdominal cavities. At a dose level of 0.1 mg/kg/day no differences were noted between the treated and the control offspring.

A teratology study was conducted with hamsters (30) using dose levels of 20, 40, 60, and 100 mg/kg. These dosages were administered daily via stomach tube on days six through ten of pregnancy. Infrequent fatal anomalies, the most common of which was fused ribs, were found. The percentage of the fetal anomalies in the treated animals was not significantly different from the controls and there was no dose-response relationship.

In another teratology study (62) on Wistar rats, single daily doses of 2,4-D acid, the dimethylamine salt, and the butyl, isooctyl, and butoxyethanol esters of 2,4-D were administered on days six through fifteen of pregnancy, with doses of 2,4-D acid up to 100 mg/kg and the isooctyl esters up to 150 mg/kg. Results were similar to those of the Schwetz, et al. (110) study. Signs of fetotxicity were observed and there was an increased number of skeletal defects at the higher dose levels, but these would not appear to adversely affect survival or normal behavior and development of the offspring. True teratogenic responses were not observed. The weight gain and viability of the offspring were undistinguishable from the controls. Doses of 50 mg/kg/day apparently had no effect.

Reproduction studies. Swedish investigators (21) fed rats 1,000 ppm in their drinking water during pregnancy and for an additional ten months. No clinical signs or morphological changes were seen in the parents or offspring throughout the experiment. The prenancies and births were normal and the litter size was essentially the same with no birth defects seen in the young. Offspring from this experiment were continued on the same treatment of 1,000 ppm in their drinking water for two years. The treated animals had reductions in food and water intake which probably accounted for their slower rate of growth. Upon autopsy no significant microscopicic or macroscopical changes were seen and the relative organ weights (heart, spleen, liver, kidneys, lungs, testes, ovaries) did not differ significantly between the treated and the control animals.

These Swedish investigators also conducted an experiment with a pregnant sow fed 2,4-D during the entire pregnancy at a rate of 500 ppm in the feed. Loss of appetite was noted and 10 out of the 15 piglets died shortly after birth. The remaining five were raised until eight months old being fed the same dietary concentration of 500 ppm 2,4-D. These young pigs suffered growth depression, persistent anemia, and moderate degenerative changes in the liver and kidneys. No cancer was reported in the mother or the offspring. These experiments also reported pigs tolerated repeated dosages of 50 mg/kg/day without clinical effects.

Three-generation reproduction data. A three generation reproduction study (49) on rats fed diets containing 100 and 500 ppm (approximately 5 mg/kg/day - 25 mg/kg/day) of 2,4-D showed no deleterious effects. A dietary level of 1500 ppm (approximately 75 mg/kg/day) also did not affect fertility or litter size and caused no birth defects. However, this high dietary level did slightly reduce the number of young that survived and depressed the weight of the weanlings. The activity of certain liver enzymes was also tested in the second generation rats and no differences were found between any of the treated and the control animals.

Movement of 2,4-D in pregnant animals has been studied in mice (76). Radioactively labeled 2,4-D was administered to mice at various stages of pregnancy. The results showed 2,4-D had a slight tendency to accumulate in the visceral yolk sac and pass into the fetus. However, it was eliminated within 24 hours from all tissues including the yolk sac.

These experiments demonstrate that pregnant animals can be subjected to relatively large amounts of 2,4-D, even during the most critical stages of pregnancy for teratological effects, without causing teratological effects in the offspring. These quantities fo 2,4-D extrapolated to humans are much higher than those to which even professional applicators of 2,4-D would be exposed. This should reassure the public and pregnant women should not be concerned about an accidental exposure to 2,4-D. The evidence clearly shows such an exposure especially from spray drift would have no harmful effect of pregnancy.

Genetic Effects

This subject has been reviewed in the IARC monograph (57) and the following are excerpts. 2,4-D is reported to be not mutagenic in different species of bacteria. It is also reported that there is no evidence suggesting that 2,4-D damages DNA (deoxyribonucleic acid is the molecule within the nuclei of cells which is associated with inheritance). No mutagenic effects were observed in yeast in host-mediated tests using mice given 2,4-D orally at the rate of 200 mg/kg. Serum from rats given 2,4-D orally was not mutagenic to bacteria. No mutagenic effects were noted in a recessive lethal test with 2,4-D in sugar fed to fruit flies. A single abdominal injection in mice did not increase dominant lethal mutations.

There has been a number of tissue culture experiments studying the effect of 2,4-D on chromosomal behavior of cells from specialized tissues such as red blood cells and kidney cells. The results were not consistent or conclusive.

A Swiss reviewer (112) reported negative mutagenic results with 2,4-D in experiments with bacteria. He also indicated there was a reference in one paper that cited another study where there was a weak response in one case with 2,4-D. There have been a few reports in the literature on marginal mutagenic effects of other phenoxy acids than 2,4-D in bacterial systems. The reviewer therefore concluded a weak mutagenic effect cannot be completely excluded.

Experiments with yeasts have given conflicting results which according to one researcher is due to differences in acidity, with the 2,4-D ion being unable to enter the cell under normal biological pH values (112). If this reasonable explanation is correct, it means that 2,4-D would not be mutagenic under practical conditions as the cases suggesting weak activity were done under acidic conditions. This paper also cites one experiment with yeast in which 2,4-D caused no mutagenic effect on yeast even uder acidia conditions (pH 4.5).

Studies on higher plants (112) for the most part indicate no mutagenic activity of 2,4-D although there have been exceptions. There certainly have been many cases where abnormal chromosonal behavior has been found but these have been due to growth responses in specific tissues and have not been considered to result in a genetic trait that would be inherited in subsequent generations. Study difficulties are obvious in evaluating such effects when the chemical being studies can kill the plant. Spraying the broad bean, a susceptible species, with 2,4-D influenced yield in the first two generations but then disappeared so it was not considered to be a mutagenic effect. In another experiment with flax using MPCA {[(4-chloro-*o*-tolyl)oxyl]acetic acid}, very closely related to 2,4-D, the treatment of flax during several successive generations did not induce any mutants. 2,4-D has also been used as a synthetic plant growth regulator in tissue culture experiments with day lillies (69). In this case it was used to stimulate normal development of a plant from an undifferentiated clump of callus tissue. No evidence of any matagenic effect was noted. Since 2,4-D is so physiologically active on plant cells the significance to mammals of such tests on plants is open to serious question and cannot be clearly determined.

Contradictory results were reported in sex-linked lethal experiments with fruit flies (112). In experiments with mice, 2,4-D was reported to have no mutagenic effect both when injected into the abdomen at the rate of 125 mg/kg or administered orally for five successive days at the rate of 15 mg/kg. Both the IARC and Swedish reviews (57, 112) mention tissue culture work on various animal tissues subjected to 2,4-D that has resulted in chromosomal and mitotic abnormalities.

A Swedish investigator (102) working with two strains of fruit flies found 2,4-D caused no mutagenic effect on one strain and a mutagenic effect of the other strain. In this case it showed in 38 males out of 5541. The control group had 4 out of 5363. Although this was statistically significant according to the authors, it does not seem to be a very strong effect. The same report quotes earlier work by one of the authors saying 2,4-D is slightly mutagenic in a recessive lethal test with the fruit fly.

A particularly interesting experiment was done very recently on mice as a part of the National Toxicology Program (71) at the Research Triangle Park in North Carolina. The effect of the components of Agent Orange containing 2 ppm or 30 ppm 2,3,7,8-TCDD on male mice and their offspring were studied. Since Agent Orange has been the subject of considerable controversy concerning its alleged role in causing birth defects, this study is of particular interest and will be discussed in detail. The actual daily doses were as follows:

a. 40 mg/kg/day 2,4-D + 40 mg/kg/day 2,4,5-T + 0.16 μg/kg/day 2,3,7,8-TCDD
b. 40 mg/kg/day 2,4-D + 40 mg/kg/day 2,4,5-T + 2.4 μg/kg/day 2,3,7,8-TCDD

c. 20 mg/kg/day 2,4-D + 20 mg/kg/day 2,4,5-T + 1.2 μg/kg/day 2,3,7,8-TDDD

Two hundred male mice were divided into two lots of 100 each, each lot consisting of four groups of 25 animals--three groups for the treatments and one for the control. One half of the total or 100 animals was used in toxicology studies and the other half was used for fertility and reproduction studies. In their discussion the authors said:

"Thus, there does not appear to be a residual or transient effect of 2,4-D, 2,4,5-T, and TCDD at the concentrations in this study, on the fertility of exposed male mice. In addition, exposure to these chemicals did not appear to influence the fetal or neonatal development of the viability of offspring sired by these mice."

They noted dose-related liver and thymus toxicity and decreased rate of body weight gain. The liver and thymus toxicity noted underwent reversal or recovery when the mice were returned to a control diet. They concluded as follows:

"Sperm concentration, motility and percent sperm abnormalities were evaluated and no significant effect was noted during or after the dosing period.

At the conclusion of an eight week dosing period treated males were mated to untreated virgin females (three per male per week for eight weeks). Mating frequency, average fertility, percent implantation, and resorption sites and percent fetal malformations were all measured in relation to the treatment. No significant decrement in fertility or reproduction was noted in the study. There was no evidence of germ cell toxicity. Survival of offspring and neonatal development were apparently unaffected by paternal exposure to the simulated mixtures of Agent Orange."

In the complex process of cell division there are a certain normal number of irregularities that take place with the chromosomes of the cell that carry the hereditary potentialities of the organism. These are loss of a chromosome, the addition of an extra chromosome, chromosome fragmentation, and sometimes changes in the cellular structure such as having an increase in micronuclei in red blood cells of mice. These events often can occur at higher rates after exposure to various experimental conditions including chemicals. However, with the exception of unicellular organisms such as bacteria and yeast it is difficult to interpret their genetic significance because unless these occur in the grem plasma or the gametes of the organism, it has no genetic influence on succeeding generations. This is one of the chief reasons the three-generation reproduction studies with animals are so important. Rats and mice, like ourselves, are mammals. Certainly it is more valid to extrapolate from genetic data obtained on another mammal to man than from bacteria or yeast to man. This is also one of the reasons why the mouse study (71) on genetic effects reviewed at length is so important.

The preponderance of data derived from short-term mutagenic microbial tests indicate little or no potential for 2,4-D to be a mutagen. Results of tests on living intact mammals are much more meaningful in assessing mutagenic potential for man. Such experiments have been performed with 2,4-D and are described in this paper. The results of these mammalian tests show that there is little or no likelihood that the use of 2,4-D presents any potential mutagenic hazard for man. Moreover residue experiments and environmental surveys (discussed later) show that the vast majority of people in the United States do not even come in contact with 2,4-D except on very infrequent occasions.

Human Metabolism

In a study done in India (65), a single dose of 5 mg/kg was administered orally to six human volunteers. The 2,4-D was quickly absorbed and significant quantities were detected in the plasma one hour after ingestion. The highest concentration of 2,4-D was found in the plasma seven to twenty-four hours after administration which then declined steadily. Seventy five percent of the 2,4-D was excreted unchanged in the urine 96 hours after ingestion. No metabolites of 2,4-D were detected. The authors concluded that 2,4-D is quickly absorbed and excreted mainly via the kidneys without undergoing any metabolic transformation in the human body. Lack of metabolic change and rapid excretion suggest that cumulative toxicity by 2,4-D is unlikely.

Another experiment with human volunteers (108) given a single oral dose of 5 mg/kg of 2,4-D showed that 95.1% was excreted in the urine. This was 82.3% as free acid and 12.8% bound with another organic compound. Quantitative excretion of 90% in human studies is considered to be complete recovery. The average half-life for excretion was 11.6 hours. It was concluded that 2,4-D would not accumulate in man.

Radioactive 2.4-D was used in another experiment on humans (44). The 2,4-D acid was dissolved in acetone and administered intravenously as well as being applied topically on the skin. One hundred percent of the intravenous dose and 5.8% of the dermal dose was excreted in the urine 120 hours after administration of the 2,4-D. These results confirm the other reported results in that 2,4-D is rapidly excreted in urine by the human body and that apparently it is not readily absorbed through the skin.

Human Toxicity

An early EPA manual (52) on clinical signs of economic poisons stated that the oral dose of 2,4-D required to produce toxic symptoms in man is probably three to four grams. In a later manual (86) EPA has listed the following symptoms for human poisoning by 2,4-D: irritation of the skin following excessive contact; burning sensations and coughing following prolonged breathing of the spray and sometimes dizziness and lack of voluntary coordination of muscular movements which usually are temporary; when swallowed 2,4-D often causes irritation of the mouth and throat and usually enough irritation of the gastrointestinal tract to cause vomiting; chest pain in common and abdominal pain, tenderness, and diarrhea usually occur, absorption of large quantities may produce uncoordinated muscle twitchings or denderness of the skeletal muscles and stiffness of the muscles of the extremities. This EPA manual (86) states 2,4-D is excreted within hours primarily in the urine and that 2,4-D is not significantly fat soluble. It also states human subjects have tolerated 0.5 gm of 2,4-D taken orally for two to four weeks without adverse effects. Paradoxically, several cases of peripheral neuropathy have been reported after seemingly minor exposure.

A man (67) voluntarily ingested 500 mg 2,4-D daily for three weeks. This was approximately 8 mg/kg/day and he noted no apparent adverse effects.

In a treatment of a terminal case of coccidioidomycosis (111), a fungal disease, as a last resort 2,4-D was used as a medication. No side effects were observed after 22 intravenous doses were administered over 33 days. Daily doses on the 11th through the 21st were 800 to 960 mg. The 22nd dose was 2,000 mg. The 23rd and final dose was 3,600 mg. Assuming this person weighed 70 kg, this last intravenous injection would be a dosage of 51.4 mg/kg. This highest dose produced toxic symptoms which included a semi-stuporous state, uncoordinated movements, weakening of the reflexes, and urinary incontinence. These toxic symptoms lasted for 24 hours after which the parient returned to his pretreatment status. At this time, the 2,4-D treatments were discontinued. Seventeen days after the last 2,4-D treatment the patient died from the fungal disease. A total of 16.3 g had been administered to this patient and there were no findings of any toxic symptoms that could be attributed to 2,4-D at the postmortem examination.

A 23-year-old farming student committed suicide by swallowing the dimethylamine salt of 2,4-D (92). The total amount in the body was estimated to be no less than six grams corresponding to a dose of approximately 80 mg/kg. All organs showed congestion of blood and there were severe degenerative changes of the nerve cells in the central nervous system.

A man (19) accidentally swallowed about 30 ml of a concentrated weed killer that contained 36.5% isooctyl ester of 2,4-D and 49% of *s*-ethyldipropylthiolcarbamate (EPTC) in a water solution. In this case the dosage amounted to 110 mg/kg of 2,4-D, 230 mg/kg of EPTC, and 2.3 mg/kg of epichlorohydrin. He showed symptoms of uncoordinated twitching and paralysis of the rib muscles. There were signs of general muscle damage as well as the presence of hemoglobin and myoglobin in the urine. The author presented some pharmacological data on epichlorohydrin and EPTC from which he concluded it was reasonable to assume these symptoms were caused by the 2,4-D. The man made a complete recovery after several months.

Applicator exposure. Forests are an area where there has been considerable controversy about the use of 2,4-D and spray drift. It is therefore of particular interest to see what has been learned in experiments designed to determine the quantitative amounts of 2,4-D that applicators might receive when applying this material in forests. A study (73) was done under field conditions in Washington and Oregon forests. Analysis of air samples taken from sampling devices attached to the workers handling and applying 2,4-D herbicides showed only one sample out of 18 had a detectable amout of 2,4-D. This amounted to 0.30 μg/km of body weight. The workers had been divided into two groups. One group followed their customary practices of operation and the other used additional precautions which included disposable clothing and closer supervision to insure that label instructions were followed. The workers taking the additional precautions showed no or very low levels of 2,4-D ranging from none detected to 0.0219 mg/kg body weight. The workers that followed their normal practices ahd levels ranging from none detected to 0.0557 mg/kg body weight. In the group following normal practices 5 out of 15 workers had no 2,4-D detected following application. In the group taking special precautions 9 out of 15 workers had no 2,4-D detected in their urine following its application in the forest.

These data were put into a computer simulated program and combined with pharmacokinetic data derived from animal and human data (from human volunteers) to determine what the body accumulation of 2,4-D would be following repeated daily exposure (100). This was found to be a maximum of 70 percent of the daily dose. Repeated daily exposure to 2,4-D products would not result in continually increased amounts accumulating in the human body. It is worth noting that a substantial number of these workers had no 2,4-D detected in their bodies following its application under field conditions in the forest.

An applicator exposure study with 2,4,5-T gave similar results (72). The exposure would be essentially the same as it would if 2,4-D had been used. The authors concluded:

" (a) ordinary forest applications of 2,4,5-T provide ample margins of safety between the dosage actually absorbed and the no-adverse-effect level indentified by EPA; and

(b) adoption of certain protection measures, such as simple protective apparel can achieve consistently high margins of safety."

Arkansas and Dow investigators (99) using 2,4,5-T exposure date (72) and pharmacokinetic data available wrote another joint paper using a computer simulated program to determine body burden of 2,4,5-T after repeated exposures. They state:

"...we conclude that under these conditions the absorption of 2,4,5-T presents a negligible toxic hazard to forest workers."

These results are in concurrence with and support the results obtained with 2,4-D.

Neuropathy. Neuropathy is a general term indicating functional disturbances and/or pathological changes is the peripheral nerves. It may have many causes among which are: alcohol, physical injury to nerve, heredity, various immunization treatements, e.g. for diphtheria and tetanus, as well as unidentified causes.

During the 37 years of use of 2,4-D, there have been some isolated case reports in the literature of neuropathy alleged to have been caused by exposure to 2,4-D. The medical clinical data given in the following cases described is not included here. Interested persons can read them in the original literature referenced. However, there did not seem to be a great deal of commonality in the data given.

One of the first reports on neuropathy (47), published in 1959, involved three people: a farmer, 52 years old; a housewife and bookkeeper, 50 years old; and another farmer, 65 years old. All had severe sensory and motor symptoms that required hospitalization. In each case, 2,4-D was used before the patient became ill. There was incomplete recovery in all three instances. The authors assume the 2,4-D was absorbed largely through the skin and concluded the clinical symptoms of these three individuals were caused by the patients' exposures to 2,4-D. Absorption of 2,4-D through the skin is low (44, 60) which suggests these symptoms were not related to their exposure.

Another case (122) involved a farm worker who was reported to have suffered severe motor response symptoms after exposure to 2,4-D that was believed to have been absorbed through the skin. He was unable to walk without crutches for two years after which time he was able to resume working on the farm.

An additional report (126) described a Puerto Rican who had been employed for a year spraying sugarcane fields with herbicides containing 2,4-D. He had not used a protective mask or clothing and had handled the herbicide freely. Suddenly he developed painful muscular stiffness and had to stop work. The pain disappeared but the muscular stiffness got worse severely affecting his walking and manual dexterity. A urine sample obtained some time after exposure had no 2,4-D present. Daily treatment with diphenylhydantoin and physical therapy produced a remission of his clinical symptoms and nearly all of his muscular problems involving his hands and feet that had lasted eight months. It is of interest to note that these same authors in this paper reported a second case, with many of the same symptoms, where the patient had no history of exposure to 2,4-D. The authors concluded:

"the cause of the disorder as unknown but damage to peripheral nerves from exposure to certain chemicals such as dichlorophenoxy acetic acid (2,4-D) may play a role. An identical experimental model can be produced in animals with 2-aziridinyl ethanol."

An apparent case of suicide (35) involved a 76-year-old man who was suffering from senile mental deterioration. He drank a large quantity of

2,4-D dissolved in kerosene. The exact amount is unknown but the man drank approximately a pint of kerosene-2,4-D mixture. After being admitted to the hospital for treatment, the propects for his recovery appeared good but he suddenly died six days after he swallowed the material. The destruction of the covering of the nerve sheaths of the brain was noted and it was suggested that 2,4-D or a metabolite might have caused this condition. The possible toxicity of kerosene was not discussed.

A Hungarian study on rats (34) which had recieved 200 mg/kg of 2,4-D injected into the abdominal cavity or crystals of 2,4-D placed directly upon the exposed cerebral part of the brain caused changes in brain wave patterns. After a single dose the brain wave patterns returned to normal. With repetitive dosing, an altered brain wave pattern appeared after the fourth day. The animals generally died on the sixth day but this in not surprising since the single oral LD_{50} for rats is 375 mg/kg. Microscopic examination of the brain revealed no changes although there were some lesions in the spinal cord. In the Hungarian literature reviewed in this paper, one research worker was cited as having studied 2,4-D toxicity in animals and found similar results to those described in the scientific literature elsewhere. His work was also reported as showing he could not demonstrate any objective changes in workers spraying 2,4-D.

A 39-year-old farmer (18) complained of numbness, tingling, and aching of the hands and feet. Later, he lost control of the fine movements of his fingers. Four days before the onset of these symptoms, he had been applying 2,4-D in his cornfield. He repeatedly had used his bare hands to fix his tractor-operated sprayer when it had plugged up and did not wash his hands after each exposure. After treatment, gradual improvement was seen that continued until he was nearly completely normal. The authors believed that the dimethylamine salt of 2,4-D had caused the neuropathy. They also concluded:

> "Despite the extensive use of 2,4-D preparations, resultant peripheral neuropathy is very rare, and an afflicted individual probably has some predisposition to neuropathy or susceptibility to the toxin."

An Italian farm worker (85) sprayed a water solution of 2,4-D with a hand pump against the wind. Consequently after spraying he has covered with the spray solution and presumably had inhaled a certain quantity. After finishing the job he returned home and became ill. His symptoms were generalized weakness, profuse perspiration, and excretion of a lowered amount of urine. His symptoms became more complex and he walked with an unsteady gait. After being hospitalized 40 days the patient returned home and gradually returned to normal although a feeling of weakness in the lower limbs presisted. A neurological examination five months after the incident still showed some slower reflexes in the lower legs although all the other symptoms had disappeared. At this time the man was declared stabilized and capable of going back to work.

The International Agency for Research on Cancer (IARC) has summarized some Russian and French reports on the toxicity of 2,4-D to humans (57). Some of the symptoms described were: muscular weakness, muscular spasms, fatigue, headache, and diarrhea. They drew no conclusions from these reports.

An excellent although old review article on 2,4-D was written in England (127). The introduction of this article says:

> "During the many years of their use throughout the world there have been notably few authenticated incidents of poisoning of domestic animals or wildlife resulting from the proper application of these compounds. The fact that fully authenticated incidents of poisoning have

not been reported cannot be taken as an absolute guarantee of safety, particularly with regard to indirect or chronic toxicity, because of the frequent difficulties of attributing the underlaying cause of an illness or death, especially in wild animals. Nevertheless all the direct and circumstantial evidence to hand at the present time seems to indicate that incidents of poisoning have been extremely few and generally under exceptional circumstances. ...there are very few reports in the literature of tests or incidents of poisoning of man by these compounds; the majority of these reports refer to accidental poisoning of children. As a result it is now generally a direct toxicity hazard to man (Barnes 1965) when correctly handled or used for weed control."

In summary it says:

"Authenticated case histories of sublethal effects are also very rare. However, complaints of transient dizziness, sickness, and other symptoms are made from time to time by workers engaged in field applications, especially under conditions where the spray is inhaled excessively. The possibility of man acquiring toxic doses of these compounds in food, milk, or water appears to be very low."

EPA (7) in their fact sheet on 2,4-D in early 1980 had this to say about the question:

Neurotoxicity--there is little definitive information on the possible neurological effects of 2,4-D. In several reported cases of impaired nerve function, it was not known if the individuals were peculiarly sensitive to that type of effect or were exposed to other toxic materials."

These extremely rare cases suggest that if neuropathy can be associated with 2,4-D exposure it occurs only on rare occasions and is not related to high exposures. This suggests some unknown factors which predispose an individual to be extremely susceptible or perhaps the neuropathy results from a hypersensetivity or an allergic reaction.

Swedish epidemiology Studies. Epidemiological research often involves either case control studies or retrospective cohort mortality studies. In case control studies individuals are selected with a known disease and compared with disease free individuals. Information on both groups is then sought regarding the proposed causal factor under study. Such studies have great potential for biased or misleading results and are often controversial because of problems with the selection of the individuals to be compared in the exposed and non-exposed groups to give a true contrast. In addition, questionnaires relying strictly on memories of the people about incidents occurring many years in the past can be troublesome. When the individual was dead, as sometimes occurred in some of these studies, the questionnaire was typically answered by other people associated with them which clearly can introduce significant errors and bias into the study.

Retrospective or cohort mortality studies are those in which one or more groups presumably exposed to the proposed causal factor being studied is compared to an unexposed group. Recognition of possible adverse effects and confusing factors such as smoking, dietary differences, and other occupational variables are also very important.

There have been five Swedish epidemiology surveys that studied the effects of phenoxy acids upon human health.

Three of these studies (27, 71, 89) are of the case control type and two (17, 120) are the retrospective or cohort type. All of these studies purport to show that the phenoxy herbicides, 2,4,5-T as well as 2,4-D, cause cancer in humans. These case control studies were based on information obtained from questionnaires and by telephone interviews. There was no documented evidence either as to intensity, frequency, or time of duration of exposure. The results could also be confused by exposure to other chemicals some such as amitrole being known carcinogens. It also appears that several subtle forms of bias could have entered into the selection of controls. Further, this bias could have entered in three of the five studies as one of the authors was involved in all of them.

This type of mortality study and the causal relationships to phenoxy acids are not clear. The interpretation of the reported stomach cancers is very tenuous due to the small size of the group studies and the possibility of distortion through a family hereditary relationship. Again the validity of the exposure information is questionable and the confusing factors of socioeconomic status and smoking were not adequately controlled.

The IARC (57) reviewed the Swedish epidemiological survey (16) on railway workers exposed to a variety of herbicides. They found a two-fold excess of all cancers in the exposed workers as compared to the national average. The IARC commented that this situation was difficult to evaluate because of the exposure to many herbicides and that most of the excess numbers of cancers seemed to be correlated with the use of amitrole (3-amino-*s*-triazole). Within the subgroups exposed to 2,4-D and 2,4,5-T only a small difference was found: 5 cancers versus 2.8 expected.

Dr. Philip Cole, Professor of Epidemiology in the Department of Public Health, University of Alabama, reviewed these studies in testimony at the EPA hearings on 2,4,5-T (November 1980). Dr. Cole was quite critical of these studies. His critique pointed out the likelihood of observer and recall bias. He also discussed recall bias that could often occur when subjects are required to recall events which occurred many years ago. Such bias was likely enhanced by the considerable publicity in Sweden concerning a possible relationship between phenoxy acids and cancer; and by the use of a questionnaire that did not mask its purpose. The question as to whether exposure to 2,4-D or 2,4,5-T compounds ever occurred in these studies is based solely on the memory of the study participants. It is not documented by spray or other written records which would confirm exposure. Dr. Cole was also quite critical of the retrospective studies (17, 120) saying both studies were small and that the cause of death must be determined on the same basis in both the control and the exposed groups. This standard procedure on determining cause of death was not done. Dr. Cole concluded these Swedish studies cannot be relied upon in assessing possible carcinogenic risks to humans from 2,4,5-T and 2,4-D.

Perhaps most important, these results are inconsistent with controlled laboratory animal test data reviewed earlier in this paper or the extensive toxicology studies on 2,4,5-T reviewed elsewhere (89).

Dioxins and 2,4-D

Chlorinated dibenzo-*p*-dioxins (CDD's) are aromatic organic compounds. They may occur as products of certain combustion processes and as possible by-products in the manufacture of certain chlorinated phenols. The number of chlorine atoms that can be attached th these dibenzo rings varies from one to eight. The toxicity of the CDD's varies considerably depending on the number and location of the chlorine atoms attached to the dibenzo rings. They vary from the relatively non-toxic dichlorodibenzo-*p*-dioxins to the most toxic TCDD (2,3,7,8-tetrachlorodibenzo-*p*-dioxin). The interest in chlorinated CDD's has surfaced in part because the highly toxic 2,3,7,8-TCDD appears as a trace contaminant in herbicidal formulations containing 2,4,5-T (31). There are 75 theoretically possible isomers in this dioxin family. None of the 75 dioxins are produced commercially, nor do any have industrial applications. 2,3,7,8-TCDD is the most toxic of all the 22 the-theotetically possible tetra DCC's tested (41, 55, 74, 95).

At a 1970 U.S. Senate hearing (39) on 2,4,5-T, it was stated that hexa, hepta, and octa chlorinated dibenzo-*p*-dioxins had been identified in 2,4-dichlorophenol and therefore, it was probable that they could be present in 2,4-D manufactured from this chemical. USDA scientists (133) identified a hexachlorodibenzo-*p*-dioxin in a sample of 2,4-D in 1972, but no tetra, penta, hepta, and octa chlorinated dibenzo-*p*-dioxins were found.

More recently, Canadian scientists (31) using a newly developed and as yet unvalidated method identified 2,7-dichlorodibenzo-*p*-dioxin, 1,3,7-trichlorodibenzo-*p*-dioxin and 1,3,6,8-tetrachloro-*p*-dioxin in certain samples of commercial 2,4-D products. Samples did not contain 2,3,7,8-TCDD using an analytical method they believe is sensitive to one part per billion. Concentrations of the dioxins identified ranged from 0.08 ppm to 8 ppm. The diisomers are a million fold less acutely toxic than 2,3,7,8-TCDD; the tetra isomers are 50,000 times less acutely toxic; and the tri isomers are 15,000 times less acutely toxic than 2,3,7,8-TCDD (55,74).

The identification of dioxin isomers is an arduous task. The preparation, purification, and analytical techniques to isolate, identify, and measure accurately these different isomers of CDD's are difficult, time consuming, and expensive. Advanced analytical methods only recently have been developed to identify and measure these trace compounds. As yet they are unvalidated techniques for determining accurately the amounts found. Therefore, the questions of how much if any and which dioxins may be present in 2,4-D are unanswerable at this time although we do know that no 2,3,7,8-TCDD is present in 2,4-D.

The United States EPA in their January 23, 1981 Fact Sheet on 2,4-D reported preliminary findings on 30 samples of 2,4-D products produced in the United States. Twenty-seven of the samples were reported to be free of any dioxin using a test method of analysis sensitive to one ppb; three of the samples contained the 2,7-dichlorodibenzo-*p*-dioxin in concentrations below 100 ppb. (Remember that the oral toxicity of the di-isomers is one million times less toxic than 2,3,7,8-TCDD.)

Many of the chlorinated dibenzo-*p*-dioxins, including those elleged to be present in some 2,4-D, may be produced by certain combustion processes in very low yields. Evidence for this has been found by scientific investigations in the Netherlands, Switzerland, Sweden, Italy, Canada, and the United States. Dioxins have been found on particulate matter from the stacks of municipal and industrial incinerators, the chimneys of weed-burning stoves and fireplaces, the smoke from cigarettes, deposits in automobile mufflers, and the stack of a fossil-fueled powerhouse (28, 68).

While the Canadian study is of considerable interest to analytical chemists, one important point must be recognized. The mere presence of the specific dioxins found at levels reported does not constitute an unreasonable hazard to human health or the environment. The herbicide 2,4-D has been used widely throughout the world for 37 years. In the research work reviewed for this report, no valid studies were found that link 2,4-D to adverse effects on humans or the environment when 2,4-D products were used in accordance with label directions.

Environmental Studies

The Herbicide Handbook of the Weed Science Society of America (53) says 2,4-D will generally last one to four weeks in warm, moist soil when used at recommended rates. A textbook on weed control (32) agrees and also says low rates of 2,4-D (12 to 3 lb/A) will be decomposed in one to four weeks in a warm moist loam soil. There is no risk of this chemical accumulating in the soil from one year to the next under conditions of temperature and rainfall for favorable plant growth. The text continues, however, by pointing out that in very dry or frozen soils the rate of decomposition may be slowed considerably.

At a recent symposium of phenoxy herbicides (98) it was stated that there is generally one to two ppm of 2,4-D in the soil after a normal application and that its half life is three to four weeks. After repeated applications of 2,4-D, degradation in soil occurs as a faster rate. They also note that the residue on the leaves of sprayed vegetation shortly after spraying is 200-500 ppm and that after ten weeks this decreases to 20-50 ppm. A British review (124) quotes American research as showing that 2,4-D is not persistent in plant tissues. One report shows 75% of a sublethal dose of 2,4-D disappeared from cucumber plants in 24 hours. Another showed 90% disappeared within 13 days when 2,4-D was applied to a pasture. Breakdown also takes place in dead plants. For instance, 88% of 2,4-D disappeared from dead leaves within 2 1/2 days and repeated treatments of forest floor litter resulted in a more rapid rate of breakdown.

Food surveys. From the standpoint of food the "market basket" surveys of the Food and Drug Administration (FDA) have rarely found any 2,4-D in our food. A "market basket" represents the basic two-week diet of a 16-19 year old male, the nation's largest eater. This is about twice the food intake for the average individual.

The FDA has been conducting pesticide residue studies of our food since 1964. Seventeen classes of food: dairy products; meat; shellfish; fish; eggs and poultry; grain and cereals; potatoes, leaf and stem vegetables; garden fruits large and small; oil; fats and shortening; tree nuts; infant and junior foods are sampled. There are 82 individual food items in these "market baskets". Thirty markets are sampled in 28 different cities.

One report (32) covers the period from June 1969 to April 1970. 2,4-D was analyzed using a test method with a sensitivity of 0.02 ppm. Some trace residues were reported which were below the sensitivity level of analysis. Such low values are only estimates. Chlorophenoxy acids were found four times during this reporting period. However, 2,4-D is listed as occurring only twice with the highest value being 0.123 ppm in the June 1969 to April 1970 reporting period. For earlier periods they report phenoxy herbicides were found seven times in 1967-1968, eight times in 1966-1967, and 13 times in 1965-1966.

A series of reports (32, 58, 80, 81) covering the period of June, 1970 through July, 1973 showed 2,4-D was present only infrequently (once or twice in all the yearly samples) and in low amounts (about 0.01 ppm). From August, 1973 through July,1975, no 2,4-D was found in any of the samples (59, 82). A summary report (37) for the period July 1963 to July 1970 gives excellent information on the amount of pesticide residues present in our raw food supply and a worst case example of how much we eat. The maximum possible amount of 2,4-D a person might have ingested during this six-year period (1964-1970) is given. These amounts are well below the daily intake quantity regarded as safe by the FAO-WHO Expert Committee and even further below the "no-effect-level" established by the WHO.

Table 2 shows the average percent occurrence in the composite samples and the daily intake of 2,4-D that might occur if everyone are the food that had the low level of 2,4-D found in this survey. This in itself of course would not happen as the samples with the traces of 2,4-D present were not found in all parts of the country. These amounts were calculated using the diet of a 19-year-old male which is twice that of a person from the general population (36).

Table 2. Percent occurrence and daily intake of 2,4-D for a five-year period

Year	1965	1966	1967	1968	1969	1970
Percent occurrence	4.2	3.0	1.7	0.6	0.3	0.3
Total daily intake (mg)	0.005	0.002	0.001	0.001	trace*	trace

*Trace is less than 0.001 mg.

The FAO-WHO expert group on pesticide residues has established an acceptable daily intake of 2,4-D for humans of 0.3 mg/kg (3). For a 132 lb person this would amount to 18 mg per day. Taking the maximum daily intake of 0.005 mg shown in Table 2 there would be a 3600 safety factor before the acceptable daily intake was even reached. This same international group (3) has also accepted 31 mg/ks/day of body weight in the rat as being a dose level that causes no toxicological effect. The use of this figure of course would result in an even larger safety factor. When considering this point, it should be noted that the EPA had issued a number of tolerances for 2,4-D. These tolerances are permissible residues of 2,4-D in our food and water that EPA considers would not be harmful to human health.

The FDA, according to Pesticide and Toxic Chemical News (6), listed 2,4-D as being found twice in its food monitoring programs in fiscal 1978 and zero in fiscal 1979. To put this in perspective the insecticide malathion and fungicide captan were found 329 and 305 times; and 141 and 185 respectively in the same time period. Thus, it may be concluded that for practical purposes there is no 2,4-D in our food supply.

Water surveys. The Water Resources Division (WRD) of the U.S. Geological Survey reported a study on 12 pesticides occurring in 11 western streams (26). The three herbicides 2,4-D, 2,4,5-T, and silvex [2-(2,4,5-trichlorophenoxy)propionic acid] were included but none were found. The sensitivity of the method was given as 100 ppt for 2,4-D and 5 ppt for 2,4,5-T and silvex. The survey was made over approximately one year.

The WRD reported on the incidence of pesticides in selected western streams (79). This report covered a three-year period, 1966-1968. Samples were taken from 20 locations over 15 western states. The highest amount of 2,4-D found was 0.35 μg/L (0.35 ppb) in James River at Huron, SD. According to this report, the Committee on Water Quality Criteria has established a standard of 100 μg/L (100 ppb, 0.1 ppm, or 0.1 mg/L) for all phenoxy herbicides. There were 321 samples analyzed for 2,4-D. Eighty-seven percent of the samples tested had no 2,4-D. Of the 41 samples containing 2,4-D, 29, or 70%, had less than 0.15 ppb. Table 3 gives a detailed breakdown of the quantities of 2,4-D found in these samples that occurred only 13% of the time.

A monitoring program on water has also been conducted by the Federal Water Quality Administration of the U.S. Department of Interior (75). In their five-year survey of water in the major river systems in the United States, no mention is made of the phenoxy herbicides. Analyses were not made for them presumably because based on earlier studies (26, 79) they were thought not to be of sufficient concern to warrant analysis.

Table 3. Occurrence of 2,4-D (ppb) in selected western streams over a three-year period.

ppb	0.01-0.05	0.06-0.10	0.11-0.15	0.16-0.20	0.21-0.25	0.26-0.30	0.31-0.35
Number of occurrences*	13	13	6	2	3	2	2

*Only in the sample containing 2,4-D; 87% of the samples had none.

The U.S. government has established an acceptable level of 0.1 ppm 2,4-D as a contaminant in what they call community water systems. This information was published in the Federal Register in 1975 (4). A tolerance of 0.1 ppm of 2,4-D in potable water has also been established by EPA. EPA published in 1980 (9) a list of 64 toxic pollutants classified under the Clean Water Act. As would be expected from the foregoing, 2,4-D is not included on this list.

Soil surveys. The National Soils Monitoring Program (132) surveyed cropland in 43 states and noncropland in 11 states. They found 2,4-D only three times out of 188 analyses and the mean residue level was less than 0.01 ppm. In this study they only analyzed for 2,4-D where use records indicated they had been applied. In another study done similarly (33), the mean residue was 0.05 lb/A. This would be 0.05 ppm using the conventional factor of 1 lb/A = 1 ppm.

Air survey. There is also a national air monitoring pesticide program (70). The data for a three-year period are given in Table 4.

Table 4. Three-year summary of 2,4-D in ambient air in the United States (nanograms per cubit meter) from 1970-1972.

	Total 3-yr average
Percent positive samples	5.64
Average values	1.54
Ave. values of positive samples	18.33
Maximum values	68.17*

*68.17 nanograms = 0.000,068,170 mg

There were 2479 samples taken in 14 to 16 different states (Alabama, Arkansas, Illinois, Kansas, Kentucky, Louisiana, Maine, Montana, New Mexico, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Tennessee). The sampling sites for 1970 and 1972 were selected for being potentially areas with a high concentration of pesticides. The analytical method had a sensitivity of 1-10 nanograms per cubic meter. It is evident that most samples were analyzed at the lower limit of the method's capability. There is no established concentration in the air for 2,4-D that is considered to be safe or unsafe for the general population. The TLV of 2,4-D for a normal working eight-hour day without adverse effect is 10 mg/m^3 and 68.17 nanograms is 0.00006817 mg. This amounts to a safety factor of 146, 700 before reaching the TLV value considered to be a safe exposure for a 40-hour working week. Again it should be remembered that over the three-year period covered by this report 2,4-D occurred in the air on the average only 5.64% of the time and the sites were potentially the worst possible situations. Thus practically speaking the general public is not exposed to 2,4-D in the air.

Effects of wildlife--general. Exposure of wildlife to 2,4-D, whether from direct spraying or eating possible residues on treated vegetation, would be very low. Therefore, considering the relatively low toxicity of 2,4-D to vertebrates, it is not surprising to learn that direct toxic effects of 2,4-D to wildlife have not been noted.

A Canadian study (78) was done with the objective of obtaining field data to permit the formulation of sound spray guidelines, taking into account the impact of these chemicals on the environment and non-target organisms. It described applications of the following phenoxy formulations: 2,4-D amine (a mixture of the dimethyl and diethanolamine), 2,4-D ester (isooctyl), a 50:50 mixture of 2,4-D and 2,4,5-T amines (monoethanol, diethanol, dimethyl, and diethyl amines), 2,4-D and 2,4,5-T (a 50:50 mixture of the isooctyl esters). These were applied at rates of 0.0, 0.5, 1.0, 2.0, and 4.0 lb per acre of the active ingredient. The following results were reported: no large quantities of chlorophenoxy residues could be detected in the air at distances greater than 20 feet; residues appeared to persist in the litter for more than 7 days (not surprising since 2,4-D is considered to persist for approximately three weeks following application and these were relatively high applications); the insect population (arthropods) was reduced approximately 60% shrotly after the treatment; no reduction in number of birds and wildlife in or near the plots was observed following the herbicide applications.

The environmental effects of 2,4-D on plant life are those of changing the type of plant dominant in the area. This is similar to changes that would occur if fire burned the area, it was suddenly flooded with water, or conversely dried up, or if man used some other tool or mechanism to change the type of plant growing in the area. For example, grazing or plowing the land changes the subsequent plant vegetation drastically.

The biggest effect of 2,4-D on wildlife results from its changing the natural vegetation pattern of the area. A recent article on butterflies (96) points out that many butterflies are disappearing due to loss of habitat from the activities of a spreading human population. For example tropical butterflies inhabiting rain forests are declining in numbers due to the lumbering operations of the forest. The article also cites the disappearance of a rare blue butterfly in England due to two changes in habitat caused by 1) a change in vegetation, and 2) a change in ant species.

Deer usually increase in number as clearings are made in the forest because the vegetation growing in the clearing provides more food for this animal. In fact a long-term study (25) on the impact of herbicides upon game, food, and cover on a utility right-of-way showed many common species used the sprayed right-of-way immediately after spraying and for more than 20 years thereafter. White-tailed deer, ruffled grouse, wild turkey, and rabbits have been particularly abundant.

The Canadian review (90) on phenoxies mentions changes in habitat affecting the number of nests in wetlands for duck species, pocket gopher populations on rangelands, chipmunk populations, Montana moles, elk, and deer. This same review points out the difficulty of obtaining meaningful long-term observations on flying insects in natural populations. One study (90) cited, examined soil fauna from fields treated for 10 of the previous 13 years with MCPA. This is closely realted to 2,4-D. Soil samplings five times both before and after spraying at 5 lb per acre showed no difference between control and treated fields. Laboratory experiments have shown contradictory results in earthworms. One investigator found earthworms to be adversely affected by 2,4-D. Another found 2,4-D had no effect. It should be noted that these detrimental effects occurred when a granular application had been made. This suggests that in such cases the earthworms ingest the granules and thus get a much higher level of the herbicide than they would from a spray application.

Way's review (127) concludes there is a hazard to bees from the use of 2,4-D and other phenoxy herbicides. However, both the English and Canadian reviews (90, 124) indicate that under laboratory conditions 2,4-D is toxic to honey bees but under usual field conditions 2,4-D is relatively non-toxic to adult bees. The question of the carrier of the herbicides is also important, as diesel fuel and other oils sometimes used in making spray solutions are toxic to bees. Way concludes there would seem to be little hazard to insects other than bees at normal rates of application. 2,4-D presented no hazard to bee colonies when fed directly into the hive at a concentration of 250 ppm (63). The USDA (2) in their leaflet on the effects of pesticides on honey bees classify 2,4-D (as well as 2,4,5-T) as being relatively non-hazardous to honey bees.

Birds. Using a technique of injecting 2,4-D directly into bird eggs (38), a most severe laboratory test and difficult to interpret and apply to field conditions, 2,4-D showed no affect upon hens' eggs at a dosage of 50 ppm.

In another experiment with chickens (130), 2,4-D was fed to laying hens at a rate of 50 and 150 mg/kg/day in their diet from an age of 28 to 48 weeks. No adverse effects were found from these treatments upon: rate of egg production, egg or yolk weight, egg shell thickness, hatchability or growth rate of the progeny. The same authors published another study (131) with chickens finding that they could tolerate large dietary doses of 2,4-D; the only adverse effects were a reduction in food consumption and growth rate. Young chickens could tolerate a level of 5000 ppm in their diet for a week and resume a normal growth rate when put back on a normal diet. Chickens were able to discriminate between the food containing the 2,4-D and that without the herbicide. When given a choice chickens rejected the food with 2,4-D and grew at a normal rate. The chickens fed levels of 2,4-D at 10 and 100 ppm grew at a rate faster than the controls although there was not a statistically significant difference. Dietary levels of 2,4-D up to 1000 mg/kg (1000 ppm) had no statistically significant difference on the growth rate of day-old chicks.

French investigators (77) concluded that 2,4-D sprayed on artificial nests containing eggs from pheasants and two species of partridge induced toxic effects that resulted in 43 to 77% mortality prior to hatching. Surviving embryos showed deformities and lack of normal sexual development. This article is deficient is that: the concentrations of 2,4-D and the specific commercial product whether ester or amine is not given; the age of the eggs are not stated; the figures for the number of deaths in the control are not given; or whether an oil formulation was used. Details of another experiment from which conclusions were drawn are not described or literature references cited. In view of these criticisms and the fact that the conclusions are not supported by other research work done in this field, raises serious questions as to the validity of this study.

Canadian researchers (115) using chicken eggs sprayed with a water solution of an amine formulation of 2,4-D at the recommended label rate and at ten times this dose found no adverse effects on hatching or subsequent growth of the live chicks. These same researchers conducted a similar experiment (116) using pheasant eggs although of a different species than used in the French study (77). In this case, a mixture to 2,4-D and 2,4,5-T was used. Phenoxy acids entered the egg and decreased in concentration as the embryos grew. None of these treatments had any adverse affects on hatching, incidence of deformed embryos or subsequent motrality of the young pheasants. In fact, the herbicide treatments were found to increase the weight gain of the males from 0-4 weeks of age although there was no such effect on the females. The results of the pheasant and chicken studies were similar and support each other.

A comparison was made between the effects of 2,4-D and diesel fuel (66) when sprayed separately on chicken and pheasant eggs. The 2,4-D was a commercial formulation of the isooctyl ester diluted with water and applied at a typical rate to control weeds in small grains (wheat, barley, etc.). Batches of eggs sprayed with water were also used for controls. There were no adverse effects from the 2,4-D treatments although the diesel oil treatments killed the pheasant eggs (no results were reported with chicken eggs for this treatment). There were only three deformed pheasant chicks in the entire experiment. One was in the 2,4-D treatment and two were in the controls.

Fish. Radioactive experiments (114) on bluegills and channel catfish showed no evidence of bioaccumulation of 2,4-D in the fish. The maximum concentration of 2,4-D in the fish was reached within 24 hours after treatment. It did not change significantly thereafter for seven days. A major portion of the radioactivity was found within the head and viscera and lower amounts were in the edible flesh. The fish did not metabolize the 2,4-D and when it was injected into the abdomen 90% was excreted within six hours of treatment.

An experiment with rainbow trout (119) showed that a non-lethal concentration of the insecticide carbaryl (Sevin) increased the toxicity of the n-butyl esters of 2,4-D and several other pesticides. This effect could be nullified by using atropine as an antidote.

A review (88) with 150 references on the effect of herbicides on water and its inhabitants discussed in detail the potential effects of 2,4-D on these subjects. There is little evidence that herbicides from agronomic or industrial usage are reaching or accumulating in our water supplies in amounts to cause a pollution or an unreasonable health risk. The conclusion was that any effects of herbicides applied according to their labeled directions would be very temporary and transient.

Effects of soil microorganisms. Both the English and Canadian reviews (90, 124) cite numerous investigators who have found 2,4-D does not appear to adversely affect soil microorganisms. 2,4-D has been shown to be comparatively harmless to mushroom stands. Many workers have found 2,4-D to have almost no effect of soil fungi at 100 ppm. Populations of soil bacteria have been temporarily reduced but recovery to normal is usually rapid. 2,4-D has almost no effect on nitrifying bacteria (91). Moderate amounts of 2,4-D can stimulate the growth of soil microorganisms. It has been found (98) that 100 ppm 2,4-D stimulated the growth of certain molds and in one case (124) a bacterium was grown in the laboratory on agar containing only 2,4-D as a source of the necessary carbon. There have been a few long-term studies on soil effects (98). Carbon dioxide production and nitrification were studies for five years with MCPA. No significant change in carbon dioxide formation was noted in a five-year study and the nitrification process appeared to be stimulated. In an 18-year study, 1/2 and 3/4 of a pound per acre of 2,4-D and MCPA were applied each year to Canadian soils and no changes in the microbial population were noted. In general, 2,4-D has no significant effects of soil microbes at field concentrations.

These results are not surprising when you consider that 2,4-D is broken down relatively rapidly by soil microflora and fauna. Further, the application of 1 lb/A assuming that all the pesticide reaches the soil, results in a concentration of only 2 ppm in the top three inches of soil. Thus there would not be very much there in the first place.

Some Opposing Views of 2,4-D

South Okanagan Environmental Coalition (SOEC), Canada. SOEC has published a book, "The Other Face of 2,4-D" (128). This lengthy review is very critical of the 2,4-D governmental regulations not only in Canada but also in the United States. This book purports to be fair "--publishing only that information which we feel will stand up to rigorous scientific scrutiny." On the contrary, it is a very one-sided review that omitted much important information. The review has many misinterpretations and errors.

The major difficulty is that the safety and toxicology of 2,4-D are technical and complex subjects. It is impossible for a person unfamiliar with the subject to be able to distinguish between the correct and the incorrect information as presented in the SOEC publication. This book has been critiqued by the Ministry of the Environment of British Columbia (93). The MEBC review is a very detailed and lengthy critique citing many errors, not only in fact but also in interpretation, that occur in SOEC's book. Here are a few general criticism from the MEBC critique of this book.

> "--The SOEC report attempts to sway the reader by leaving 'impressions of facts'. Actually many of these impressions are misleading.
>
> --Much is made of the'scientific content' of the SOEC report by their writers. A collection of references is not a scientific document and many of their sources cannot be considered credible by any intellectually honest scientific community. We noted about twenty-five references to newspapers and magazine articles, more than twenty clearly unpublished papers and many unauthenticated letters making unverified claims.
>
> --The commentary is in the present case often contradictory to the actual evidence presented and the conclusions reached in the references cited."

This MEBC review cites one specific error that will be discussed in more detail because it deals with a point that is often of great public concern: namely, birth defects. The SOEC's brochure mentions the case of a couple living on Galiano Island, British Columbia. Their daughters were born in 1973 and 1975 with defective closures of the spinal column (spina bifida) which is a serious birth defect. This was supposedly caused by the mother contacting 2,4-D residues while pregnant. The SOEC report also speaks of the high incidence of spina bifida in the area at the same time. Dr. R. B. Lowry, M.B., BSc., F.R.C.P.(C), Director, Medical Genetics Clinic, Professor of Pediatrics at the Albert Childrens' Hospital wrote the following in a learned medical opinion about this matter:

> There was no shocking incident of babies suffering from gross deformities of the skull and spinal column; these facts are completely incorrect--there is no proof in the medical or scientific literature that 2,4-D causes birth defects in humans."

A few other comments about the "Other Face of 2,4-D" further illustrate that it is neither an accurate nor a reliable source of information about 2,4-D. The SOEC report says:

> "The only difference between 2,4,5-T and 2,4,5-TP is that the former is manufactured with acetic acid, the latter with picolinic acid."

This comment is attributed to Ashton and Craft, two well-known and respected scientists specialiazing in weed science. Both the statement and its alleged source are incorrect. 2,4,5-TP, with common name of silvex in North America and fenoprop in the United Kingdom, is manufactured with propionic acid. Propionic acid differs slightly from acetic acid (vinegar) by having one more carbon atom is the chain. Technically this is an aliphatic acid which differs greatly from the aromatic or cyclic picolinic acid that is a ring structured compound closely related to nicotinic acid, a member of the vitamin B complex.

The following statement is also made regarding long-tem research studies on teratogenicity and mutagenic hazards:

> "Only after the product has been introduced and health problems identified, have the regulatory agencies moved to commission the necessary studies."

This statement is incorrect. An agricultural chemical cannot be registered until the regulatory agencies, in either Canada or the United States, are certain that the product may be used safely. Some of the criteria that the regulatory agencies use in reaching their decision are the data from long-term toxicological studies on carcinogenicity, teratogenicity, and mutagenicity as well as reproduction studies. If a product is not registered, it cannot be commercially sold in either country.

Another SOEC statement is:

> "Fourthly, a significant number of chlorine-based chemical compounds have been proven to be carcinogens."

The most common chlorine-based compound is undoubtedly sodium chloride (table salt) which is not considered to be carcinogenic and in fact is a necessary component in our diet. The fact is that one cannot reliably predict activity from structural relationships. Chemical literature abounds with examples where a slight change is structure drastically alters the physiological properties of the compound. A common example is wood alcohol which is very toxic to man versus ethyl alcohol which is commonly drunk in beverages such as wine without ill effects and even serves as a source of food calories. The chemical difference in these two compounds is the addition of a CH_2 group.

There is also a general section in the SOEC book entitled "The dangers of sccinic acid." This is quite a misleading caption as succinic acid is one of the important compounds involved in metabolism of almost all living creatures.

Due to its widespread distribution and because it is frequently cited as an authoritative source, this book, "The Other Face of 2,4-D," has been reviewed in some detail. There are many other criticisms that could be made. However, the foregoing comments appear sufficient justification for saying this book has so many serious inaccuracies both as to factual content and interpretation that it should not be used as a source of scientific or general information on 2,4-D.

Seattle review. A brochure (113) "Literature Reviews on Four Selected Herbicides: 2,4-D, Dichlobenil, Diquat, and Endothal" has been printed by the Municipality of Metropolitan Seattle. One aspect of this brochure addresses Public Health Effects by Ruth Shearer. The following comments refer only to this Public Health section on 2,4-D as the other material was not reviewed for this article. This review of the health effects of 2,4-D suffers from a lack of objectivity and/or incomplete reporting since frequently only the adverse aspects of the articles cited are mentioned.

For instance, an article (23) concerning the tumor promoting potential on the skin by phenolic compounds is cited as showing a 20% solution of 2,4-dinitrophenol promoted the appearance of skin cancer in mice following a single initiating dose of DMBA (dimethylbenzenanthracene). DMBA itself is a well-know initiator of skin cancer, again a point not mentioned in the Seattle review. The Seattle review of this article concludes:

> "This indicates that 2,4-dichlorophenol is a skin carcinogen in mice, or at least a co-carcinogen with benzene which is not carcinogenic by itself in this system."

The implication is that therefore 2,4-dichlorophenol is carcinogenic in humans.

2,4-D is not broken down into 2,4-dichlorophenol in man or rats but is excreted unchanged as the acid. In fact experiments (65, 108) in man have shown 75-95% of 2,4-D administered orally is excreted in the urine. Thus speculations on possible toxicity of 2,4-dichlorophenol in man because it is a metabolite of 2,4-D seem unwarranted. Moreover, EPA (11) states:

> "Based on available toxicity data, for the protection of public health, the derived level is 3.09 mg/L." (309 ppm in water)

Using odor and taste test data, EPA gave an estimated value of 0.3 μg/L (0.3 ppb) above which the water would have an unpleasant odor or taste.

Furthermore, if the original paper by Boutwell and Bosch is read, one finds most of the article deals with phenolic effects following a DMBA initiating dose. These authors equate the activity of 2,4-dichlorophenol in tumor formation as being equal to that of phenol. It is pointed out there is no evidence of ill effects of repeated applications of 5% phenol except for the development of benign papillomas (non-carcinogenic epithelial tumors like warts) in mice that first had been treated with DMBA.

The original article also discusses an experiment showing the different effects obtained with different strains of mice. Three strains of the mice were used and no tumors were formed in two of the three strains when treated for one year with phenol alone in contrast to 10% papillomas in the third strain. No carcinomas (cancer tumors) appeared in the third strain of mice treated with phenol alone but did appear six months after a single application of DMBA. Boutwell and Bosch also state:

> "....we are aware of no association between exposure to phenol and the incidence of human cancer. It is pertinent that small amounts of phenolic compounds are formed in the animal body, at least in part by bacterial metabolism in the intestine. The results with mice suggest that even in susceptible animals tumors result only after continued exposure to relatively large quantities of the reagent."

Thus the original Boutwell and Bosch article has a very different thrust than the way it has been interpreted in the Seattle review.

The Seattle review (113) emphasizes the possability of 2,4-dichlorophenol being hazardous and of it being a major breakdown product in the metabolism of 2,4-D. While correctly pointing out that 2,4-dichlorophenol has been suggested as a step in the degredation of 2,4-D in soil by soil microorganisms, it fails to point out that another recognized major pathway for microbial degradation is via a hydroxylated phenoxyacetic acid intermediate which does not invove 2,4-dinitrophenol (109). The degradation pathways of 2,4-D are varied and complex, and how important 2,4-dichlorophenol may be in this process is not clear. It should also be noted that phenol is a natural degradation product of plant material such as bark and leaves.

The Seattle review also cites Huston's paper (54) as saying the primary contaminants of 2,4-D are: bis(2,6-dichlorophenoxy)methane, 2,2[1],4,6[1]-tetrachlorodiphenoxymethane, and bis(2,4-dichlorophenoxy)methane (compounds I, II, and III respectively). However, it doesn't point out that these were found to be present at concentrations of 1, 10, and 30 ppm, respectively. To put this into perspective, EPA's prpposed guidelines on May 9, 1980 subpart D, do not require the identification of impurities that potentially might occur in quantities of less than 0.1% by weight (1,000 ppm). Although the Seattle review raises the fear specter of the lack of toxicological knowledge of these compounds, Huston's original paper says:

> "However from a study of the teratogenic effects of both production grade 2,4-D and purified 2,4-D (Khera 1972), it appears that compounds I, II, and III have no adverse effects at the levels administered in his investigation."

Palmer and Radeleff's study (93) on the toxicity of certain fungicides and herbicides on sheep and cattle is also cited and summarized. [A very similar article (94) by the same authors is reviewed in the chronic toxicity section of this paper.] The Seattle review correctly points out that cattle and sheep died after 5 to 34 oral doses of 2,4-D alkanolamine salt. These animals were given post mortem examinations and the observed toxic effects were described. The doses which varied from 200-500 mg/kg in these cases were not mentioned. More important this review omits saying that no effects were seen in sheep after 481 daily doses of 100 mg/kg and no discernable effects were seen in cattle after 112 daily doses of 50 mg/kg. Both the alkanolamine salt and an ester of 2,4-D were tested and Palmer and Radeleff said:

> "There appeared to be very little, if any, difference in the toxicity of the two derivatives. The remarkable tolerance of 481 daily doses, each of 100 mg/kg by sheep indicates that there is little probability of acute poisoning in normal applications of the compounds."

Again the original article gives a totally different impression than the very incomplete summary written in the Seattle review.

This Seattle review cites a paper by Dow researchers (110) as describing fertility effects of 2,4-D and then says no such experiment was done. Upon reading the original article Table 6 is found which gives data on reproduction and lactation indices and data is listed under a column heading of a fertility index. This is not an experiment on fertility in the classic way of feeding animals the compound prior to conception and subsequently during pregnancy to determine its effect on fertility. However, it is also true that compounds administered to pregnant animals can affect fertility casuing resorption of fetuses, so observations on this point are both pertinent and valid. This latter effect on fertility is described in this article and very clearly defined. Thus criticisms as to such an experiment not being done are invalid.

More examples could be given but the preceding are sufficient to illustrate the prejudicial quality of this review on 2,4-D. As the examples noted illustrate, the Seattle review (113) cannot be used as an authoritative source of information on 2,4-D.

Reuber's unpublished (as of May 1, 1981) critique on 2,4-D. A manuscript written by Reuber (103) has not been published but it has been widely circulated by Friends of the Earth and other environmental groups that oppose the use of 2,4-D. This Reuber manuscript will be reviewed here since reference is frequently made to this document, and it is sometimes quoted as being the authoritative toxicological reference on 2,4-D.

This unpublished paper reviews the Hansen, et al. study on rats and dogs (49) and the Innes study on mice (56).

Reuber claims in this unpublished paper that 2,4-D is carcinogenic. This claim is in disagreement with the conclusions both of the original authors who conducted the studies as well as other toxicologists who have reviewed these papers. Following are two reviews of this research work which disagree with Dr. Reuber's conclusions. In view of the frequency with which Reuber's comments are quoted, Dr. M. A. Weinberger's remarks (129) (he was acting Director, Division of Pathology of the Food and Drug Administration) will be completely quoted on this subject.

> "Following review of the pathology tumor data and after a discussion with Dr. Umberto Saffiotti, Associate Director for Carcinogenesis, National Cancer Institute, I have reached the following conclusions regarding the carcinogenic potential of 2,4-D under these test conditions.
>
> 1. There is little to support a positive carcinogenic effect on 2,4-D.
> 2. The tumors observed were all of the type that may be observed in aging rats of the Osborne-Mendel Colony.
> 3. No "target organ" tumors were observed.
> 4. The "latent period" of tumor bearers (based roughly upon the age of tumor bearers) was similar for treated tumor bearers and control animals.
> 5. With the possible exception of pituitary adenoma, individual tumor types appear to be randomly distributed among the various dosage levels and controls.
> 6. The number of animals surviving the two-year study did not differ significantly from group to group. With a carcinogen one would expect fewer surviving the high dose group.
>
> In her report, the statistician (Anne Alderman) has indicated a statistically significant linear relationship between the proportion of female rats with tumors and dose level and between the proportion of male rats with malignant tumors and dose level. This relationship did not hold between dosage and male rats with tumors and female rats with malignant tumors.
>
> The statistical data therefore show some inconsistencies. Moreover, the important interpretation here is how significant pathologically are the differences recorded by the statistician. In my opinion, they do not reflect important pathologic differences.
>
> There are a number of parameters that have not been recorded that are of importance in making a judgment about potential carcinogenesis of an agent. These include more accurate information about the latent period of the tumors (as determined by clinical palpation); tumor size and growth rate for the various groups; an accurate record of the number of multiple tumor bearers in the various groups, etc. Because of the absence of these data, carcinogenesis for 2,4-D cannot be positively ruled out. Based upon the available data, it appears to be unlikely."

Mr. E. Johnson, deputy assistant administrator of the Office of Pesticide Programs for EPA, requested information and comments on "new data on oncogenicity of 2,4-dichlorophenoxyacetic acid" from the Toxicology Branch of EPA. Dr. M. L. Quaife (97) of EPA in a memorandum dated January 24, 1977 said:

> "Summary: In sum, no new data (on carcinogenicity studies) are contained in the documents accompanying Mr. E. Johnson's memo. The data evaluated by the original workers (Drs. Habermann and Fitzhugh and Mr.

Hansen) at FDA and found negative with respect to the carcinogenicity of 2,4-dichlorophenoxyacetic acid."

Under the Federal insecticide, Fungicide, and Rodenticide Act (FIFRA) a Scientific Advisory Panel (SAP) was authorized to advise EPA on certain scientific matters (45). This panel has been established and it had the following comments to make on this subject.

"The FIFRA Scientific Advisory Panel has reviewed the chronic toxicity study on 2,4-D carried out in rats and dogs by Hansen et al. which was published in Toxicology and Applied Pharmacology (TAP). In addition to peer review of this subject by the editor and editorial board of TAP, the study has also been reviewed by the National Cancer Institution (NCI) and by Dr. M. Reuber. The NCI review agreed with the conclusion of the authors of this paper that a carcinogenic effect was not demonstrated for 2,4-D whereas Dr. Reuber's conclusion was that 2,4-D is carcinogenic in male and female rats and probably also in mice. In Dr. Reuber's report, he agreed (page 5) that this FDA study (Hansen et al.) must be considered as an acceptable study, and thus the major difference in the conclusions of Dr. Reuber and the authors of this study derives primarily from differences in the interpretation and evaluation of the rat histopathologic data. Dr. Reuber agrees with the authors of the FDA study that 2,4-D was not shown to be carcinogenic in dogs but argues that two years is an insufficient study period to detect carcinogenesis in this species. It should be pointed out that carcinogenic effects have been produced in dogs in studies of less that 2 years duration and the 2-year period is the recommended exposure period in the current FIFRA quidelines for chronic toxicity studies in dogs. The FIFRA Scientific Advisory Panel recommends that the Agency attempt to resolve the apparent controversy between Dr. Reuber's pathologic interpretation of the rat histologic findings and those of the authors of the FDA study before requesting any additional oncogenicity testing in rats with 2,4-D.

In connection with the issue of additional oncogenicity testing with 2,4-D in rats, the FIFRA Scientific Advisory Panel wishes to remind the Agency that it is virtually impossible to carry out a chronic toxicity study that is totally without flaws. The decision of whether these flaws are inconsequential or whether they render the study useless for toxicologic evaluation depends both on the judgment and experience of the evaluator and on the rest of the information contained in the toxicity data base."

The SAP's summary comments on this point were:

"The panel is of the opinion that the Agency should resolve the controversy between the study conducted by Hansen et al. 1971 and the pathologic interpretation of that study by Reuber 1979 prior to certification that additional oncogenicity studies are required. In the event the results of the oncogenicity studies of Hansen et al. 1971 are validated as a result of examination of the appropriate slide related to lymphosarcoma in female rats, then the Panel would recommend that the testing requirement be limited to a standard oral exposure study in mice. In the event the results of the report by Hansen et al. 1971 are not validated on reexamination of tissue specimens, then an oral exposure study in both rats and mice is recommended."

The following is part of a personal communication (109) on the FIFRA SAP's public hearing on "Special Review of Data Requirements for 2.4-D held in

Arlington, Virginia, May 28, 1980.

> "Hank Spencer, EPA, made the initial presentation of the Hazard Evaluation Division's (HED) evaluation of the published and submitted data on 2,4-D and their conclusion that 2,4-D did not present a hazard to man or the environment. However, because of public pressure and because the toxicological studies which have been conducted did not meet today's standards, they would be requesting additional studies." "Hank showed a comparison of the tumors reported in the Hansen study and those reported by Dr. Reuber. Reuber claimed to have found more lymphomas than reported by Hansen. Dr. Ed Schmuckler, a pathologist from the University of California medical school and a member of the SAP, said diagnosing of lymphomas was difficult and very subjective and he would like to see the slides for himself. Dr. Bob Neal, who was moderating the SAP review stated that Dr. Reuber has reviewed several studies and reportedly finds cancer when other pathologists do not and that he seems to find cancer in every study."

Reuber has also published a paper (104) on methoxychlor concluding it is carcinogenic. Yet as he says in this paper the IARC, upon reviewing methoxychlor, concluded that the available data did not provide evidence that methoxychlor is carcinogenic in animals.

Recnetly (10) Dr. Reuber's professional conduct has been very severely criticized by his supervisor Dr. M. G. Hanna of the Frederick Cancer Research Center where Dr. Reuber works. Two points will be quoted from this lengthy criticism since they may well be applicable to his 2,4-D paper being discussed in this review.

> "...With regard to malathion and malaoxon, your statement in a letter to Mr. Rominger, the Director of the Department of Food and Agriculture in Sacramento, California, was that your reinterpretation was based on 'examination of every histological slide,' (up to 24,000 slides) of the three studies. Based on this statement, and assuming that a competent pathologist would spend a minimum of five minutes per slide in order to adequately reinterpret diagnosis, you spent a total of 333 days in the respository reading these slides. I have checked the repository records and you have not spend that amount of time in the repository. Therefore, I can only assume that your statement regarding your thorough evaluation of these slides was incorrect and misleading. On the other hand, you may have spent considerably less time per slide, thus raising a question of whether your interpretation is scientifically valid.
>
> "...Dr. Reuber's scientific communications and publications were not reviewed through the NCI system, since in your own words, Dr. Hanna noted, the papers would 'not have gotten through the system.' I can only assume this statement to mean that you knew your comments would not have passed critical scientific review and evaluation. You nevertheless used these materials to create a political and economic controversy to the discredit of the NCI Carcinogenesis Testing Program, and misrepresented the publications as having the endorsement of both the NCI and the contractor of FCRC, Litton Bionetics, Inc."

Certainly Reuber is entitled to his own views on 2,4-D. However, it should be remembered that this is only one man's opinion. Further it is not in accord with the conclusion of the original researchers who did the work or several national and international experts in the field who have reviewed this subject.

Conclusions

This review shows that government agencies such as EPA who are concerned with the effect of agricultural pesticides on human health and the environment have authorized the use and sale of products containing 2,4-D. EPA has established food tolerances and a tolerance in potable water for 2,4-D. The international World Health Organization in Rome has established an acceptable daily intake value for 2,4-D by humans of 0.3 mg/kg of body weight. This would be 18 mg/day for a person weighing 132 pounds.

However, surveys of food, soil, water, and air in this country have shown no or only occasional traces of 2,4-D presence. Practically speaking the majority of people in this country are not exposed to 2,4-D. Considering the acceptable daily intake of 2,4-D by humans, established by the World Health Organization, and the minimal amounts of 2,4-D to which the general public is exposed means there is a very large safety margin before even the acceptable intake level would be reached.

The worst case situation of exposure would be applicators applying the product daily. Data are available for such situations that show these individuals also have a considerable safety margin before their potential exposure would exceed the "no-effect dose level" found from toxicological experiments with animals and humans.

Considering the short-lived persistence of 2,4-D in the environment; its rapid excretion unmetabolized in mammals and man; its moderate acute oral toxicity; that it is not present except occasionally in traces in our environment, it is evident that the approved uses of 2,4-D are not hazardous to man or the environment.

The public, therefore, should be completely reassured and not concerned if they have an accidental exposure to 2,4-D. The evidence clearly shows that such an exposure would not be harmful and this included pregnant women. The most likely form of accidental exposure would be from spray drift and this quantity would be so minimal that practically speaking it could be considered to be zero.

To conclude the California Department of Food and Agriculture completed a detailed study April 6, 1978 on the aerial application of phenoxy herbicides in California (29). Public hearings were also held on this subject. 2,4,5-T and 2,4-D have been in use in this state for more than 25 years. In their summary it was stated:

> "At the public hearings, allegations were made concerning gross, readily apparent effects of the herbicides, and these alleged gross effects were the target of a subsequent investigation by the Phenoxy Herbicide Investigation Team. None of these effects, such as human illness, animal deaths or deformities, plant damage, or environmental damage, could be attributed to or associated with spraying of phenoxy herbicides. Similarly, no substantiation could be provided for any correlation between geographical locations of residents in relationship to the spray site and the etiology of disease. Examination of pesticide illness reports from California physicians by this Department have not revealed any significant health hazard that can be attributed to the phenoxy herbicides as used today in California."

Literature Cited

1. Anonymous. Unpublished Data. The Toxicology Department, The Dow Chemical Company.
2. Anonymous. Protecting honey bees from pesticides. Leaflet No. 544. U.S. Department of Agriculture.

3. Anonymous. 1972. WHO Pesticide Residue Series, No. 1. 1971 Evaluations of some pesticide residues in food. World Health Organization, Geneva, France 1972.

4. Anonymous. 1975. Part IV. Environmental Protection Agency, Water Programs, National Interim Primary Drinking Water Regulations. Federal Register. December 24. p. 59571.

5. Anonymous. 1978. Review of - The Other Face of 2,4-D - A citizens report. Environmental and Engineering Services, Water Investigations Branch. British Columbia, Ministry of the Environment.

6. Anonymous. 1979. FDA lists pesticides most frequently found in food monitoring programs. Pesticide and Toxic Chemical News, p. 16, Oct. 24, 1979.

7. Anonymous. 1980. 2,4-D fact sheet given out with a news release by EPA titled "EPA asks for more information on herbicide 2,4-D." April 29, 1980.

8. Anonymous. 1980. TLV's threshold limit values for chemical substances in workroom air adopted by ACGIH for 1980. American Conference Governmental Industrial Hygienists, Cincinnati, OH.

9. Anonymous. 1980. Part V. Environmental Protection Agency, Water Quality Driteria Documents, Available. Federal Register Nov. 28, p. 79318.

10. Anonymous. 1981. Dr. Mel Reuber, pathologist, gets sharp censure. Warning from his supervisor. 9:22-23.

11. Anonymous. 1981. Part V. Environmental Protection Agency, Water Quality Criteria Documents Availability. Federal Register Nov. 28, p. 79333.

12. Anonymous. 1981. Fact sheet on 2,4-D. Environmnetal Protection Agency. Jan. 23.

13. Aleksashina, Z. A., S. Y. Buslovich, and V. M. Kalosovskaya. 1973. Embryo-toxic effect of 2,4-D diethylamine salt. Gig. Sanit. 38(2): 100-101.

14. Arkhipov, G. N. and I. N. Kozlova. 1974. Carcinogenic properties of herbicides: 2,4-D amine salt. Voprosy Pitaniya 5:83-84.

15. Ashton, F. M. and A. S. Crafts. 1973. Mode of Action of Herbicides. John Wiley and Sons. New York. pp 276-284.

16. Axelson, O. and L. Sundell. 1974. Herbicide exposure, mortality and tumor incidence. An epidemiological investigation of Swedish railroad workers. Work-Environment-Health 11:21-28.

17. Axelson, O., L. Sundell, K. Andersson, D. Edling, C. Hogstedt, and H. Kling. 1980. Herbicide exposure and tumor mortality; an updated epidemiological investigation on Swedish railroad workers (Manuscript from 1980).

18. Berkley, M. C. and K. R. Magee. 1963. Neuropathy following exposure to a dimethylamine salt of 2,4-D. Arch. Internal Medicine 111:351-352.

19. Berwick, P. 1970. 2,4-Dichlorophenoxyacetic acid poisoning in man. Some interesting clinical and laboratory findings. J. Amer. Medical Assn. 214:1114-1117.

20. Binns, W. and A. E. Johnson. 1970. Chronic and teratogenic effects of 2,4-D (2,4-dichlorophenoxyacetic acid) and atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) to sheep. Proc. North Central Weed Cont. Conf. 25:100.

21. Bjorklund, N. E. and K. Erne. 1966. Toxicological studies of phenoxy-acetic herbicides in animals. Acta Vet. Scand. 7:364-390.

22. Blair, E. H. 1973. Chlorodioxins--Origin and fate. pp. 141. Adv. in Chem. Series. Amer. Chem. Soc. Washington, D.C.

23. Boutwell, R. K. and D. K. Bosch. 1959. The tumor-promoting action of phenol and related compounds for mouse skin. Cancer Res. 19:413-424.

24. Bovey, R. W. and A. L. Young. 1980. The Science of 2,4,5-T and Associated Phenoxy Herbicides. John Wiley and Sons. New York. 462 p.

25. Bramble, W. C. and W. R. Burns. 1974. A long-term ecological study of game food and cover on a sprayed utility right-of-way. Purdue Univ. Res. Bul. No. 918. 16 p.

26. Brown, E. and Y. A. Nishloka. 1967. Pesticides in selected western streams. A contribution to the national program. Pest. Monitoring J. 1:38-46.

27. Bucher, N. L. R. 1946. Effects of 2,4-dichlorophenoxyacetic acid on experimental animals. Proc. Soc. Exp. Biol. and Medicine. 63:204-205.

28. Bumb, R. R., W. B. Crummett, S. S. Cutie, J. R. Gledhill, R. H. Hummel, R. O. Kagel, L. L. Lamparski, E. V. Luoma, D. L. Miller, T. J. Nestrick, L. A. Shadoff, R. H. Stehl, and J. S. Woods. 1980. Trace chemistries of fire: A source of chlorinated dioxins. Sicnece 210:385-390.

29. California Department of Food and Agriculture. 1978. CDFA releases report of phenoxy investigation. News Release No. 78-48. April 6, 1978.

30. Collins, T. F. X. and C. H. Williams. 1971. Teratogenic studies with 2,4,5-T and 2,4-D in the hamster. Bul. Environ. Toxicol. 6:559-567.

31. Cochrane, W. P., J. Singh, W. Miles, B. Wakeford, and J. Scott. 1980. Analysis of technical and formulated products of 2,4-dichlorophenoxy acetic acid for the presence of chlorinated dibenzo-*p*-dioxins. Input of Chlorinated Dioxins and Related Compounds on the Environment Workshop. Oct. 22-24, 1980. Rome, Italy.

32. Corneliussen, P. E. 1972. Pesticide residues in total diet samples (VI). Pest. Monitoring J. 5:313-330.

33. Crocket, A. B., G. B. Wiersmaa, H. Tai, W. F. Mitchell, P. F. Sand, and A. E. Carey. 1974. Pesticide residue levels in soils and crops, FY-70 - National Soils Monitoring Program (II). Pest. Monitoring J. 8:69-97.

34. Desi, I., J. Sos, J. Olasz, and V. Markus. 1962. Nervous system effects of a chemical herbicide. Arch. Environ. Health 4:95-108.

35. Dudley, A. W. and N. T. Thapar. 1972. Fatal human ingestion of 2,4-D, a common herbicide. Arch. Pathol. 94:270-275.

36. Duggan, R. E. and P. E. Corneliussen. 1972. Dietary intake of pesticide chemicals in the United States (III), June 1968 - April 1970. Pest. Monitoring J. 5:331-341.

37 Duggan, R. E., G. Q. Lipscombe, E. L. Cox, R. E. Heatwole, and R. C. Kling. 1972. Residues in food and feed. Pesticide residue levels in foods in the United States from July 1, 1963 to June 30, 1969. Pest. Monitoring J. 5: 73-212.

38. Dunachie, J. F. and W. W. Fletcher. 1970. The toxicity of certain herbicides to hens' eggs assessed by the egg-injection technique. Ann. Appl. Biol. 66:515-520.

39. Epstein, S. S. 1970. Testimony on effects of 2,4,5-T on man and the environment. Presented at hearings before the Subcommittee on Energy, Natural Resources, and the Environment of the Committee on Commerce, United States Senate Ninety First Congress, Second Session on effects of 2,4,5-T on man and the environment. April 7 and 15, 1970. Serial 91-60.

40. Eriksson, M., L. Hardell, N. O. Berg, T. Moler, and O. Axelson. 1979. Case control study on malignant mesenchymal tumors of the soft tissue and exposure to chemical substances. Lakartidningen 76:3872-3875. (EPA translation)

41. Esposito, E. M., H. M. Drake, J. A. Smith, and T. W. Owens. 1980. Dioxins: Volume I. Sources, Exposure, Transport, and Control. PEDCo Environmental, Inc. 11499 Chester Rd., Cincinnati, OH 45246. Prepared for Industrial Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH 45268.

42. Eyzaguirre, C., B. P. Folk, K. L. Zierler, and J. L. Lilienthal, Jr. 1958. Experimental myotonia and repetitive phenomena: The veratrinic effects of 2,4-dichlorophenoxyacetic acid (2,4-D) in the rat. Amer. J. Physiol. 155:69-76.

43. FAO/WHO. 1972. Pesticide residues in food. Report of the 1971 joint meeting of the FAO Working Party of Experts on Pesticide Residues and the WHO Expert Committee on Pesticide Residues. WHO Tech. Rep. Ser. No. 502, Agricultural Studies, No. 88. Rome: FAO 46 pp.

44. Feldmann, R. J. and H. I. Maibach. 1974. Percutaneous penetration of some pesticides and herbicides in man. Toxicol. Appl. Pharmacol. 28:126-132.

45. Fowler, H. W., Jr. 1980. Special review of data requirements on 2,4-D defensive data call-in May 28-29, 1980. Personal Communication.

46. Gehring, P. J. and J. E. Betso. 1978. Phenoxy acids: Effects and fate in mammals. *In:* Chlorinated Phenoxy Acids and Their Dioxins. Ramel, D. (ed.). Ecol. Bul. (Stockholm) NFR27:122-133.

47. Goldstein, N. P., P. H. Jones, and J. R. Brown. 1959. Peripheral neoropathy after exposure to an ester of dichlorophenoxyacetic acid. J. Amer. Med. Assn. 171:1306-1309.

48. Hamner, C. L. and H. B. Tukey. 1944. Herbicidal action of 2,4-dichlorophenoxy acetic acid and trichlorophenoxy acetic acid on bindweed. Science 100:154-155.

49. Hansen, W. H., M. L. Quaife, R. T. Habermann, and O. G. Fitzhugh. 1971. Chronic toxicity of 2,4-dichlorophenoxyacetic acid in rats and dogs. Toxicol. Appl. Pharmacol. 20:122-129.

50. Hardell, L., M. Eriksson, and P. Lenner. 1980. Malignant lymphoma and exposure to chemical substances, especially organic solvents, chlorophenols and phenoxy acids. Lakartidningen 77(4):208-210. (EPA translation)

51. Hardell, L. and A. Sandstrom. 1979. Case control study: Soft tissue

sarcomas and exposure to phenoxy acetic acids or chlorophenols. Brit. J. Cancer 39:711-717.

52. Hayes, W. J. 1963. Clinical handbook of economic poisons. Environmental Protection Agency. pp. 106-109.

53. Herbicide Handbook Committee. 1979. Herbicide Handbook of the Weed Science Society of America, Fourth Edition. Weed Sci. Soc. Amer., 309 West Clark St., Champaign, IL 61820. p. 134.

54. Huston, B. L. 1972. Identification of three neutral contaminants in production grade 2,4-D. J. Agr. Food Chem. 20:724-727.

55. IARC. 1978. Long-term hazards of polychlorinated dibenzodioxins and polychlorinated dibenzofurans. Joint NIEHS/IARC Working Group Rept. Lyon, France. June 1978.

56. Innes, J. R. M., B. M. Ulland, M. G. Valerio, L. Petrucelli, L. Fishbein, E. R. Hart, A. J. Pallota, R. R. Bates, H. L. Falk, J. J. Gart, M. Klein, I. Mitchell, and J. Peters. 1969. Bioassay of pesticides and industrial chemicals for tumorigenicity in mice: A preliminary Note. J. Natl. Cancer Inst. 42:1101-1114.

57. International Agency for Research on Cancer. 1977. IARC monographs on the evaluation of the carcinogenic risk of chemicals to man - Some fumigants, the herbicides 2,4-D and 2,4,5-T, chlorinated dibenzodioxins and miscellaneous industrial chemicals. 15:111-138.

58. Johnson, R. D. and D. D. Manske. 1976. Pesticide residues in total diet samples (IX). Pest. Monitoring J. 9:157-169.

59. Johnson, R. D. and D. D. Manske. 1977. Pesticide and other chemical residue in total diet samples. Pest. Monitoring J. 11:116-131.

60. Kay, J. H., R. J. Palazzolo, and J. C. Calandra. 1965. Subacute dermal toxicity of 2,4-D. Arch. Environ. Health 11:648-651.

61. Kearney, P. C. and D. D. Kaufman. 1969. Degradation of Herbicides. Marcel Dekker, Inc. New York. 394 pp.

62. Khera, K. S. and W. P. McKinley. 1972. Pre- and postnatal studies on 2,4,5-trichlorophenoxyacetic acid, 2,4-dichlorophenoxyacetic acid and their derivatives in rats. Toxicol. Appl. Pharmacol. 22:15-28.

63. King, C. C. 1964. Effects of herbicides on honey bees. Gleanings in Bee Culture. April. pp. 230-234,251.

64. Klingman, G. C. 1961. Weed Control as a Science. John Wiley and Sons, Inc. p. 130.

65. Kohli, J. D., R. N. Khanna, B. N. Gupta, M. M. Dhar, J. S. Tandon, and K. P. Sircar. 1974. Absorption and excretion of 2,4-dichlorophenoxyacetic acid in man. Xenobiotica 4:97-100.

66. Kopischke, E. D. 1972. The effect of 2,4-D and diesel fuel on egg hatchability. J. Wildlife Mgt. 36:1353-1356.

67. Kraus, E. J. 1945. Tuesday afternoon session of the North Central Weed Cont. Conf., L. W. Kephart, Moderator. Proc. 2nd Ann. Mtg. N. C. Weed Cont. Conf. St. Paul, MN 2:74.

68. Kriebel, D. 1981. The dioxins: Toxic and still troublesome. Environment 23:6-13.

69. Krikorian, A. D. and R. P. Kann. 1979. Micropropagation of daylilies through aseptic culture techniques - Its basics, status, problems, and prospects. Hemerocallis J. 33:44-61.

70. Kutz, F. W., A. R. Yobs, and H. S. C. Yang. 1976. National pesticide monitoring progams. *In*: Air Pollution from Pesticides and Agricultural Processes. R. E. Lee, Jr., Ed. CRC Press, Inc. Boca Raton, FL.

71. Lamb, J. C., J. A. Moore, and T. A. Marks. 1980. Evalusation of 2, 4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) toxicity in C57BL/6 mice: Reproduction and fertility in treated male mice and evaluation of congenital malformations in their offspring. (NTP-80-44) National Toxicology Program, Research Triangle Park, NC 27709.

72. Lavy, T. L. 1978. Project completion report to National Forest Products Association - Measurement of 2,4,5-T exposure to forest workers, August 30 to October 3, 1978. Altheimer Lab., Univ. of Arkansas.

73. Lavy, T. L. 1980. Project completion report to National Forest Products Association. Determination of 2,4-D exposure received by forest applicators, spring, 1980. Altheimer Lab., Dept. Agronomy, Univ. Arkansas, Layetteville, AR.

74. Leng, M. L. 1979. Comparative toxicology of various chlorinated dioxins as related to chemical structure. Symposium of Collaborative International Pesticide Council (CIPAC), Baltimore, MD, June 7, 1979.

75. Lichtenberg, J. J., J. W. Eichelberger, R. C. Dressman, and J. E. Longbittom. 1970. Pesticides in surface waters of the United States. A five-year summary 1964-1968. Pest. Monitoring J. 4:71-86.

76. Lindquist, N. G. and S. Ullberg. 1971. Distribution of the herbicides 2,4,5-T and 2,4-D in pregnant mice. Accumulation in the yolk-sac epithelium. Experimentia 27:1439-1441.

77. Lutz, H. and H. Lutz-Ostertag. 1970. Action nefaste de l'herbicide 2,4-D sur le developpement embryonnaire et la fecondite du gibier a plumes. Comptes Rendus l'Academie Science Paris Serie D 271:2418-2421.

78. Mackenzie, C. J. G., W. K. Oldham, W. D. Powrie. 1975. Final report of the commissioners May 30, 1975. Appendix RR, Effects of pesticides on fish and wildlife in British Columbia p. 33. *In*: Royal Commission of Inquiry into the Use of Pesticides and Herbicides.

79. Manigold, D. B. and J. A. Schulze. 1969. Pesticides in water--Pesticides in selected western streams. A progress report. Pest. Monitoring J. 3:124-135.

80. Manske, D. D. and P. E. Corneliussen. 1974. Pesticide residues in total diet samples (VII). Pest. Monitoring J. 8:110-124.

81. Manske, D. D. and R. D. Johnson. 1975. Pesticide residues in total diet samples (VIII). Pest. Monitoring J. 9:94-105.

82. Manske, D. D. and R. D. Johnson. 1977. Pesticides and other chemical residues in total diet samples (X). Pest. Monitoring J. 10: 134-148.

83. Mitchell, J. W. and C. L. Hamner. 1944. Polyethylene glycols as

carriers for growth regulating substances. Bot. Gaz. 105:474-483.

84. Mitchell, J. W., R. E. Hodgson, and C. F. Gaetjens. 1946. Tolerance of farm animals to feed containing 2,4-dichlorophenoxyacetic acid. J. Animal Sci. 5:226-232.

85. Monarca, G. and G. DiVito. 1961. On the acute poisoning by the weed killer 2,4-dichlorophenoxyacetic acid. Folia Medica 44:480-485.

86. Morgan, D. P. 1977. Recognition and management of pesticide poisonings. 2nd Edition. U.S. Environmental Protection Agency. pp. 18-20.

87. Mrak, E. M. 1969. Report of the secretary's commission on pesticides and their relationship to environmental health. Parts I and II. U. S. Department of Health, Education, and Welfare. 677 pp.

88. Mullison, W. R. 1970. Effects of herbicides on water and its inhabitants. Weed Sci. 18:738-750.

89. Mullison, W. R. 1980. Public concerns about 2,4,5-T. Proc. West. Soc. Weed Sci. 33:15-25.

90. National Research Council of Canada Associate Committee on Scientific Criteria for Environmental Quality. 1978. Phenoxy herbicides. Their effects on environmental quality with accompanying scientific criteria for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). Natl. Res. Council Canada. 440 pp.

91. Newman, A. S. and C. R. Downing. 1958. Herbicides and the soil. J. Agr. Food Chem. 6:352-353.

92. Nielsen, K., B. Kaempi, and J. Jensen-Holm. 1965. Fatal poisoning in man by 2,4-dichlorophenoxyacetic acid (2,4-D): Determination of the agent in forensic materials. Acta Pharmacol. Toxicol. 22:224-234.

93. Palmer, J. S. and R. D. Radeleff. 1964. The toxicologic effects of certain fungicides and herbicides on sheep and cattle. Ann N.Y. Acad. Sci. 111:729-736.

94. Palmer, J. S. and R. D. Radeleff. 1969. The toxicity of some organic herbicides to cattle, sheep, and chickens. Production Res. Rept. No. 106. Agr. Res. Serv., U.S. Dept. Agr.

95. Poland, A. and A. Kende. 1976. 2,3,7,8-tetrachlorodibenzo-*p*-dioxin: Environmental contaminant and molecular probe. Fed. Proc. 35:2040-2411.

96. Pyle, R. M. 1981. Butterflies, now you see them. International Wildlife. 11:4-10.

97. Quaife, M. L. 1977. Response to 12/15/76 note of Mr. E. Johnson, Dep. Asst. Adm., Office of Pesticide Programs, EPA regarding "new data on oncogenicity" of 2,4-dichlorophenoxyacetic acid (2,4-D) "from Jim Michic" comment on. Dr. Quaife at that time was in the Toxicology Branch of EPA.

98. Ramel, C. 1977. Chlorinated phenoxy acids and their dioxins. Mode of action, health risks, and environmental effects. Ecological Bulletins/NFR27, Royal Swedish Acad. Sci., Stockholm, Sweden.

99. Ramsey, J. C., T. L. Lavy, and W. H. Braun. 1978. Exposure of forest workers to 2,4,5-T: Calculated dose levels. Toxicology Laboratory, Dow Chemical U.S.A., Midland, MI and Altheimer Lab., Univ. Arkansas.

100. Ramsey, J. C., F. A. Smith, T. L. Lavy, C. N. Park, and W. H. Braun. 1980. Dose levels of 2,4-D in forest workers. Toxicology Research Laboratory, Health and Environmental Sciences, 1803 Building, Dow Chemical U.S.A., Midland, MI 48640.

101. Rao, K. S. and B. A. Schwetz. 1980. Birth defects in humans and teratogenesis in animals. A perspective. Down to Earth 36(2):26-32.

102. Rasmuson, B. and H. Svahlin. 1978. Mutagenicity tests of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid in genetically stable and unstable strains of *Drosophila melanogaster*. *In*: Chlorinated Phenoxy Acids and Their Dioxins. C. Ramel (ed.) Ecol. Bul. (Stockholm) NFR 27:190-192.

103. Reuber, M. D. 1979. Carcinogenicity of 2,4-dichlorophenoxyacetic acid (unpublished manuscript). June 12, 1979.

104. Reuber, M. D. 1980. Carcinogenicity and toxicity of methoxychlor. Environmental Health Perspectives. 36:205-219.

105. Rowe, V. K. 1952. Health hazards associated with handling and use of herbicides. Agr. Chem. 42-45, 110-111, 113.

106. Rowe, V. K. and T. A. Hymas. 1954. Summary of toxicological information on 2,4-D and 2,4,5-T type herbicides and an evaluation of the hazards to livestock associated with their use. Amer. J. Veterin. Res. 15:622-629.

107. Sauerhoff, M. W., W. H. Braun, G. E. Blau, and P. J. Gehring. 1976. The dose-dependent pharmacokinetic profile of 2,4,5-trichlorophenoxyacetic acid following intravenous administration to rats. Toxicol. Appl. Pharmocol. 36:491-501.

108. Sauerhoff, M. W., W. H. Braun, G. E. Blau, and J. E. LeBeau. 1976. The fate of 2,4-dichlorophenoxyacetic acid (2,4-D) following oral administration to man. Toxicol. Appl. Pharmacol. 37:136-137.

109. Schober, A. E. Environmental Protection Agency Science Advisory Panel on 2,4-D defensive data call-in May 28-29, 1980. Personal Communication.

110. Schwetz, B. A., G. L. Sparschu, and P. J. Gehring. 1971. The effect of 2,4-dichlorophenoxyacetic acid (2,4-D) and esters of 2,4-D on rat embryonal, foetal, and neonatal growth and development. Food Cosmetics Toxicol. 9(b):801-817.

111. Seabury, J. H. 1963. Toxicity of 2,4-dichlorophenoxyacetic acid for man and dog. Arch. Environ. Health 7:202-209.

112. Seiler, J. P. 1978. The genetic toxicology of phenoxy acids other than 2,4,5-T. Mutation Res. 55:197-226.

113. Shearer, R. and M. Halter. 1980. Literature reviews of four selected herbicides: 2,4-D, dichlobenil, diquat, and endothal. Public health effects of R. Shearer, Effects of the acquatic environment by M. Halter. Municipality of Metropolitan Seattle. 168pp.

114. Sikka, H. C., H. T. Appleton, and E. O. Gangstad. 1977. Uptake and metabolism of dimethylamine salt of 2,4-dichlorophenoxyacetic acid by fish. Agr. Food Chem. 25:1030-1033.

115. Somers, J. D., E. T. Moran, Jr., and B. S. Reinhart. 1973. Effect of external application of 2,4-D and picloram to the fertile egg on hatching success and early chick performance. Down to Earth. 29:15-17.

116. Somers, J., E. T. Moran, Jr., and B. S. Reinhart. 1974. Effect of external application of pesticides to the fertile egg on hatching success and early chick performance. 2. Commercial-herbicide mixtures of 2,4-D with picloram or 2,4,5-T using the pheasant. Bul. Environ. Contamination and Toxicol. 11:339-342.

117. Spector, W. S. 1956. Handbook of Biological Data. W. B. Saunders. Philadelphia. p. 392.

118. Staff report to the Subcommittee on Administrative Practice and Procedure of the Committee on the Judiciary of the United States Senate. The Environmental Protection Agency and the regulation of pesticides. December 1976.

119. Statham, C. N. and J. L. Lech. 1975. Potentiation of the acute toxicity of several pesticides and herbicides in trout by carbaryl. Toxicol. Appl. Pharmacol. 34:83-87.

120. Thiess, A. M. and R. Frentzel-Beyme. 1977. Mortality study of persons exposed to dioxin following an accident which occurred in the BASF on November 13, 1953. Presented at the Fifth International Conference on Medichem, San Francisco, CA, September 1977.

121. Timmons, F. L. 1970. A history of weed control in the United States and Canada. Weed Sci. 18:294-307.

122. Todd, R. L. 1962. A case of 2,4-D intoxication. J. Iowa Med. Soc. 52:663-664.

123. Tucker, R. K. and D. G. Crabtree. 1970. Handbook of Toxicity of Pesticides to Wildlife. U.S. Dept. Interior, Fish and Wildlife Serv., Bur. Sport Fisheries and Wildlife, Denver Res. Center. Resource Publication No. 84.

124. Turner, D. J. 1977. The safety of the herbicides 2,4-D and 2,4,5-T. Forestry Commission Bul. 57. London. Her Majesty's Stationary Office.

125. Von Rumker, R. and F. Horay. 1972. Pesticide Manual. Part I: Safe handling and use of pesticides. Part II: Basic information on thirty-five pesticide chemicals. RVR Consultants. Shawnee Mission, KS.

126. Wallis, W. E., A. V. Poznak, and F. Plum. 1970. Generalized muscular stiffness, fasiculations, and myokymia of peripheral nerve origin. Arch. Neurol. 22:430-439.

127. Way, J. M. 1969. Toxicity and hazards to man, domestic animals, and wildlife from some commonly used auxin herbicides. Residue Reviews 26:37-62.

128. Warnock, J. W. and J. Lewis. 1979. The other face of 2,4-D. South Okanagan Environmental Coalition, Penticton, British Columbia, Canada.

129. Weinberger, M. A. 1970. Memorandum to Dr. Clara Williams, Residue Toxicology Branch EPA titled Evaluation of 2,4-dichlorophenoxyacetic acid chronic toxicity study in rats in regard to carcinogenic potential of the agent. Dept. Health, Education, and Welfare, Public Health Service, Food and Drug Adm. October 23, 1970.

130. Whitehead, C. C. and R. J. Pettigrew. 1972. The effect of 2,4-dichlorophenoxyacetic acid on laying hens. Brit. Poultry Sci. 13:191-195.

131. Whitehead, C. C. and R. J. Pettigrew. 1972. The subacute toxicity of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid to chicks. Toxicol. Appl. Pharmacol. 21:348-354.

132. Wiersma, G. B., H. Tai, and P. F. Sand. 1972. Pesticide residue levels in soils, FY 1969 - National Soils Monitoring Program. Pest. Monitorning J. 6:194-228.

133. Woolson, E. A., R. F. Thomas, and P. D. J. Ensor. 1972. Survey of polychlorodibenzo-*p*-dioxin in selected pesticides. J. Agr. Food Chem. 20:351-354.

THE PLACE OF THE WEED MANAGER IN TODAY'S CROP MANAGEMENT SYSTEM

Harold M. Kempen[1]

Abstract. Production systems are becoming increasingly complex in irrigated California agriculture. Recent new regulations being implemented will only increase that complexity, no doubt favoring large growers. A weed manager or "Weed management practitioner" is needed to utilize weed science research in crop management systems. By close association with several 1 to 5000 acre farmers, certain weed management techniques such as proper identification of weeds, predictive techniques, planning of integrated weed management programs, advice on application and timing of operations and monitoring of results were evaluated. As a result, essentially "fail-safe" programs were established after several years on many vegetable, field, and tree crops. Preventative weed control, so necessary against perennials, seem necessary on many aggressive annuals as well. Identification and roguing of severe competitors seemed logical despite increasing labor costs. Proper timing of plantings and varietal selection greatly affected weed problems. Little interaction with entomology or pathology was apparent unless crops were reduced in competitive ability.

Introduction

Farms in California are usually from 1,000 to 6,000 acres. In many parts of California farm agribusinessmen can grow one of more than 200 crops and face 50 or more weeds as competitors in each of their many fields.

Irrigated crops cost $300 to $6,000 per acre to grow (averaging $650 per A) and are subject to the many unpredictable weather and pest problems.

In cotton, San Joaquin Valley growers spend about $50/A for weed control, including 3 to 4 cultivations. This compares to an average of about $9/A for nematode control (sandy loams only), $1 per pathogens, $22 for insects and mites and $15 for defoliation. Thus weed control is over half of the total pest management cost in the San Joaquin Valley. Therefore it is a candidate for cost reduction research and better implementation of existing technologies.

Weed control costs in vegetables such as the cole crops, tomatoes, peppers, lettuce, onions, garlic, and asparagus will average $75/A. Nut crops such as almonds and walnuts will require $50 to #60/A, citrus and grapes somewhat less. Where mistakes are made, vegetable weeding costs climb to $150/A and losses in production and quality in tree and vegetable crops can be 10 percent, or $60 to $150/A.

Though farmers regularly use private entomology consultants, at fees of $3 to $10/A on various crops, they rarely employ weed management consultants. Instead they rely on agricultural chemical salesmen (pest control

---

[1]University of California Cooperative Extension, P. O. Box 2509, Bakersfield, CA 93303.

advisors) to advise them.

Most pest control advisors provide very good service to farmers. They know what herbicides are available and how to use them. Many others, however, are unable to give the in-depth service and planning aid a diversified farmer needs. For example on cotton, the profit without service on a dinitro-aniline is often less that 10%. If priced at $28/gallon, then the profit is only 35 cents/A. A salesman can't spend too much time advising for that kind of money.

Methods a Weed Manager Would Use

A weed manager could probably service a number of 2,000 to 5,000 acre farmers. He could cover about 20,000 to 25,000 acres in a five-day week. Farmers who grow 5 to 10 crops, especially vegetables, would be most likely candidates for service. Small farmers below 1,000 acres could not be efficiently serviced because communication becomes a limiting factor.

Such an advisor would first develop a log of weeds which infest his clients' fields (1, 2). This would require visits about twice a year, especially near harvest. But he would learn about the growth habits of problem weeds, to assure himself that certain ones which mature quickly, such as tumble pigweed (*Amarnathus albus* L.) or Orcutt's lovegrass (*Eragrostis orcuttiana* Vasey), are not maturing before cultivations or hand-weeding. A continued logging of weeds would be necessary to enable better predictive capacity, since soils often contain a reservoir of weeds, both winter or summer germinating species. These may last for seven years in tilled soils or 10 to 20 years in non-tilled orchard soils (2).

After such a log is developed a better prognostication can be made as to which fields to rotate crops to, which herbicides to use, when to plant for optimum crop competition, how to best irrigate and cultivate, and what to do in case of inclement weather, equipment breakdown, or limitations of staff, irrigation scheduling, or regulations.

As the season unfolds, the consultant would make weekly visits to the fields to observe and make written recommendation of weed management practices. Application is a very stage and calibration would be made with new practices, being spot-checked later by him or the farm staff. Because he cannot be in all locations, he would rely on an instructed farm staff to do most day-to-day monitoring of applications. However, he would be on call by radio to handle problems which always arise on farms, due to weather, equipment breakdowns, irrigation snafus, and regulations.

After crops and weeds were emerging, he would concurrently evaluate performance of herbicides used and weeds present in fields. By doing so, he would develop a "profile" on reliability of herbicides and application practices in order to "fine-tune" techniques. This probably would be one of his most valuable contributions, one that is not done by pest control advisors or farmers because of lack of time and diversion of interests to other aspects of their business.

Discussion

How does the weed manager fit in, in practice? Can agriculture afford him? Can he do the things his farmer clients would like him to do? Do regulations hurt his choice of options? Can he use "IPM"? And where can public and private research institutions aid him as a practitioner, or weed doctor?

Having been purposely very closely associated with a few 3,000 acre diversified farms in order to evaluate the weed management (practitioner) aspect of weed science, I feel a consultant could go in several directions.

The best of these would be to offer total weed manager services to a farm on a $3 to $4/A retainer. This would include keeping weed records, advising on crops and weed programs, recommendations on the timing and application of herbicides and cultivation, spot-checking calibration, monitoring results of programs, limited research, keeping up on latest scientific and regulatory developments and perhaps aiding public agencies in gaining special local needs labels. Weekly visits for 75% of the year would be required as well as direct radio communication.

A second approach would be to offer weed program evaluation to growers with but limited evaluation of weeds present. This would give the grower access to a disinterested third party specialist on which herbicides are safe (a most important consideration) and also effective, but for a lower fee. The consultant would monitor many more fields but more quickly, relying more so on public agricultural advisors than in the previous case. He could also provide a newsletter service and/or be available by telephone and/or radio. He might keep track of prices and availability of chemicals. Litigation risk would be greater with this type of service.

Such a weed management service would fit into a full service concept that some advisory firms are offering in California; a service that includes nematode evaluation, insect and mites, soil fertility evaluation, plant growth analysis, and defoliation. Newly released growth regulators, such as PIX, would require service there as well. Some firms include soil moisture monitoring, using the neutron probe and computerized weather records as well.

Unfortunately, litigation hazard is a major deterent to wholesale entry into the weed management field. Acceptable service and grower rapport with pest control advisors and the close relationship of weed management with farm management are other factors. Entomology services operate almost independently of farming operations, relying on scouting (monitoring) of pest populations and then responding to them. Weed management is a much more active, creative service which must involve farm staff. Perhaps each farmer should be a weed manager as well as a crop manager.

As farm businesses become even more sophisticated, farm owners (especially absentee and foreign investors) will request more crop production advisory services. The downside economic hazard of high technology agriculture is too great not to utilize experise wisely.

Can agriculture afford such weed management services? When considering that farmers spend close to $50/A for weed control in cotton, he surely should be able to make a return on a $3/A investment, especially since nearly all herbicides used in cotton can cause a carryover problem to subsequent crops. New weeds such as nightshade (*Solanum* sp.), can cost $90/A or more to remove by hand. Some growers cannot harvest infested fields. Annual morningglory, once established can add an annual control cost of $10 to $15/A--in perpetuity--plus losses. All perennials fit in the same category. Field bindweed (*Convolvulus arvensis* L.) control costs in cotton are $75/A. To clean up johnsongrass [*Sorghum Halepense* (L.) Pers] requires an investment of $50 to $100/A, a loss of up to 65% if left untended, plus annual costs for seedling control for seven years. This on a $600/A crop. Bermudagrass [*Cynodon dactylon* (L.) Pers.) regularly reduces cotton lint value because it is classed as grassy.

Pistachios, almonds, and certain grape varieties gross $2,000 to $10,000/A. Can a grower risk using a herbicide costing $3/A and having only a 2X safety margin or should he spend $50/A for newer less effective herbicides which have a 4X safety margin.

Vegetable crops such as onions, tomatoes, peppers, garlic can require hand-weeding costs of $200/A plus 10 to 20% losses. The grower must make certain all labor regulations and pesticide safety regulations are followed and then maybe risk litigation over alleged injuries.

Can a weed manager do the things a diversified farmer wants of him? Yes and no. He can some a lot closer to doing the job correctly.

The predictability of weeds is not at all exact. Grassy weeds seem to reflect if weeds go to seed the previous year more so than broadleaved weeds. Greater dormany in broadleaved weeds may account for this. Germination of annuals in cotton (which is every third acre in Kern County) and which is planted into moist soil after an earlier pre-irrigation, is only 10-25% of what occurs when crops such as tomatoes or onions are sprinkler irrigated. When rains occur after planting cotton, much more germination occurs. Thus it is difficult to assess the amount of weed seeds in the soil in such situations. Likewise, preplant residual prophylactic treatments prevent analysis of weeds in the early season, unless banded. Therefore, exacting predictive techniques are not available nor are they cost-feasible. Soil sampling techniaues would probably not be feasible either inasmuch as nematode sampling is generally too costly or inaccurate.

Prediction becomes less important in view of 20 years of experience personally and with innovative farmers, PCA's, and consultants, which show (quite conclusively I might add) that preventative programs are desired. We have known this for years relative to competitive perennials such as johnsongrass, bermudagrass, and field bindweed. But in recent years we can show that if annuals are kept at low levels, weed costs can be kept down. In part, this was possible with effective, low cost herbicides. Being very cost-effective, they have lessened the need for predicting whether populations of weeds will be light, medium, or heavy. Prevention not only cuts weeding costs, it lessens the hazard of unpredictable situations such as frosts, cold periods, disease or insect problems, or delayed harvests.

However, knowledge of which aggressive weeds are uncontrollable in crops is important (4). Weeds such as sunflower (*Helianthus annuus* L.), cocklebur [*Xanthium strumarium* L. var. *canadense* (Mill.) T&G], velvetleaf (*Abutilon throphrasti* Medic.), and annual morningglory, require vigilence on the part of the weed consultant so that they can be rogued out before maturity.

Some weed problems are just not easily solved. For example, nutsedge (*Cyperus* sp.) is essentially not controllable in onions. Winter weeds such as London rocket (*Sisymbrium irio* L.), shepherdspurse [*Capsella bursa-pastoris* (L) Medic.], and groundsel (*Senecio vulgaris* L.) are not predictably controllable with herbicides; an expert needs luck to get good results. The *Solanum* species have moved in rapidly, going to seed in tomatoes, peppers, cantaloupe, beans, onions, garlic, carrots, lettuce, potatoes, cotton, corn, cereals, sorghum, alfalfa, and peanuts, despite usage of herbicides which are effective in many crops. The nightshades are examples of weeds which are capable of survival in our mechanized monoculture despite optimum usage of all weed management concepts. Cold steel and hand weeding may be the only option left in some such problem situations, but usually a weed consultant can blend these with an optimum mix of rotation and herbicides to give a least-cost solution. At least he can more quickly evaluate and develop solutions than a busy farmer can.

Do regulations hurt the weed manager's choice of options? At present they do. The major reason for this is that a grower can legally tank-mix two or more products. A weed management advisor must consider the risk potential on such decisions. Manufacturers may not support such a non-labelled use. Also usage rates below those on labels may be normally effective, but fail on occasion and thereby subject an advisor to litigatory risk. A seemingly new practice is for insurance carriers to name advisors and applicators after settling an insurance claim of crop damage from drift onto a neighbor. Regulators often develop standards of practice, which if an advisor doesn't adhere thereto, can result in jeopardy to him.

At the state and federal levels, new more costly regulations result in few registrations for minor crops. New troublesome weeds encourage manufacturers to research herbicides for them in major crops, but not for the minor crops which are 90% of all crops grown. Many farmers are tempted to use illegal applications of effective herbicides on minor crops. This burdens an advisor.

New state regulations will require considerably more record-keeping (paper-shuffling) than is presently required. Farmers probably will be unable to cope with it. Also much more planning of pest management strategies will be required; only experts and time (which equals money) will satisfy the requirements of these new rules.

Can a weed management practitioner use IPM?

He has, can, and will use sound weed management principles. Record-keeping on weeds will permit optimum rotations, field selection, and timing of plantings. Frequent monitoring of applications, cultivations, and effectiveness of herbicides will enable maximum crop production. Farm sanitation around reservoirs, field ends, ditches, and sprinkler mainlines will reduce re-infection of weeds and with consistent preventative programs will reduce subsequent herbicide usage. Keeping alert to new troublesome weeds will preclude added herbicide costs.

Better mechanical systems will be utilized. For example, laser beam controlled levelling systems noticeably reduce weed problems in rice. New guidance systems from companies such as Agnav, Geosource and monitoring equipment from Dickey-John, Lely, and others will aid advisors in reducing weeding costs. New low-cost microcomputers will greatly enhance chemical application, cost analysis, and record-keeping systems and permit better IPM decisions.

The universities, USDA, and industry weed research scientists can aid weed managers by developing the data needed for better IPM decision making. Programming computers will receive a lot of attention in the 1980's and will enable weed managers to utilize the myriad of details we should have at our fingertips but presently do not. Developing that delivery system will be our big immediate task.

Our public researchers must continue to provide inputs into educating the urban sector to overcome the disenchantment with plant protection chemicals. Politicians are public relations animals who respond to media pronouncements even though we all know that the media does not represent the views and wishes of the public. We need to focus in on *special interest* groups who call themselves "public interest" groups. These groups and their henchmen now in the bureaucracies of America are continuing to direct legislation that is and will cost millions in lost effort. Is it not evident that the trauma caused by regulation exceeds the injury caused by the chemicals being regulated?

And at what costs? EPA estimates registrants (ultimately consumers) will fork over $700 million in the 1980's to meet new guidelines. Disposing of silvex [2-(2,4,5-trichlorophenoxy)propionic acid] will cost $4 million. California regulations will cost about $10 million a year. (If it stopped all pesticide injuries where a day or more of work was lost, that would be nearly $250,000 per person saved from injury.)

Obviously the plan for California is to reduce "pesticide" usage by creating a hugh overhead of charges and regulations that will make use of plant protection chemicals too costly. Old compounds will require more toxicology data which will probably not be affordable. New compounds will not be registered because of delaying tactics. Air pollution standards can knock out some more or disrupt marketing and research systems. Disposal may further increase cost. Finally, laws to allow public and private litigation against companies and farmers for negligence anywhere enroute, during or after the fact, are being proposed.

If adverse publicity occurs from new programs or if hearings show inadequate support, then the "public interest" mailing lists and supportive metropolitan media contacts are asked to generate support. Of course, industry and other special interest groups have been mounting "PR" programs, but governmental regulatory agencies have not done so skillful a job in the past. I have seen agencies develop a need for regulation, get mass media "support" then legislation and then confirm that need legislation by relating that the media, as representative of the public mood, supported it. Perhaps this has been going on for centuries, but it appears to me that there is little accomodation of viewpoints in recent years.

It seems to me that we in research and Extension have our PR work cut out for us. As Anson Bertrand, Director of Science and Education, USDA said, we had better do a better job with our administrators, politicians, and public or we may not be given the choice to continue doing agricultural research.

Literature Cited

1. Fischer, B. B., A. H. Lange, and J. McCaskill. University of California Weed Identification Handbook.
2. Miller, J. F. Commom weed seedlings of the United States and Canada. University of Georgia. 31 pp.
3. Robert, H. A. 1970. Rept. Natl. Veg. Res. Sta., Wellesbourne, Warwickshire, U.K. pp 25-38.
4. Holm, L. G. D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. The World's Worst Weeds. Univ. Hawaii Press. 609 pp.

PESTICIDES AND CONTROVERSY: WHAT CAN WE DO?

R. D. Gibson, W. W. Draper, and J. C. Steeet[1]

Because of increased environmental interest, pesticide controversies are becoming evermore prominent in the public's eye. These controversies in general are emotional, acrimonious conflicts that generate nothing of lasting value. Although the long term effects on the non-involved public are difficult to assess, it is becoming increasingly apparent to those who study these incidents, that more and more people are questioning the need for agricultural chemicals. The non-involved public, you say? Who are they? In the past, it was a rare occasion that the major media reported a pesticide controversy. Today, because increased interest in the environment has made chronic health effects of toxic chemicals a hot news item, one can hardly watch television, or read a newspaper, without being bombarded with the horrible effects of the poisons in which humanity is swimming. For the general public who has had: 1) no formal training in pest management and food production, 2) no previous bad experiences with pesticide products, and 3) no real opinion on the continued use of chemicals, these media presentations become a formidable array of facts that cannot help but have a

[1]Departments of Plant and Animal Science, Utah State University, Logan, UT.

negative influence. If the individual has had a bad experience personally or if someone close to them has had a bad experience, the reaction is more intense. What difference does that make? Humanity cannot afford to make a mistake here. The final decision on the continued use of pesticides will occur not in the legislature, in the courts, or by bureaucrats. It will be made in the minds of the public; by those who who are even now forming opinions. Unless means can be found to reduce or eliminate the intense emotionalism surrounding these incidents, and to interject facts where now hearsay, half-truths, and off-the-handle reactions now reign, the possibility remains high that future decisions will be made on the basis of unfounded fears rather than fact.

Proper citizenship requires all sectors to be responsible for their actions, and the agricultural chemical community comprised of university research and extension, manufacturers, distributors, applicators, and consumers cannot and do not want to be excluded. No one with legal and moral scruples wants to knowingly cause harmful health or environmental effects by their actions; to do so would violate basic humanistic responsibility. Yet, any and all related to the use of pesticides are being accused of this and much more. Clearly a communication problem exists and effective communication must be founded on truth, reality, and fact. If valid problems are uncovered related to pesticide use, changes must be made; but, where no unreasonable risks exist, the public deserves, indeed must be made, to know. The solution to conflicts arising from the use of pesticides will be found in the generation, evaluation, and distribution of hard facts.

Realizing this, the Utah Pesticide Impact Assessment Program was assigned the responsibility to study pesticide incidents and find ways to develop, assimilate, and distribute data. To accomplish this, the efforts of an agricultural chemical specialist, an environmental chemist, and a mammalian toxicologist were linked to characterize the risks and benefits of pesticide use within the state. The purpose of this paper is to share some the experiences and thoughts of this team.

In 1976 and 1977, the Environmental Protection Agency conducted the National Household Pesticide Usage Study. Approximately 10,000 households randomly selected from throughout the country were personally visited to assess the pesticide usage patterns by region. Of the households studied, 90.7% reported using a house, yard, or garden pesticide product during the course of the year. The region showing the greatest usage was that covered by EPA Region IV, headquartered in Atlanta, Georgia with a total of 97.1%. Least usage was the intermountain west area covered by EPA Region VIII in Denver, Colorado. Homes reporting usage totaled 83.3%. Nationally, the majority of all products were used in the home, followed by yard and garden in that order. Clearly, there is significant potential for the public to experience real or imagined poisonings and other adverse effects.

A separate study monitored all 1980 pesticide-related calls to the Intermountain Regional Poison Control Center in Salt Lake City, Utah. These calls were each reviewed and tabulated by effect and outcome. Only 10.1% were related to exposures actually resulting in verifiable symptoms. The remainder, 89.9%, resulted from symptoms unrelated to the exposures, asymptomatic exposures, and questions about the hypothetical effects (what if....?) of specific chemicals.

The above studies underscore two enlightening conclusions. First, the vast majority of homes in the United States apply pesticides in the home, garden, and yare areas. Because of this significant pesticide exposure potential, people do not necessarily have to live in rural, agricultural areas to have a bad experience with chemicals. Second, the majority of pesticide-related incidents received by one regional poison control center are the result of minor, exaggerated, assumed, or unverifiable exposures. The possibility exists that many of the bad experiences people cite as evidence of the need to eliminate pesticides stem from incidents which in reality were not incidents at all.

If the general public is in a position to decide the ultimate fate of agricultural chemicals, is exposed to sufficient potential to have had experiences, is reporting symptoms and concerns from non-existant and minor exposures, and is forming opinions based on these experiences, what can be done to ensure that regulatory decisions are based on facts instead of fears? The following are important but not exclusive.

First, incorporate yield loss studies, where time, personnel, and funds allow, into existing frameworks of research. Yield loss functions attributable, where possible, to specific pests or pest complexes are exceptionally effective in demonstrating the effect of yield constraints on food and fiber crops. Combined with efficacy data for non-chemical versus chemical controls, good demonstrations can be constructed to show the value of chemical control agents. Regulatory agencies are especially hungry for these types of data.

Second, support non-target exposure studies by multidisciplinary teams. Most incidents center around alleged drift or volitilization exposures from both aerial and ground applications. High volume air sampling techniques, patch tests, and uninalyses document the amount of exposure from representative applications and allow the calculation of expected exposures from similar applications. Trained toxicologists can then decide whether exposures can indeed cause the symptoms alleged to have occurred. In one recent study, the authors measured 0.044 mg/kg exposure from an aerial application of carbofuran at 13.7 meters from the field edge. Such levels are well below amounts expected to cause symptoms and allowed, at one time, a positive response to an angry crowd demanding that all applications cease. Support for exposure studies can be given by helping to identify cooperators and applicators with whom the teams might work.

Third, assist in identifying and assessing incidents involving the use of pesticides. Unsolved incidents, whether real or imagined, are like festering sores which can only cause problems in the future. In most cases, simply giving individuals time to talk about the problem and providing valid information addressing their concerns is sufficient to resolve the issue. Groundless fears are the greatest adversary.

Finally, develop educational programs to help distribute information to the general public. Although extension programs are helpful and important, it is equally important to inject data into scientific societies on the state level. Health care professionals, state health officials, special interest groups, educators, and other groups are more receptive to new ideas when they are distributed through acredited scientific sources. Industry and organized agriculture could especially help themselves by initiating a positive public education and advertising campaign. The greater the exposure, the greater the opportunity for a change of attitude.

Certainly much can and must be done to evaluate the extent of the problem, and to develop and distribute information. Where data is lacking, unfounded fears, suppositions, hearsay, and half-truths will fill the vacuum. Only by making infomation available can there be even a possibility that the data will be put to use in the regulatory procedure.

MINUTES OF THE WESTERN SOCIETY OF WEED SCIENCE BUSINESS METTING
MARCH 19, 1981, SAN DIEGO, CALIFORNIA

President L. E. (Jack) Warren convened the meeting at 8:10 a.m. with about 105 people in attendance. There were 262 members and 15 graduate students registered for the meeting.

Minutes from the 1980 business meeting were approved as published in the 1980 Proceedings of the Western Society of Weed Science.

Research Section Report. Phil Olson reported that the 1981 Research Progress Report contained 197 reports and 248 pages. This is approximately the same size as the 1980 Research Progress Report. Phil mentioned that the quality of the reports had improved over last year, but that there was still room for improvement. Pete Fay, Montana State University, Bozeman, Montana, will be chairman of the Research Section for 1982.

The reports from the individual project sections are as follows:

Project 1: Perennial Herbaceous Weeds: Ralph Whitesides, Chairman. Gus Foster, Velsicol Chemical Corporation, Fort Collins, Colorado will serve as chirman during 1981-82. The Chairman-elect for 1981-82 is Tom Schwartz, Union Carbide, Denver, Colorado.

Subject 1. Can weed wipers be used effectively to control perennial weeds? This topic was introduced by Dr. W. Orvid Lee (USDA-Oregon State University) who reported that grass seed growers in the Willamette Valley of Oregon believe they can successfully eradicate light stands of quackgrass while controlling volunteer grains and other grasses. The most popular wiper units are swathers converted to roller wipers, wick wipers, and specially designed carpet rollers.

Wipers can be effective if adequate height differences occur, if weeds are treated at the proper growth stage, and if the correct wiper and herbicide is used. Where weeds are very dense, wick wipers have not been as effective as carpet rollers.

Subject 2. Carbohydrate starvation, fact or fiction? Dr. Lowell Jordan (University of California-Riverside) introduced the topic by challenging the success of the concept of carbohydrate starvation. Successes were reported from Idaho and Montana although the practicality was questionable. It was concluded that carbohydrate starvation can be made to work but that the inputs are so great its use in not practical. There is merit to the concept, however, and it should be included as part of a total weed mangagement program.

Subject 3. Are management systems effective for perennial weed control? A total management system of crop rotation, cultivation, and herbicide application was suggested as effective by Dr. Richard Chase (Utah State University). Others agreed with the concept and felt that persistence in maintaining the program is the most critical factor in a successful operation. Most participants felt that growers did not follow perennial weed management systems religiously because of time constraints in normal farm operations.

Project 2: Herbacous Weeds of Range and Forest: Don Robinson, Eli Lilly, Chairman. There were 20 people registered for the session.. Ron Vore, University of Wyoming, is 1981-82 chairman. Jim Krall, University of Nevada-Reno was elected chairman-elect for 1982-83.

Paul Skinner, USFS, Fort Collins, Colorado, introduced a feasibility study update on Inventory and Analysis of Leafy Spurge (*Euphorbia esula*) Sites. Remote sensing may provide (1) an aerial-ground inventory system for leafy spurge, (2) be a method for survey purposes and (3) monitor treatment areas. This study was undertaken to evaluate scale/film combinations, scale/season/film combinations, to determine leafy spurge community descriptions allowing interpretation of remote sensing data and to evaluate accuracy and cost of mapping infestations. A combination of the above parameters may be used to identify high probability areas of leafy spurge infestations.

Remote sensing feasibility on leafy spurge is as yet unproven. Through the efforts of the USFS group involved on this project, this issue may be resoved. There were a number of concerns raised in the discussion, one of which was whether this technology could be applicable for other problem species. Separation of species in the survey site was also questioned and is a major concern for this technique. Economic comparisons need to be completed, if remote sensing is found to be feasible, to determine how this method of survey compares with ground activity.

Paul Ritty, Dow Chemical USA, updated the group on the status of Dowco 290 (Lontrel) and Garlon. Dowco 290 is a picolinic acid derivative. It is a fairly selective compound having activity on broadleaf weeds and some brush species. It shows promise for use in small grains with the control spectrum improved in combination with 2,4-D. Activity has been exhibited on several biennial and perennial problem weeds. This compound has a short residual period with soil degradation being concentration dependent. Garlon is cleared for use on perennials, woody and shrub species on industrial and forest sites. This compound is being reviewed as a basal treatment on oak and as a poisonous plant control herbicide.

Project 3: Undesireable Woody Plants: Roy Johnson, Chairman. The physiological basis for woody plant control and optimum timing indicators for herbicide applications were discussed.

Ray Evans, University of Nevada-Reno, is the chairman for 1981-82. Ron Vore, University of Wyoming, Laramie was selected as chairman-elect.

Project 4: Weeds in Horticultural Crops: Chuck Stanger, Chairman. Dr. William T. Cobb, Eli Lilly, will be the 1981-82 chairman. Ray William, Horticulture Department, Oregon State University, was elected as chairman-elect.

Subject 1. Sonalan--its uses, strengths and weaknesses. Sonalan is being evaluated for weed control in dry beans, green beans, and lentils. Sonalan will effectively control nightshade species at rates above 1.25 lbs ae/A. It is also effective on other annual broadleaf weeds and grasses. Most varieties of dry beans and lentils have crop tolerance. Certain varieties of green beans are susceptible to injury. Research work is underway to identify varietal responses to Sonalan treatments. Sonalan has less soil persistence than trifluralin under similar environmental conditions. Experimental trials are underway evaluating tolerance of other crops to Sonalan.

Subject 2. Comparing herbicides for grass control as postemergence treatments. Diclofop, BAS 9052 OH, and RO 13-8895 were discussed. All materials have excellent selectivity in broadleaf crops. BAS 9052 OH and RO 13-8895 have good activity on annual grasses at rates of 0.25 to 0.50 lb ai/A resulting in excellent control. These same herbicides on perennial grasses at higher rates have shown some potential for control but results have been variable. Results reported from research conducted in Arizona has shown that soil moisture is critical and control of johnsongrass has been good when treatments are applied following an irrigation when soils are moist. Some soil activity (1-2 weeks) has been observed with both BAS

9052 OH and Ro 13-8895. Diclofop has soil activity which has persisted for several months. Manufacturers of these herbicides are interested in registrations of each material in broadleaf crops. All three materials are compatible with bromoxynil applied as a tank mix.

Subject 3. Spray monitoring and spray control systems, movie presentation followed by discission. Information presented by Mr. Earl Lee who resides at 1938 Pride Place, Visalia, California. Mr Lee reported that the equipment has been used commercially for several years in central and eastern states. Equipment is being introduced to the western states at the present time. Sensing device is controlled by radar equipment which monitors speed and electronically controls rate of application. Reports equipment to be trouble free and extremely accurate, applying rates with ±2% of desired rate. Monitoring and control spray systems can be mounted on most all equipment used for spraying.

Project 5: Weeds in Agronomic Crops: Richard Gibson, Chairman. Pat Rardon, Montana State University, Moccasin, Montana, will be the 1981-82 chairman. Larry Thompson, Lilly Research, Fresno, California, is the chairman-elect.

Alternatives to phenoxy herbicides in agronomic crops and the successes and failures in the development of wick, wiper, and recirculating sprayer application techniques were thoroughly discussed from the floor.

Subject 1. Phenoxy herbicides are most commonly used agronomically to control broadleaved weeds in small grains. Loss of these compounds would greatly decrease economic returns in these crops. Although 2,4-D and its alternatives control basically the same weeds, the difference in price would generally reduce the grower's margin of profit. Application of the economic threshold concept to weed control might, in some instances, reduce the overall cost to the grower but most present felt that the methodology was still limited by insufficient data.

Subject 2. Rope wick and wiper applicators have generally replaced recirculating sprayers. The configuration of ropes varies greatly depending upon the target weeds, weed intensity, and geographical location. New wicks made of more absorbent materials have been introduced. Controlled droplet applicators are gaining in popularity. Research on the efficacy of herbicide combinations applied through these applicators is needed. Complete weed control can not be expected from one application. Best results occur when wicks and wipers are part of a complete management program.

Project 6: Aquatic, Ditchbank, and Noncrop Weeds: Nathan Dechoretz, Chairman. Floyd Colbert, Lilly Research, Fresno, California is the chairman for 1981-82. Les Sonders, CSFA, Sacramento, California is the chairman-elect. There were 44 society members in attendance.

Subject 1. Regulations--Present and Future, and their impact on aquatic and noncropland herbicide research, registration, and use. Panel members included Fred Whiting, CDFA, Stan Heathman, University of Arizona, George Algard, Montana Department of Agriculture, and Carl Tennis, Department of Water and Power Resource Service, Sacramento, California. Panel members provided brief addresses regarding regulations in aquatic systems in their states and their impact on research and use. In an open discussion session several questions from the audience were addressed to the CDFA regarding regulations toward doing research in California with chemical agencies for the control of problem aquatic weeds. Some of the problem areas were related to the effects to nontarget animals (fish) and plant species. Additional discussion was related to the need for better communication among the various involved groups in aquatic use systems so as to relieve the need for unnecessary and burdensome laws and regulations.

Subject 2. Requirement for California State and Federal government research personnel to obtain California EUP to initiate and conduct research with new products or new uses for old products which do not have a California state registration off state or federally controlled lands. Concern was expressed that this action would hamper research and development needs in aquatic and noncropland ecosystems.

Project 7: Chemical and Physological Studies: Steve Radosevich, Chairman. Lowell Jordan, University of California, Riverside is the chairman for 1981-82, and Robert Norris, University of California, Davis is the chairman-elect.

Three topics were discussed in Project 7. These were (1) The various strategies of physiological responses of weeds and other plants to the environment. (2) The influence of environment on herbicide effectiveness. The influence of water stress and light on herbicide affectiveness were of most concern. (3) Some of the instrumentation to measure field level physiological responses and environmental factors was also discussed.

WSSA Report. Harold Alley submitted the following report from the 1981 meeting of the Weed Science Society of America held in Las Vegas, Nevada on February 17-19.

The Board of Directors of WSSA met with incumbent President W. D. Carpenter on February 16, with the final board meeting being held with the new president D. E. Davis on February 19, at which time the new Board members assumed their duties. New 1981-82 officers and Board members of the WSSA are as follows:

President	D. E. Davis
President Elect	T. J. Sheets
Vice President	C. G. McWhorter
Past President	W. D. Carpenter
Secretary	Orvin Burnside
Members-at-large	J. D. Nalewaja, M. G. Merkle, Homer Lebaron, J. D. Riggleman
WSWS Representative	H. P. Alley
SWSS Representative	H. D. Cable
NCWCC Representative	Alen Dexter
NEWSS Representative	Dean Linscott
Treasurer	W. D. Carpenter
Editor-in-Chief	J. L. Hilton
Executive Secretary	C. J. Cruse
Chairman, Constitution & Operating Procedure Committee	R. D. Ilnicki

The WSWS did not have anyone elected as a Fellow of WSSA this year or have any member receive awards. WSSA members honored as Fellows were John F. Ahrens, Lawrence H. Hannah, William F. Meggit, Roman R. Romanowski, and Charles R. Swanson. Lew J. Mathews was awarded the Honorary Memger and gave the major address at the General Session. Dr. Morris G. Merkle, Texas A&M, received the Teacher Award, Dr. Jerome B. Weber, North Carolina State the Research Award, Dr. James Miller, University of Georgia the Extension Award, the outstanding article in Weed Science was presented to Dr. W. T. Patterson and E. P. Flint, Southern Weed Scinece Lab. The Outstanding Graduate

Student Award was presented to Philip Westra, University of Minnesota and Edward Scott Hagood, Jr., Purdue University.

Major actions of the Board are as follows:

1. Limit one paper to senior author. Over 300 papers submitted for 1981 WSSA meeting which required seven concurrent session. Any other papers submitted would have to be in the poster session.
2. Recommended deadline for accepting papers. Board support chairman.
3. Changed the photo contest to a picture of weeds for a calendar or other uses.
4. Discontinued single slide concept and the black and white photo contest.
5. To purchase up to three $100,000 certificates if beneficial.
6. Voted to join FSAS with Fred Slife as representative.
7. Directed International Affairs Committee to obtain details on inviting scientist from PRC scientists to the annual meeting and authorized the President to invite and to support two to three PRC scientists while attending WSSA annual meeting.
8. Establish a retired membership category for WSSA with all rights of regular members, except they will not receive the Journal.
9. Approved awarding of a watch to award winners of Outstanding Papers in Weed Science and Weeds Today, if a sponsor available.
10. Ahthorized the Parent Awards Committee to establish guidelines for establishment of a Young Scientist award.

Harold strongly suggested that nominations for Fellow of the WSSA be made by individuals or groups of individuals in the WSWS in that there are several people within our membership deserving of this award.

The 1982 meeting of the WSSA will be held in Boston, Massachusetts on February 7-11.

Financial Statement. The Treasurer-Business Manager report was presented by LaMar Anderson. He reported that the society has the equivalent of about one year's operating expense in reserves and savings. The Research Progress Report and Proceedings are paying their own way, but are not adding additional revenue to the society's financial reserves.

Western Society of Weed Science
Financial Statement
March 10, 1980 - March 10, 1981

Income	
Registration, Salt Lake City Meeting (266 + 40)	$ 6,650.00
Dues, members not attending annual meeting (111)	555.00
Spouse luncheon tickets	104.00
1980 Research Progress Report sales	2,280.64
1980 Proceedings sales	2,727.86
Sale of back issues of publications	107.50
Advance order payments	94.00
Payment of outstanding invoices for previous year	84.00
Interest	54.39
Room charge reimbursements	60.00
Total fiscal year receipts	$12,717.39
Assets, March 10, 1980	11,217.55
	$23,934.94

Expenditures	
1980 Annual meeting incidental expenses	443.39
1981 Annual meeting incidental expenses	46.15
Luncheon, 1980 meeting	2,748.75
Guest speaker expenses	1,052.04
Graduate Student room subsidy	328.86
Business Manager honorarium	500.00
Dues, CAST	500.00
1980 Research Progress Report	2,125.00
1980 Proceedings	2,391.76
Postage	1,085.93
Newsletter printing costs	157.85
Office supplies	451.75
Refunds	7.00
1981 Program, printing	395.77
Total 1980-81 expenditures	$12,234.25
Assets	
Savings certificates	$11,500.00
Checking	150.69
Cash on hand	50.00
	$11,700.69

Finance Committee. Rick Chase presented the finance committee report. He reported that the financial affairs of the society were in excellent order. A motion was made and seconded to accept the report and financial statement as presented. This motion was unanimously passed by the membership.

Other topics of business were also introduced for discussion. First, it was mentioned that the society should consider paying the travel expenses for the Executive Committee members that attend the summer business meeting. No action was taken on this item of business. Second, the need to have one or two years operating funds in reserve was discussed. The discussion favored maintaining a one year operating reserve. No formal action was taken. Third, the possibility of allowing sustaining memberships in the society was discussed. A discussion ensued about the pros and cons of sustaining memberships. No formal action was taken.

CAST Activities. Lowell Jordan submitted the following report on CAST and FSAS (Federation of Scientific Agricultural Societies) activities.

CAST (Council for Agricultural Science and Technology) is a consortium of scientists. CAST is composed of 25 agricultural sicence societies who have sole responsibility for its actions. CAST provides scientific information on agricultural matters of national concern. Reports are prepared by task forces of eminent scientists in the field. Recent reports of interest to WSWS include "Social and Economic Impacts of Restricting Pesticide Use in Agriculture." Reports being prepared include "Chemical Hazards in the Environment," "Integrated Pest Management," "Aerial Application of Pesticides," and "The Delaney Clause."

Weed Science was been well represented in CAST activities. Numerous task forces have been chaired (11) and represented (28) by weed scientists. A major portion of CAST's output has been in the interest of Weed Science. CAST continues to be the best collection of spokesmen who can influence national policy concerning Weed Science. CAST deserves and needs the support of each serious, professional Weed Scientist by becoming an individual member.

The president elect for CAST is Dr. R. Phillip Upchurch of the University of Arizona who will succeed Dr. O. D. Butler of Texas A&M University. Dr. Upchurch is a past president of the Weed Science Society of America.

CAST is in a sound financial condition, although with inflation new sources of income will be required for future activities. No higher dues are being assessed this year.

The objectives of CAST are "to advance the understanding and use of agricultural science and technology in the public interest, such to be accomplished by (1) coordinating the efforts of scientific agricultural societies to provide information to the government and the public for solution of problems of national and international concern, (2) improving communication and promoting unity among the various branches of agricultural science and technology, and (3) cooperating with organizations representing other sciences on matters of common interest. The purposes of CAST are (1) to serve as a resource group from which the public and government may seek information on the science and technology of food and agricultural issues of current concern, and independently to identify developing issues of broad public concern on which food and agricultural scientists and technologists from the relevant disciplines can provide information, (2) to organize task forces of food and agricultural scientists and technologists from the relevant disciplines to assemble and interpret factual information related to these issues, and (3) to disseminate the information in a usable and effective form to the public, the news media, and the government, as appropriate."

FSAS (Federation of Scientific Agricultural Societies) has the objective, according to Roger Mitchell, Interim President, to "provide a forum for interdisciplinary communication and enhance the capability of scientific agricultural societies to speak in a unified voice. The Federation would: (1) identify and articulate national goals and priorities related to education and research in food, agriculture, and natural resources (2) advise and counsel governmental agencies and policy makers on legislation, policy decisions and public concerns that impact upon the production of food and fiber and the conservation and development of natural resources (3) develop recommendations and advise governmental agencies on funding of agricultural research, teaching, and extension programs (4) assist colleges and universities in their efforts to maintain and strengthen programs in teaching, research, and extension and in recruiting highly qualified students into careers related to food, agriculture, and natural resources."

Dr. Mitchell further states that "FSAS seeks to play a role as a collective voice of scientists in agricultural societies within the objectives state above. We hope to complement CAST by: (1) speaking more to goals and priorities for extension, research, and teaching. The information on which to develop these goals will most often be derived from studies done by other groups (e.g. Joint Council, Users Advisory, USDA/SEA, CAST, Division of Agriculture-NASULGC) (2) we propose to select certain key issues and strive to educate Congress and the Executive Branch on their importance (3) current examples include: (a) the projected and current shortage of Ph-D's to conduct agriculture and food research, (b) germ plasm resource questions, (c) the need for an Agricultural Thesaurus, (d) there are many other broad issues that may be considered but they will require more discussion within FSAS first. In summary, we will seek to add a voice on carefully selected key issues after others, including CAST, have done the detailed studies. Additionally, we may serve a role in identifying studies needed and encourage others, including CAST, to consider doing them."

It is not yet clear how FSAS will accomplish its objectives. It is planned that financial support will be from member societies based on their membership number. A society the size of WSWS would pay annual dues of $100 and provide expenses for a representative to attend FSAS meetings twice a year. FSAS leaders envision that the societies would be able to provide a uniform voice through FSAS in promoting and urging executive and legislative support for high priority areas of research and education. As such, FSAS would provide information concerning legislation and fund allocation in a context other than lobying.

Seven agricultural scientific societies have voted to join FSAS and 17 are considering affiliation. Many are present members of CAST.

The information of FSAS and its activities should be watched very closely by WSWS. If it can achieve its goals without competing with, duplicating the activities of, or decreasing the support for CAST; FSAS will be a valuable organization for the promotion of scientific agriculture and for the welfare of the agricultural community. Careful planning, cooperation, and coordination of efforts will be required if both organizations are to succeed in their goals without adverse effects on each other.

In addition to the preceeding report, Lowell provided the Executive Committee with the following material: First, a list of CAST task forces chaired by representatives from weed science societies; second, information on a proposed National Academy of Agricultural Sciences, which would be an affiliate of the National Academy of Science; and third, a packet of information pertaining to FSAS. Contact a member of the Executive Committee if you are interested in a copy of the above information.

Resolutions Committee. Vern Stewart presented the following resolutions in behalf of the resolutions committee:

Resolution No. 1: Local Arrangements and Program

Whereas, the facilities and arrangements for the 1981 annual meeting of the Western Society of Weed Science are of satisfactory quality and well organized, and

Whereas, the organization and content of the program have been of good quality,

Therefore Be It Resolved, that the membership of the Western Society of Weed Science in conference assembled express its appreciation to Chairman C. L. Elmore and members of the 1981 Local Arrangements Committee and to the San Diego Hilton and Chairman Alex Ogg, Jr. and members of the Program Committee.

It was moved that the resolution be adopted. The motion was seconded and passed unanimously.

Resolution No. 2: U.S. and State Support for Production Goals in Society.

Whereas, agriculture, range, and forestry products annually contribute about 154 billion dollars directly to the nation's income and an additional 300 to 500 billion dollars through related business activities, and provides over 40 billion dollars worth of export food and fiber, and

Whereas, food production is essential to the survival of the world, and

Whereas, the needs for food and fiber in the world are continuing to increase at a rapid rate, and

Whereas, funding for basic and applied research in agriculture has been reduced in part because of inflation, and

Whereas, the reduction in funding has resulted in the loss of productive programs,

Therefore Be It Resolved that the Western Society of Weed Science urge Federal and State agencies to increase funding for agricultural research and extension programs.

It was moved that the resolution be adopted. The motion was seconded and passed unanimously.

A third resolution was introduced from the floor by Jack Evans, Utah State University.

Resolution No. 3: (Summary) The Western Society of Weed Science recommends and requests the Idaho State legislative and Administrative personnel to take immediate action to reinstate the Idahl State Weed Coordinator position and to guard against the loss of this position.

It was moved that the resolution be adopted. The motion was seconded and passed unanimously.

1982 Local Arrangements: Harvey Tripple presented the following report on local arrangments for 1982. The WSWS meeting in 1982 will be held at Stouffer Denver Inn, Denver, Colorado, March 9-11. Room rates will be $56 single and $64 double occupancy. A limited number of $56 quad rooms for graduate students will be available. Extended convention rates for two nights prior and following convention will be offered.

Site Selection Committee Reprot. Jim McKinley reported the site selection committee had selected the Adams Hotel in downtown Phoenix, Arizona for the 1985 WSWS meeting the week of March 17.

The new Adams Hotel in downtown Phoenix was found to be an excellent facility with ideal meeting rooms to accomodate the general meeting as well as the breakout sessons. The meeting room facilities are ideal for a group our size, but could not accomodate any other convention of any size at the same time. There are 500 sleeping rooms. Current prices are very competitive.

Sites for the 1983 and 1984 WSWS meetings are as follows: March 8-10, 1983, MGM Grand, Las Vegas, Nevada; March 12-14, 1984, Sheraton, Spokane, Washington.

Nominations Committee: Garry Massey presented the nominations committee report. There were a total of 170 ballots cast is this year's elections. The new WSWS officers for 1981-82 are as follows:

President-elect	J. Wayne Whitworth
Secretary	Robert Callihan
Chairman-elect, Reseasrch Sect.	Harvey Tripple
Chairman-elect, Education and Regulatory Section	Richard Gibson

New Business: Larry Mitich, editor of the WSSA newsletter, would like individuals to send in informational news on themselves or other weed scientists. He also mentioned that thesis reports are published periodically, and procedures for nominating Fellows in the WSSA will be in the July issue of the newsletter.

Necrology: The Executive Committee was informed of the recent passing of two of our colleagues: Dr. Leonard Baver, Director of the Experiment Station of the Hawaiian Sugar Planter's Association, and Mr. Murray Pryor who was retired from the California Department of Agriculture.

L. E. (Jack) Warren turned the business meeting over to the new President, Alex Ogg, Jr., who adjourned the meeting at 9:35 a.m.

Respectfully submitted, Don Thill, Secretary.

FELLOW OF THE WESTERN SOCIETY OF WEED SCIENCE

P. Eugene Heikes and J. Wayne Whitworth were elected Fellows of the Western Society of Weed Science. The announcement was made at the awards banquet Wednesday, March 18, 1981.

P. Eugene Heikes was born February 7, 1921 and raised on a ranch near Great Falls, Montana. He attended Montana State College and graduated with a B.S. in Agricultural Economics in 1949. Later, he returned to Montana State College and graduated with a M.S. in Applied Science in 1959.

Between 1949 and 1961, Gene worked with the Montana Extension Service, serving as Extension Weed Specialist from 1955 until 1961. While at Montana he managed an 80-acre demonstration farm on the heavy problem soils along the Milk River, in a cooperative project with the U.S. Bureau of Reclamation. He organized the Montana Polled Hereford Association and was instumental in organizing the Montana Noxious Weed Association in 1958.

In 1961 Gene began working at Colorado State University as an Extension Weed Specialist. He has held this position for the past 19 years, being involved in Extension, teaching, and applied research.

In 1976 he was awarded the "Professional Excellence Award" by Epsilon Sigma Phi. Gene has been involved in the Western Society of Weed Science for a number of years, serving on several committees and offices, and was President in the 1963-64 term. Other professional involvements include the Weed Science Society of America and the Colorado Agricultural Chemicals Association. He also has served on the editorial committee for "Weeds Today," the Pesticide Advisory Committee, the State Agricultural Commission, and the Advisory Committee to the State Agricultural Stabilization Committee.

J. Wayne Whitworth was born in Brigham City, Utah, May 25, 1923. He attended Weber State College for 1 year, 1941, before entering the United States Army where he was employed for the next 3 years. After returning from the service, he attended Utah State University where he received his B.S. degree in 1950 and his M.S. degree in Weed Control in 1953. He earned his Ph-D degree in Agronomy (Weed Control) at Washington State University in 1961 while on sabbatical leave from New Mexico State University. Wayne has headed-up the weed control research project at New Mexico State University since 1953, and he has taught both graduate and undergraduate courses in Weed Control and Environmental Pollution during the past 28 years. His research activities include the evaluation of herbicides, the effect of sustained use of herbicides on plant communities, and physiological studies on weeds and weed seed. He is a pioneer in the development of weed control practices in guayule, and in 1978 was assigned a leadership role at New Mexico State University on a regional guayule imrovement project.

Wayne has been active on a host of committees at New Mexico State University and in the Western Society of Weed Science. Other professional and honorary societies that he is active in include the Weed Science Society of America, Sigma Xi, Alpha Zeta, and Phi Kappa Phi.

FELLOWS OF WSWS

Robert B. Falcom, 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 M. 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. A. Anliker, 1980	P. Eugene Heikes, 1981
J. Wayne Whitworth, 1981	

HONORARY MEMBERS

Dick Beeler, 1976	Dale H. Bohmont, 1978

EDITORIAL RULES FOR PREPARATION OF PAPERS FOR PUBLICATION IN THE WESTERN SOCIETY OF WEED SCIENCE RESEARCH PROGRESS REPORT

The Research Progress Reports are a photodirect copy of the papers accepted for publication. WSWS will not retype or make typographical corrections on papers submitted for the 1982 WSWS Research Progress Report. It will be the responsibility of each author to submit his paper in ready-for-publication condition following the guidelines outlined below.

The style for the 1982 Research Progress Report will be similar to that used for the 1980 or 1981 Report. As the reports of 1982 will not be retyped, it is essential that reports be typed in the correct style. It is suggested that authors consult the 1981 Research Progress Report and follow the style used therein.

Prepare a typed original copy of your paper as it is to appear in the Research Progress Report. Submit this unfolded original (it is essential that it be flat for "camera-ready" use) copy and one photocopy to the appropriate Section Chairman to arrive no later than December 1st.

Instruction for typing.

1. Type-face and ribbon: Elite type only; Letter Gothic or equivalent preferred (do not use pica or running script). Use carbon ribbon only. Corrections with white opaque or by lift-off tape are acceptable, do not use strike-overs.
2. Paper and margins: Paper should be "offset book, smooth finish, 60 lb." All the text or tabular material must fit within a 6 1/2 x 9 inch space, leaving at least one inch for each margin. Large tables could be photoreduced to leave appropriate margins.
3. Numbering pages: DO NOT TYPE PAGE NUMBERS. Lightly pencil the page numbers in the upper right hand corner of each page.
4. Spacing: Use single spacing throughout the text; type tables using spacing that provides greatest clarity.

Preparation of manuscript.

1. Title: Indent to the fifth place and capitalize only the first letter of the first word. Continuously underline the entire title.
2. Name of Contributor: Begin three spaces after the end of the title. List surname first, then first name or initials of senior author. Second and third contributor should list given name or initials first, then surname (e.g.: Doe, J. Q. and V. P. Smith).
3. Text of Report: Begin three spaces after the author's name. The report should clearly present the objectives of the research, methods and the results with a minimum of discussion. Text exclusive of tables

should not exceed two pages and should be single spaced, including footnotes.

4. Tables: A maximum of two pages is allowed for tabular material, which may be single or double spaces. Titles should be centered, and should not be labeled "Table 1," unless more than one table is used. Several tables may be included on one typewritten page; small tables should be typed on the same page with the text to reduce printing costs. Capitalize only the first letter of the first word in both title and subheadings. Use no periods. Graphs and photos are not acceptable. Be sure your tables leave at least one inch margins on the page.

5. Contributing agency: Three spaces after the last word of the text, briefly list author's affiliation and mailing address (including zip code) in parentheses: e.g., (Weed Research Laboratory, Colorado State University, Fort Collins, CO 80523).

6. Approval: If your agency or institution requires official approval for this type of publication, you will be responsible for obtaining such approval.

7. Index outline: In order to enhance the publishing procedure, as index outline for each paper must be prepared by the author and submitted with the manuscript to the appropriate Project Chairman. The outline will include: Title of paper, author(s), list of herbicides (common and chemical names), list of crops, list of woody plants, list of weeds (common and scientific names). Papers submitted without an index outline will be returned.

8. Nomenclature: Use only the common berbicide names approved by the WSSA which appear on the back cover of Weed Science. If there is no approved common name, use the code number. An appendix table in the final Progress Report will give the equivalent chemical name for all common names and code numbers.
   Herbicide rates: Express all herbicide rates as active ingredient or acid equivalent. Where it is appropriate to mention a specific formulation such as an ester or salt, tell which formulation you used.
   Weed names: Use only the common names designated by WSSA (see Weed Sci. 19:435-476, 1971) in the text. If more than one species of the same genus is included in the report, identify it specifically, if possible, or refer to it as pigweed spp., etc.
   Abbreviations: Use those shown on pages 239 and 240 of the 1978 Research Progress Report; other abbreviations should conform to those acceptable to WSSA.

9. Suggestions: If the following suggestions are observed, it will greatly improve the uniformity of the reports: Use April 29, 1981 (not 4/29/81); 2 to 3 (not 2-3); 2 by 3 (not 2 x 3); 2 inches (not 2"); 2 ft. (not 2'); 10 F (not 10°F); 4 lb ai/A (not 4 lb ai dalapon/A). The symbol ® is not needed. Do not use numbers in report titles. The use of metric units is recommended, but English units are acceptible.

10. Rejection: Any paper submitted to the appropriate Project Chairman which does not conform to the rules and regulations heretofore outlined will be returned to the senior author for revision. The author will be responsible for correcting the manuscript and returning it to the Project Chairman by December 1st.

Membership List of the Western Society of Weed Science - May 15, 1981

Walter W. Abramitis
ARMAK
1315 59th Street
Downers Grove, IL 60516

W. E. Albeke
PPG Industries
16107 S. Wilson Rd
Oregon City, OR 97045

Jack Aldridge
Nor-Am Agric. Products
P.O. Box 13
Caruthers, CA 93609

George A. Algard
Montana Dept. of Agriculture
630 Leslie
Helena, MT 59601

Sayed Ali
FMC Co. B124
P.O. Box 8
Princeton, NJ 08540

Bill Allison
Dow Chemical Company
Drawer H
Walnut Creek, CA 94598

Harold P. Alley
Plant Science Division
University of Wyoming
Laramie, WY 82071

Karen T. Almas
Fremont County Weed & Pest
P.O. Box 445
Lander, WY 82520

James E. Anderson
Mobay
2224 27th Ave. Ct.
Greeley, CO 80631

J. LaMar Anderson
Plant Science Department
Utah State University, UMC 48
Logan, UT 84322

Lars W. J. Anderson
USDA Aquatic Weed Research
Botany Department
University of California
Davis, CA 95616

Ty Anderson, Dist. Supervisor
Blaine County Weed District
P.O. Box 1212
Chinook, MT 59523

W. Powell Anderson
New Mexico State University
Agronomy Department, Box 3Q
Las Cruces, NM 88003

W. L. Anliker
Ciba-Geigy Corp.
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 No. Lindbergh Blvd C35C
St. Louis, MO 63166

Jon H. Arvik
Monsanto Agr. Products Co.
800 N. Lindbergh Blvd.
St. Louis, MO 63166

Floyd M. Ashton
Department of Botany 0900
University of California
Davis, CA 95616

David G. Austin
P. O. Box 3276
Thousand Oaks, CA 91359

Alvin A. Baber
DuPont Company
340 Rosecrans St.
San Diego, CA 92106

Richard W. Bagley
MAAG Agrochemicals
P.O. Box X
Vero Beach, FL 32960

Richard B. Bahme
AgriDevelopment Company
3 Fleetwood Court
Orinda, CA 94563

John L. Baker
Fremont County Weed & Pest
P.O. Box 445
Lander, WY 82520

Laurence O. Baker
Plant & Soil Science Dept.
Montana State University
Bozeman, MT 59717

Robert B. Balcom
4720 44th St. N.W.
Washington, D.C. 20000

Daniel A. Ball
University of California
955 Via Zapata #17
Riverside, CA 92507

Claire L. Barreto
Montana State University
915 D. South Black
Bozeman, MT 59715

Tom Barta
Western Farm Service
P.O. Box 3434
Spokane, WA 99036

Sam N. Bartee
Berkloff Associates, Inc.
Suite 430 34 Corporate Woods
10950 Grandview
Overland Park, KS 66210

Paul G. Bartels
Dept. of Plant Sciences
University of Arizona
Tucson, AZ 85721

Brooks Bauer
Zoecon Corporation
20592 Ayers Ave.
Escalon, CA 95320

Dick Beeler
Agrichemical Age
83 Stevenson Street
San Francisco, CA 94105

Carl Bell
Univ. Calif. Coop. Extension
Court House, 939 Main
El Centro, CA 92243

Wayne S. Belles
Sandoz, Inc.
Rt. 2, Box 284A
Moscow, ID 83843

Randy Benedict
Wilbur-Ellis Company
501 E. Main Street
Imperial, CA 92227

Warren E. Bendixen
University of California
P.O. Box 697
Santa Maria, CA 93454

Larry H. Bennett
Chemonics Industries
P.O. Box 21568
Phoenix, AZ 85036

E. Ray Bigler, Agronomist
Chemonics Industries
P.O. Box 21568
Phoenix, AZ 85036

Dale W. Bohmont
College of Agriculture
University of Nevada
Reno, NV 89507

Edward J. Bowles
Pennwalt Corporation
1630 East Shaw Ave.
Fresno, CA 93710

Raymond J. Boyd
U.S. Forest Service
1221 S. Main Street
Moscow, ID 83843

Ronald G. Brenchley
Mobay Chemical Company
Rt. # 1, Box 31
Ashton, ID 83420

High C. Bringhurst, Jr.
Salt Lake County
1814 W. 6020 South
Salt Lake City, UT 84118

Bart Brinkman
Velsicol Chemical Corp.
5130 2nd Ave. S.E.
Salem, OR 97302

David L. Bruce
Stauffer Chemical Company
220 South Clovis Ave., Apt 240
Fresno, CA 93727

Henry Buckwalter
BASF
5276 S. Country Club Way
Tempe, AZ 85283

Donald J. Bunnell, Jr.
Chem. Applicators. of Houston
P.O. Box 517
Pearland, TX 77581

Lee Burge
1625 California Ave.
Reno, NV 89507

Ronald J. Burr
Rhone-Poulenc Inc.
5835 Basil St. N.E.
Salem, OR 97301

Larry C. Burrill
IPPC, Gilmore Annex
Oregon State University
Corvallis, OR 97331

Les Burrough
Sublett County Weed & Pest
P.O. Box 651
Pinedale, WY 82941

Roger Burtner
Micron Sprayers
P.O. Box 311
Reedley, CA 93654

Jim Burton
Weed Research Laboratory
Colorado State University
Fort Collins, CO 80523

Robert H. Callihan
Plant Science Department
University of Idaho
Moscow, ID 83210

Catherine Calpouzos
American Cyanamic Company
Treetop Apts. #87
Macopin Road
Bloomingdale, NJ 07403

Buddy Camors
Stauffer Chemical Company
P.O. Box 1381
Houston, TX 77001

Chuck Carter
BASF Corporation
1796 Margo Drive
Concord, CA 94519

Richard L. Chase
Plant Science Department
Utah State University UMC 48
Logan, UT 84322

Tom Cheney
University of Idaho
517 East C Street
Moscow. ID 83843

M. Dale Christensen
Ciba-Geigy Corporation
1951 Chateau Ct.
Walnut Creek, CA 94598

M. Brent Chugg
Del Monte Corporation
P.O. Box 9260
Ogden, UT 84409

Donald R. Clark
New Mexico State University
P.O. Box 627
Mesilla, NM 88046

Sharon Clay
University of Idaho
Rt. 1, Box 129, Lot G
Moscow, ID 83843

Robert G. Duncan
Velsicol Chemical Corporation
4902 34th Street, Unit 9-200
Lubbock, TX 79410

Allen Dunlap
Arizona Agrochemical Company
P.O. Box 21537
Phoenix, AZ 85036

Robert Dunlap
Union Carbide Agr. Products
3239 E. Vartikian
Fresno, CA 93710

K. W. Dunster
Union Carbide Agr. Products
P.O. Box 2188
Fremont, CA 94536

John W. Durfee
Union Carbide
P.O. Box 17610
Jacksonville, FL 32216

Tim Dutt
Monsanto Company
1520 E. Shaw Ave. #115
Fresno, CA 93710

Donal P. Dwyer
Nor-Am Agr. Products
4190 North Sherman
Fresno, CA 93726

Bill Dyer
Plant & Soil Science Dept.
Montana State University
Bozeman, MT 59717

Warren Edmonds
FBC Chemicals, Inc.
11230 Wakely Road
Colorado Springs, CO 80908

Kenneth A. Edwards
P.O. Box 3935
Long Beach, CA 90803

Matthew Ehlhardt
American Hoechst
P.O. Box 425
Palouse, WA 99161

Clyde Elmore
Botany Department
University of California
Davis, CA 95616

Don Emenegger
Thompson-Hayward Chem.
1830 N.W. 17th
Corvallis, OR 97330

Barbara Emerson
Union Carbide Agr. Products Co.
Ambler, PA 19002

Lambert C. Erickson
842 East 7th
Moscow, ID 83843

John O. Evans
Plant Science Department
Utah State Univ. UMC 48
Logan, UT 84322

Raymond A. Evans
USDA, AR
920 Valley Road
Reno, NV 89509

Peter Fay
Montana State University
302 North 3rd
Bozeman, MT 59717

Robert D. Fears
Dow Chemical, Ag Products Dept.
P.O. Box 1706
Midland, MI 84640

Volker Fischer
BASF
P.O. Box 758
Dinuba, CA 93618

Lewis L. Flanagan
Ramsey Seed, Inc.
435 Palomino Ct.
Manteca, CA 95336

Donald H. Ford
Lilly Research Laboratories
7521 W. California Ave.
Fresno, CA 93706

John Fortino
Mobay
P.O. Box 4913
Kansas City, MO 64120

R. A. Fosse
Union Carbide Agr. Products
10144 E. French Camp Rd.
Monteca, CA 95336

Gus Foster
Velsicol Chemical Corporation
2809 Redwing Road
Fort Collins, CO 80526

R. Ron Frazier
Nalco Chemical Company
1124 W. Escalon
Fresno, CA 93711

Virgil H. Freed
Dept. Agricultural Chemistry
Oregon State University
Corvallis, OR 97331

Johnnie Frizzell
Pennwalt Corporation
P.O. Box 1911
Montgomery AL 36101

Allen Frost
Monsanto
800 N. Lindbergh Drive
St. Louis, MO 63166

Marvin H. Frost, Jr.
Nor-Am Western Field Station
266 S. Monroe
Fresno, CA 93706

Darlene M. Frye
Monsanto Company
702 South 68th Ave.
Yakima, WA 98908

James M Gaggero
Union Carbide Agr. Products
8276 Canyon Oak Drive
Citrus Heights, CA 95610

John Gallagher
Union Carbide Agr. Products
Brookside Ave.
Ambler, PA 19002

William T. Cobb
Lilly Research Labs
815 S. Kellogg
Kennewick, WA 99336

Donald R. Colbert
American Cyanamid Company
2133 Jackson Street
Lodi, CA 95240

Floyd O. Colbert
Eli Lilly & Company
7521 W. Califonria Ave.
Fresno, CA 93706

Robert W. Colby
Dow Chemical USA
Rt. 1, P.O.Box 1313
Davis, CA 95616

J. Wayne Cole
Univ. of Idaho Extension Serv.
P.O. Box 427
Preston, ID 83263

Don M. Collins
Monsanto Company
800 N. Lindbergh C3SC
St. Louis, MO 63166

Ron Collins
Consulting Entomologist
Route 2, Box 344
Hillsboro, OR 97123

Richard D. Comes
ARS, USDA, P.O. Box 30
Irr. Agric. Res. & Ext. Center
Prosser, WA 99350

Fred Corbus
4633 North 42nd Place
Phoenix, AZ 85018

Garvin Crabtree
Department of Horticulture
Oregon State University
Corvallis, OR 97331

Roe Crabtree
Western Farm Service
P.O. Box 3434
Spokane, WA 99220

Alden S. Crafts
Botany Department
University of California
Davis, CA 95616

Will Crites
Shell Development Company
P.O. Box 241
San Ramon, CA 94583

Cecil H. Crutchfield
Chevron Chemical Company
940 Hensley Street
Richmond, CA 94804

Dave Cudney
Dept. of Botany & Plant Sci.
University of California
Riverside, CA 92521

Randy K. Dahlin
Rohm & Haas
5656 Peachtree Street
Boise, ID 83703

Edwin A. Davis
USDA Forest Service Lab
Arizona State University
Tempe, AZ 85281

Jean H. Dawson
USDA, Irr. Agric. Res. Center
P.O. Box 30
Prosser, WA 99350

Boysie E. Day
Dept. of Plant Pathology
University of California
Berkeley, CA 96720

Mike Day
FBC Chemicals
11364 Peconic Drive
Boise, ID 83709

Delvan W. Dean
932 Singingwood Road
Sacramento CA 95825

Nathan Dechortez
USDA Aquatic Weed Research
Botany Department
University of California
Davis, CA 95616

Donald L. DeLay
Nor-Am Ag. Products, Inc.
35462 Road 150
Visalia, CA 93291

Steven A. Dewey
Oregon State University
3435 N.W. Orchard Ave.
Corvallis, OR 97330

George W. Dickerson
New Mexico State University
1316 Puma Trail
Las Cruces, NM 88001

Jeffrey R. Dickerson
Montana State University
P.O. Box 262
Bozeman, MT 59715

Edward J. Dimock, II
Forestry Sciences Laboratory
3200 Jefferson Way
Corvallis, OR 97331

William W. Donald
USDA Metabalism & Radiation Lat
State University Station
Fargo, ND 58105

Dean Donaldson
Univ. Calif. Extension Serv.
1436 Polk Street
Napa, CA 94558

Joseph E. Dorr
Ciba-Geigy Corporation
925 N. Grand Ave.
Covina, CA 91724

Charles H. Doty
Univ. Arizona Cotton Res. Cent.
4201 East Broadway
Phoenix, AZ 85040

Brian Drew
Crop Science Bldg
University of Saskatchewan
Saskatoon, Saskatchewan
CANADA S7N 0W0

Chuck Duerksen
Stauffer Chemical Company
P.O. Box 248
Orange Grove, CA 93646

Tad H. Gantenbein
John Taylor Fertilizer Co.
P.O. Box 15289
Sacramento, CA 95813

Allen Gardner
Cache County Weed Dept.
P.O. Box C
Logan, UT 84321

Leland Gardner
Jefferson County
Courthouse
Rigby, ID 83442

William B. Gardner
P.O. Box 277
Mecca, CA 92254

Don Gates
3M Company
3M Center, Ag. Chem, 223-6
St. Paul, MN 55101

Jay Gehrett
Velsicol Chemical Company
36 Lenore Street
Walla Walla, WA 99362

Mike Gerhardt
Mobay Chemical Corporation
257 A Woodland Estate
Great Falls, MT 59404

John M. Gibson
8073 Vallejo Road
Boise, ID 83709

Richard Gibson
Univ. Arizona Extension Serv.
820 E. Cottonwood Ln., Bldg C
Casa Grande, AZ 85222

Jess Gilbert
Nevada State Highway Dept.
P.O. Box 930
Reno, NV 89504

Walter L. Gould
Box 3-Q, Agronomy Department
New Mexico State University
Las Cruces, NM 88003

Eugene A. Gruenberg
Wilbur-Ellis Co.
462 Washington Street
Calexico, CA 92231

Steven M. Guckeen
Datamyte
14560 Industrial Rd
Minnetonka, MN 55343

John Guneyli
Upjohn International, Inc.
Ag. Chemicals
Kalamazoo, MI 49001

Murray Gwyer
Stauffer Chemical Company
5-28 Woodrow Pl.
Winnipeg, Manitoba R3G 1J3
Canada

Delane M. Hall
Power County
P.O. Box 121
American Falls, ID 83211

K. C. Hamilton
Department of Plant Sciences
University of Arizona
Tucson, AZ 85721

Jack Handly
University of Idaho
1315 Linda Lane #1
Moscow, ID 83843

Ronald H. Hanson
Union Carbide Agr. Products
8172 Pollard Ave.
Fair Oaks, CA 95628

Ronald Harding
DuPont
20447 Seton Hill Drive
Walnut, CA 91789

W. A. Harvey
University of California
14 Parkside Drive
Davis, CA 95616

Scott Hathorn III
Ciga-Geigy Corp.
P.O. Box 11422
Greensboro, NC 27403

Hans Hayden
Arbon, ID 83212

Stanley Heathman
Plant Sciences Department
University of Arizona
Tucson, AZ 85721

Eugene Heikes
Weed Research Lab.
Colorado State University
Fort Collins, CO 80521

Robert H. Heilmann
Nestle Enterprises, Inc.
Read Road, Route 3
Janesville, WI 53545

James F. Henson
Dept. Botany & Plant Science
University of California
Riverside, CA 92521

John S. Herlihy
Velsicol Chemical
3900 Blackbird
Modesto CA 95356

Robert Higgins
AMS/Oil Dealer
161 Crestview Rd.
Twin Falls, ID 83301

Larry K. Hiller
Hort. Dept., Johnson 149
Washington State University
Pullman WA 99164

Charles B. Hinkley
Agua Tek Corporation
3256 "F" Street
San Diego CA 92102

George F. Hittle
Wyoming Dept. Agriculture
P.O. Box 5001
Cheyenne, WY 82001

F. A. Holmes
DuPont
118 Blueberry Hill
Los Gatos CA 95030

Ralph H. Horne
Utah State Univ. Extension
10 South 200 East
Provo UT 84601

Jime Howe
Arizona Agrochemical
1148 Hereford Ave
Yuma AZ 85364

Don R. Howell
University of Arizona
1047 4th Avenue
Yuma AZ 85364

Neil Humburg
University of Wyoming
P.O. Box 3353, Univ. Station
Laramie, WY 82071

Christine Humy
Mobil Chemical
152 Colby Lane
Boise ID 83706

C. R. Hunt
Monsanto Company
1514 Meadowlark Drive
Great Falls, MT 59404

Clyde J. Hurst
Nat'l Park Service
Dept. Range Science, UMC 52
Utah State University
Logan UT 84322

Chuck Huston
Washington State University
NE 670 Gray Lane #2
Pullman, WA 99163

Robert A. Hyer
Lilly Research Lab
7521 W. California Avenue
Fresno CA 93706

John Jachetta
506 S.W. Adams
Corvallis, OR 97330

Lucinda Jackson
Monsanto Company
800 N. Lindbergy Blvd
St. Louis MO 63166

M. J. Jackson
Montana Extension Agronomist
300 Johnson Hall, M.S.U.
Bozeman MT 59717

Nelroy Jackson
Monsanto Company
1850 S. Belle Avenue
Corona, CA 91720

Arthur O. Jensen
American Cyanamid Company
106 Las Vegas Road
Orinda CA 94563

James I. Jessen
Stauffer Chemical Company
Box 1383
Glendive MT 59330

Glen Johnson
American Cyanamid
2101 W. McNair Street
Chandler AZ 85224

Roy Johnson
Union Carbide Corporation
1727 Butler Pike
Ambler PA 19002

Ivan Blaine Jones
Utah State Univ.Extension
P.O.Box 76
Nephi, UT 84645

Jeff Jones
Velsicol Chemical
5606 S. Hazelton Lane
Tempe AZ 85283

Lowell S. Jordan
Dept. Botany & Plant Science
University of California
Riverside CA 92521

Larry K. Justesen
Carbon County Weed & Pest
P.O. Box 14
Rawlins, WY 82301

Donald L. Kambitsch
Plant and Soil Science
University of Idaho
Moscow ID 83843

J. Philip Keathley
DuPont
2180 Sand Hill Road
Menlo Park CA 94025

Paul E. Keeley
U.S. Cotton Research Station
17053 Shafter Ave.
Shafter CA 93263

Harold M. Kempen
Univ. Calif. Ag. Extension Serv
P.O. Box 2509
Bakersfield CA 93303

George S. Kido
Scotts
3636 Brunell Drive
Oakland CA 94602

Mike Kilpatrick
Univ. Nevada RNR Center
1000 Valley Road
Reno NV 84512

Steven L. Kimball
Monsanto Company
800 N. Linbergh Blvd
St. Louis MO 63166

Gary D. King
Diamond Shamrock Corporation
1066 S. Grand, Apt. E-19
Diamond Bar CA 91765

Michael G. King
Botany Department 0900
University of California
Davis CA 95616

Wayne O. King
Utah State University
RFD Box 14
Garland UT 84312

Mary M. Klein
American Hoechst
P.O. Box 2129
Red Lodge MT 59068

John Koerwer
Union Carbide
1305 McKean Road
Ambler PA 19002

Jim Krall
Dept. Plant, Soil & Water
University of Nevada
Reno NV 89507

Lester B. Kreps
Calif. Dept. of Agriculture
2135 Akard Ave., Rm 8-D
Redding CA 96001

Robert Krueger
Dept of Botany & Plant Sci.
University of California
Riverside CA 92521

Ronald Kukas
BASF
2308 Northridge
Modesto CA 95390

Andizg Kwiatkowski
Plant & Soil Science
Montana State University
Bozeman MT 59715

Harry B. Lagerstedt
USDA-AR, 1034 Cordley Hall
Oregon State University
Corvallis OR 97331

Gale Lamb
Sweetwater Weed & Pest Control
McKinnon WY 82938

Barb Landgraf
Montana State University
37 N. Church
Bozeman MT 59715

Arthur H. Lange
Herb. Research Institute
9400 S. Lac Jac
Reedley CA 93654

John Lanigir
Mobil Chemical Company
4975 E. Butler #139
Fresno CA 93727

John Lauck
Chevron Chemical Company
5910 N. Monroe
Fresno CA 93711

Earl Lee
Lee Equipment Sales
1938 Pride Place
Visalia CA 93277

William O. Lee
USDA, Crop Science Dept.
Oregon State University
Corvallis OR 97331

Stanley K. Lehman
FBC Chemicals, Inc.
5100 N. Sixth, Suite 149
Fresno, CA 93710

Philip W. Leino
University of Idaho
P.O. Box AA
Aberdeen, ID 83210

D. T. Lillie
Rhone Poulenc, Inc.
P.O. Box 5416
Fresno CA 93755

Joan Lish
Plant Science Department
University of Idaho
Moscow, ID 83843

John R. Lowe
Big Horn County Weed & Pest
Basin WY 82410

Al Luke
Union Carbide Corporation
1446 Joseph Street
Idaho Falls ID 83401

Nai-chia Luke
American Cyanamid
P.O. Box 400
Princeton NJ 08540

Earl E. Lukkes
Big Horn Weed & Pest
147 E. Main
Lovell, WY 82431

Rodney G. Lym
North Dakota State University
Agronomy Dept., P.O. Box 5051
Fargo ND 58105

Bert C. Marley
DuPont Company
Star Route, Box 105
McCammon ID 82350

Louis Y. Marquis
USDA/SEA/AR-WR
Irr. Agr. Res. & Ext. Center
Prosser, WA 99350

E. R. Marshall
Soilserv Inc.
P.O. Box 3650
Salinas CA 93912

Manny Martinex
Zoecon Corporation
11816 Sunburst Avenue
Yuma AZ 85364

Garry Massey
3M Company
653 E. Dovewood
Fresno CA 93710

C. Daryl Matlock
Nevada I.D.
P. O. Box 1019
Grass Valley CA 95945

Terry W. Mayberry
Nor-Am Inc.
Rt 1 Box 218
Pendelton OR 97801

Tom McCaffrey
Stauffer Chemical Company
700 N.E. Multnomah
Portland OR 97232

Robert F. McGowan
Hooker Chem. Corp., SCD
P.O. Box 728 345 3rd St.
Niagara Falls NY 14302

W. B. McHenry
Department of Botany
University of California
Davis, CA 95616

James R. McKinley
Union Carbide
1452 N.W. Skyline Drive
Albany OR 97321

John McKissick
Central Calif. Irrigation Dist
1335 West I Street
Los Banos CA 93635

Terry McNabb
Applied Biochemist, Inc.
3250 Quartz Lane C-27
Fullerton CA 92631

Robert J. Meyer
Weed Control Consultant
156 Pasatiempo Drive
Bakersfield CA 93305

Thomas J. McNabb
American Lake & Canal
1037 Second St./Suite 12
Lafayette CA 94549

C. David McNeal
Univ. of Idaho Coop. Ext.
1330 Filer Avenue
Twin Falls ID 83301

Robert M. Menges
USDA, SEA, AR
P.O. Box 267
Weslaco TX 78596

Raymond W. Meyer
Wash. State Univ. Extension
Rt. 3, Box 85C
Moscow ID 83843

Reao H. Mickelson
Caribou County Weed Control
P.O. Box 638
Soda Springs ID 83276

Micron Corporation
P.O. Box 19698
Houston, TX 77024

John H. Miller
USDA
U.S. Cotton Research Station
Shafter CA 93263

Timothy L. Miller
University of Idaho
Plant Science Dept. 314A
Moscow ID 83843

Larry W. Mitich
Botany Department
University of Calfironia
Davis CA 95616

Bill Moore
Pennwalt Corp.
210 Valencia Shores Drive
Winter Garden FL 32787

Janet L. Moore
Ciba-Geigy
3007 Charing Cross
Moorhead, MN 56560

Don W. Morishita
Dept. Plant & Soil Science
University of Idaho
Moscow ID 83843

Sud Morishita
Bonneville County Weed Control
605 N. Capital
Idaho Falls ID 83401

Larry Morrow
Agron. & Soil Dept.,
215 Johnson Hall
Washington State University
Pullman WA 99164

Howard L. Morton
USDA, SEA, AR
2000 E. Allen Road
Tucson AZ 85719

W. R. Mullison
The Dow Chemical Company
P.O. Box 1706, Agr. Prod. Dept
Midland, MI 48540

Glen A. Mundt
American Hoechst
Rt #1, Northwood Drive
Genoa IL 60135

Tom Neidlinger
Tohm & Haas Company
13016 N.E. Pacific Court
Portland OR 92730

Dick Neilson
PPG Industries, Inc.
2852 Viehas View Place
Alpine CA 92001

J. E. Nel
Counsellor (Agric.-Sci.)
Embassy of South Africa S.350
4801 Massachusetts Ave, NW
Washington DC 20016

Marlyn J. Nelson
Bingham County
P. O. Box 583
Blackfoot ID 83221

Randi Nelson
Ciba-Geigy
1817 E. Grand #29
Escondido CA 92027

David F. Nichols
Occidental Chemical Company
2712 Stoneridge Drive
Modesto CA 95355

Richard S. Nielsen
American Cyanamid Co.
1140 W. Escalon
Fresno CA 93611

Wesley O. Noel
Velsicol Chemical Corp.
2000 Hillside Lane
Bozeman MT 58715

Robert F. Norris
Botany Department
University of California
Davis CA 95616

J. R. Offutt
Lower Tule River Irr. Dist.
P. O. Box 511
Woodville CA 92357

Alex Ogg, Jr.
USDA, SEA, AR
IAREC Box 30
Prosser WA 99350

Paul J. Ogg
American Cyanamid
3619 Mountain View
Longmont CO 80501

Tom R. O'Hare
American Cyanamid Company
P.O. Box 4004
Pocatello ID 83201

G. Ron Oliver
Ag Specialty Services
3495 S. Maple Ave.
Fresno, CA 93725

Ben Oller
Mobay #152
1900 N. Gateway Blvd. Suite
Fresno CA 93727

H. C. Olson
DuPont
2180 Sand Hill Road
Menlo Park, CA 94025

Phil Olson
American Hoechst
E 2655 Prarie Avenue
Post Falls ID 83854

A. Omid
Chevron Chemical Company
940 Hensley Street
Richmond, CA 94804

Oregon Department of Agric.
Commodity Inspection Division
Noxious Weed Control Program
Agriculture Building
Salem OR 93710

John E. Orr
BASF Corporation
P.O. Box 7562
Boise, ID 83707

Charles E. Osgood
Diamond Shamrock Corporation
11134 Chickadee Drive
Boise ID 83709

Karen Wagner Ott
Stauffer Chemical Company
P.O. Box 760
Mt. View CA 94042

Robert I. Papendick
USDA/SEA-AR
215 Johnson Hall, Wash. S.U.
Pullman, WA 99164

Bob Park
DuPont Company, Biochem Dept.
Market St.
Wilmington DE 19898

Deane W. Parker
Agricultural Products/3M
223-6SE-04 3M Center
St. Paul MN 55144

Karl G. Parker
Fordom
281 Steward Hill Drive
Logan UT 84321

Robert Parker
Washington State Universiyt
IAREC Box 30
Prosser WA 99350

Sharon Parker
Moyer Chemical Company
P.O. Box 945
San Jose CA 95108

Warren Passey
Bear Lake County Weed Control
P. O. Box 218
Paris ID 83261

Dwight V. Peabody
N.W. Wash. Research & Ext. Unit
1468 Memorial Hwy.
Mt. Vernon WA 98273

Richard Pocock
Mobay
Rt. #1
Sugar City ID 83448

P. L. Pontoriero
Shell Development Company
2401 Crow Canyon Rd
San Ramon CA 94583

C. L. Prochnow
Stauffer Chemical Company
11509 N.E. 3rd Avenue
Vancouver WA 98665

Joe Purchase
Elanco Products Company
P.O. Box 1675
Bellevue WA 98009

Mickey Qualls
Stauffer Chemical Company
374 Dodson Rd
Ephrata WA 98823

Jim Quinn
Elanco Products Company
Indianapolis IN 46032

Steve Radosevick
Botany Department
University of California
Davis, CA 95616

Dan W. Ragsdale
Zoecon
975 California Ave
Palo Alto CA 94304

Si Ragsdale
Velsicol Chemical Corporation
3018 Adrienne Drive
College Station TX 77840

Patrick L. Rardon
Montana State University
Experiment Station
Moccasin MT 59462

Thomas A. Reeve
U.S.U. Extension Service
Courthouse Room 201
Manti UT 84642

Howard Rhoads
Calif. Poly State Univ.
962 West Street
San Luis Obispo, CA 93401

William D. Richards
Pacific Coast Nursery
Rt. 1, Box 320
Portland OR 97231

Richard S. Riddle
Stauffer Chemical Company
3729 Oak Ridge Crive
Yuba City CA 95991

James D. Riggleman
DuPont Biochem Dept.
Wilmington, DE 19898

Raymond W. Rinder
S.D. County Dept of Agric.
5555 Overland Ave, Bldg 3
San Diego CA 92123

Paul M. Ritty
Dow Chemical U.S.A.
10890 Benson Drive
Shawnee Mission, KS 66210

Don Robinson
Eli Lilly & Company
7521 West California Avenue
Fresno CA 93710

Laren R. Robison
Agronomy & Horticulture Dept.
275 WIDB
Brigham Young University
Provo UT 83601

James E. Rodebush
Stauffer Chemical Company
P.O. Box 7222
Omaha NB 68107

Linda Romander
Agrichemical Age
83 Stevenson Street
San Francisco CA 94105

Jack D. Root
ICI Americas, Inc.
6900 E. Camelback Rd, Suite 930
Scottsdale AZ 85251

Ed Rose
Stauffer Chemical Company
12150 E. Kings Canyon Rd
Sanger CA 93657

Janet Rose
USDA-Water Management Research
12150 E. Kings Canyon Rd.
Sanger CA 93657

Eugene Ross
Idaho State Dept. of Agric.
P.O. Box 790
Boise ID 83642

Robert C. Russell
Dept. Botany & Plant Sci.
University of California
Riverside CA 92521

Louis Russo
Sandoz, Inc.
1610 W. Sierra Ave.
Fresno CA 93711

George F. Ryan
Washington State University
West. Wash. Res. & Ext. Center
Puyallup WA 98371

Donald J. Rydrych
Pendleton Exp. Station
P.O. Box 370
Pendleton OR 97801

Joseph N. Sagaser
Mobay Chemical Corporation
6197 N. Millbrook Avenue
Fresno CA 93710

John L. Saladini
DuPont Company
276 B South Monaco Parkway
Denver CO 80224

John F. Saylor
Stauffer Chemical Company
Nyala Farm Road
Westport CT 06880

James M Schell
Mobay Chemical Corporation
7140 S.W. Fir Loop, Suite 110
Portland, OR 97223

Robert H. Schieferstein
Shell Development Company
7846 South Centaur Drive
Evergreen, CO 80439

Walter A. Schlabes
1410 Clara Lane
Davis, CA 95616

John T. Schlesselman
Rohm & Haas Company
726 E. Kip Patrick Drive
Reedley CA 93654

R. A. Schnackenberg
Agri-Turf Supplies, Inc.
P.O. Box 4248
Santa Barbara CA 93103

Russ Schneider
Monsanto Company
9475 E. Hampden Ave, Suite 420
Denver CO 80231

Wayne Schumacher
Dept. Plant & Soil Science
University of Idaho
Moscow ID 83843

Thomas K. Schwartz
Union Carbide Agr. Products
1277 North 18th
Laramie, WY 82071

Richard A. Schwartzbeck 301
Farmland Industries
P.O. Box 7305
Kansas City MO 64116

Edward E. Schweizer
USDA/SEA Crops Res. Lab.
Colorado State University
Fort Collins CO 80523

Beverly Seder
Montana State University
1206 South 6th
Bozeman MT 59715

Clay Shelton
Stauffer Chemical Company
700 N.E. Multnomah
Portland OR 97232

David A. Shields
BASF
P.O. Box 758
Dinuba CA 93618

Edwin E. Sieckert
Monsanto Company
601 University Ave Suite 266
Sacramento CA 95824

H. G. Simkover
Shell Development Company
P.O. Box 4248
Modesto CA 95352

Ralph Simnacher
Sweetwater County Weed & Pest
P.O. Box 73
Farson WY 82932

Siriwardana G.
Weed Research Lab
Colorado State University
Fort Collins CA 80523

Siskiyou County
Department of Agriculture
525 S. Foothill Drive
Yreka, CA 96097

Paul Skinner
U.S. Forest Service
240 W. Prospect
Fort Collins, CO 80523

Fred A. Smith
American Cyanamid Company
1232 W. Palo Verde Drive
Phoenix, AZ 85013

Jerry D. Smith
California Dept. Food & Agric.
1220 N Street, Rm A557
Sacramento CA 95814

Leslie W. Sonder
California Dept. Food & Agric.
1220 N Street
Sacramento CA 95814

Veldon M. Sorensen
Monsanto Company
430 Jade Circle
Kimberly ID 83341

Paul Sprankle
Monsanto Company
800 N. Lindbergh Blvd
St. Louis MO 63166

Bob Stanford
Western AG-Visory Company
350 Mesquite
Yuma AZ 85364

Charles E. Stanger
Malheur Exp. Station, OSU
Rt. 1, Box 620
Ontario OR 97914

Sam Stedman
Univ. Arizona Extension Serv.
1320 N. Arbor
Casa Grande AZ 85222

Vern R. Stewart
N.W. Montana Agr. Res. Center
1570 Montana 35
Kalispell MT 59901

Loyd L. Stitt
Field Seed Mgt.
1085 Johnson Place
Reno NV 89509

Diane E. Stott
Dept. Soil & Environmental Sci
University of California
Riverside CA 92521

Harry Strang
Mobay Chemical Corporation
P.O. Box 4913
Kansas City MO 64120

Dean G. Swan
173 Jsn Hall, Coop. Ext.
Washington State University
Pullman, WA 99164

Fred R. Taylor
PPG Industries
12920 Fillmore Ct.
Northglenn CO 80241

Fred E. Temby
Pennwalt Corporation
2678 W. Browning
Fresno CA 93711

Carlyle R. Tennis
U.S. Water & Power Resources
2800 Cottage Way
Sacramento CA 95821

Donald C. Thill
Dept. Plant & Soil Science
University of Idaho
Moscow ID 83843

Larry G. Thompson
Eli Lilly & Company
7521 W. California Ave.
Fresno CA 93706

W. T. Thomson
Monterey Chemical Company
1118 W. Stuart
Fresno CA 93711

Bruce Thornton
1507 Peterson
Fort Collins, CO 80521

Tom Threewitt
Ciba-Geigy Corporation
R.R. 1
Larned KS 67550

Robert J. Thullen
U.S. Cotton Research Station
17053 Shafter Avenue
Shafter CA 93263

F. L. Timmons
1047 North Caribe
Tucson AZ 85710

D. C. Tingey
653 East 400 North
Logan, UT 84321

Lee Torgerson
Electro/General Corp.
14960 Industrial Road
Minnetonka MN 55343

Dan Toya
Stauffer Chemical Company
Route 2, Box 187 A
Blackfoot ID 83221

Harvey D. Tripple
Monsanto Company
Dayton East Office Bldg
9745 E. Hampton Ave, Suite 420
Denver CO 80121

Susie Trulson
Bannock County Weed Control
1121 South 2nd
Pocatello ID 83201

Neal Tuft
Uinta County Weed Dist.
Box 825
Evanston WY 82930

Stuart W. Turner
Stuart W. Turner & Company
P.O. Box 10539
Bainbridge Island, WA 98110

Eric L. Ummel
Sandoz, Inc.
480 Del Rio South
San Diego CA 92108

Union Carbide Agr. Products Co.
Product Development Library
300 Brookside Avenue
Ambler PA 19002

Ramon Uranga
Monsanto Company
2677 16th Place
Yuma AZ 85364

Joe Vandepeute
Rhone-Poulenc, Inc.
2729 Green Bay Way
Sacramento CA 95826

Lee Van Deren
Union Carbide Agr. Products
P.O. Box 877
Carpinteria CA 93013

Richard A. Van Deusen
Flag Farm Consultants
Rt 1
Wilder ID 83676

Tim C. Vargas
Stauffer Chemical Company
Rt 1
Jerome ID 83338

Ron Vore
University of Wyoming
Box 3354, Univ. Station
Laramie WY 82071

John D. Walker
Farm Crops Department
Ricks College
Rexburg ID 83440

Jack Warren
Mobay Chemical Corporation
P.O. Box 97
Beavercreek OR 97004

L. E. Warren
Dow Chemical Company
Rt 1, Box 1313
Davis CA 95616

Robert P. Watwood
Mobay Chemical Corporation
65 Paseo Hermoso
Salinas CA 93908

Mark B. Weed
DuPont Company
2417 Shellpot Drive
Wilmington DE 19803

Drew Wenner
American Hoechst Corporation
W. 5542 Pacific Park Drive
Spokane WA 99208

Georgina M. Werner
Union Carbide Agr. Products Co
P.O. Box 416
Clayton NC 27520

Doug West
PPG Industries, Inc.
2033 "F" Street #311
Davis CA 95616

Louis Whitendale
ICI Americas Inc.
498 North Mariposa Avenue
Visalia CA 93277

Ralph E. Whitesides
Crop Science Department
Oregon State University
Corvallis OR 97331

Fred Whiting
Calif. Dept. Food & Agric.
1220 N Street
Sacramento CA 95814

J. Wayne Whitworth
New Mexico State University
P.O. Box 3 Q
Las Cruces NM 88003

James A. Wilkerson
Thompson-Hayward Chem. Co.
P.O. Box 3530
Visalia CA 93278

Ray William
Extension, Horticulture Dept.
Oregon State University
Corvallis OR 97331

M. Coburn Williams
USDA/SEA, Biology Dept.
Utah State Univ, UMC 45
Logan UT 84322

Roger W. Willemsen
Lilly Research Labs
7521 W. California Ave.
Fresno CA 93706

Linda L. Willitts
ICI Americas Inc.
498 N. Mariposa
Visalia CA 93277

Mark E. Winkle
Monsanto Company
E. 12929 Sprague Suite 3
Spokane WA 99216

Ray R. Winter
Stauffer Chemical Company
P.O. Box 760
Mt. View CA 94042

Lawrence E. Wittsell
Shell Development Company
P.O. Box 4248
Modesto CA 95352

Richard Yeo
USDA, Botany Department
University of California
Davis CA 95616

Alvin L. Young, USAF
520 A Magnolia
Maxwell AFB
Montgomery AL 36113

Stanford A. Young
Plant Science Department
Utah State University UMC 48
Logan UT 84322

Robert L. Zimdahl
Weed Research Lab
Colorado State University
Fort Collins CO 80523

William C. Zschoche
Monsanto Company
3717 GlennView Ct.
Modesto CA 95355

Bert L. Bohmont
Ext., 127 Shepardson Bldg
Colorado State University
Fort Collins CO 80523