

H. M. Hull

Proceedings SIXTEENTH WESTERN WEED CONTROL CONFERENCE



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OFFICERS OF THE WESTERN WEED CONTROL CONFERENCE

Sixteenth (1958)

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Seventeenth (1960)

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PREFACE

The Proceedings of the Sixteenth Western Weed Control Conference is a record of the papers and reports presented at the 1958 Conference in Spokane, Washington, March 18-20, 1958. Copies of this Proceedings are available at \$2.00 per copy from Eugene Heikes, Secretary-Treasurer, Western Weed Control Conference, Extension Weed Specialist, Bozeman, Montana. A Research Progress Report published by the Western Weed Control Conference is also available at \$2.00 per copy from the same address.

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PROFITS FROM WEED CONTROL RESEARCH

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Riverside, California

I was asked to talk to you on the subject of "Profits from Research". Your chairman asked me to try to pin this subject down in some way and avoid talking in vague generalities as much as possible. As a point of approach I thought it might be best to see how the dictionary defines the words "profits" and "research". "Profit" is defined in a monetary sense as the "excess of income over expenditure" in a particular transaction. It is also defined as "to be of use or advantage", "to benefit", and "to give progress". The word "research" is defined as "diligent and systematic inquiry or investigation into a subject in order to discover facts or principles". Thus it seems I can remain within my title if I discuss any sort of benefit in the field of weed control that derives from studious inquiry.

I shall base my discussion on benefits obtained from research in our area--the eleven western states. It is obvious that these benefits do not all, or even in the most part, come from research carried out in the western area. Many of our improved methods stem directly from research done in other parts of the United States and in foreign countries, for research in weed control as in most other fields of scientific endeavor, is truly a worldwide cooperative enterprise. On the other hand the findings by research workers in our conference area are beneficial to persons in other parts of the world. Therefore, if we assume that we are doing our fair and proportionate share of research work in weed control, then we should be able to make a valid assessment of the profits from research within our own area.

Usually we gather at these conferences to enumerate and discuss the many unsolved problems that confront us in weed control. These problems are so numerous and difficult that I am sure many of us go away with the discouraging feeling that all we have is problems and no solutions to problems. As a matter of fact, as we look back over the years, we find that research has solved many problems in weed control. I do not propose that we have obtained the ultimate solution to any problem, that is, a solution that cannot be improved upon. To accept such a point of view would be to close the door on further progress. But, we have developed solutions--important and valuable solutions--solutions that are in everyday use in weed control.

For example, wheat is the most extensively-grown crop in the eleven western states--some twelve million acres being devoted to its production. Currently about 70 percent of this acreage is treated annually with 2,4-D for control of weeds. Estimates of the net dollar profit accruing to growers in the various areas range from \$1.50 to \$10.00 per acre. Using \$5.00 per acre as an average net profit from treatment it appears that the income from this crop is enhanced by approximately \$40,000,000 annually in the eleven western states. 2,4-D is a product of research, correspondingly this savings to the wheat grower is a profit from research.

I recently asked a number of my colleagues in research and extension throughout the Western Weed Conference area to fill out a comprehensive questionnaire on the extent of use and economic benefits obtained from modern herbicides in their several states and areas. These workers were asked to state the kind of herbicide treatments, the savings accruing to the user, and the percentage of the acreage of each individual crop treated. Further information was gathered from official publications of the various states. I have used these estimates and statistics in an attempt to draw an over-all picture of the extent of use and economic advantage obtained from modern weed control methods in the eleven western states. I wish to point out that these figures in most cases are not carefully documented statistics but should be classed as "educated guesses". In a court of law these might be called "expert opinion." Not being an economist I have not felt compelled to use refined methods in assessing the accuracy of the figures or in drawing conclusions from them. Thus unencumbered by the actual information and unrestricted by training or experience in such matters I feel free to tell you how much money agriculture and industry is saving each year through weed control methods developed by research in recent years.

As I have told you before wheat farmers save about \$40,000,000 by treating 70 percent of their acreage with 2,4-D. With the other small grains, some 40 percent of the oat acreage, 50 to 60 percent of barley, and about 25 percent of rice, is treated. Growers of these crops are estimated to save, respectively, on the order of \$6,000,000; \$18,000,000; and \$1,300,000 per year. The questionnaire and other figures indicate that about 80 percent of the flax acreage in the West is treated with one or more herbicides each year. Dinitro, MCP, 2,4-D, and IPC are used. Estimates of savings through the use of these chemicals run as high as \$40 per acre. Using a conservative basis of \$20. per acre the net profit to flax growers in the West amounts to about \$3,000,000.

Perhaps only five percent of the acreage of dried field peas is treated with herbicide. The saving to the growers amounts to about \$150,000 per year. Nearly all of the acreage of green peas in the northwestern area is treated with either dinitro or IPC. A lower proportion of acreage is treated in other western areas. The annual saving from this source amounts to about \$8,000,000.

The acreage devoted to hay production is second only to wheat acreage in the western states. Between five and ten percent of this acreage is treated each year for a net savings of approximately \$5 per acre and a total profit of \$4,000,000. Treatment of about five percent of the acreage in grain sorghums accounts for a profit of about \$1,300,000. Herbicide applications are made to approximately ten percent of the sugar beet acreage for a net profit of about \$10 per acre amounting to over \$6,000,000. Potato growers do not make extensive use of herbicides. Approximately three percent of the potato acreage was treated chemically for weed control last year for a net saving of \$300,000.

About 50 percent of the acreage of subtropical fruits was treated with herbicides in 1957 for a net reduction in production cost of about \$15 per acre amounting to a \$2,000,000 increase in income to this industry. Carrots are almost universally treated with selective oil although the use of herbicides in other vegetable crops is not extensive at present, amount-

ing to less than five percent of western acreage. I was surprised to find that my panel of experts estimated that only about 40 percent of the strawberry acreage was treated with herbicide; however, it was the opinion of the persons reporting that the net profit generally obtained from the chemical weeding of strawberries amounts to about \$60 per acre. About five percent of the cotton acreage is treated with herbicides for a net return of \$5 to \$10 per acre.

I was unable to find any reasonable basis for estimating the acreage and economic value of herbicide use in range weed control for the entire conference area. This is understandable when we consider the wide variation in climate and vegetation. In California slightly over a million acres of brush has been burned as a range improvement measure in the last ten years. About 40 percent of this acreage has had follow-up treatment with chemicals and a similar percentage has been seeded. The total cost of burning, chemical treatment, and seeding amounts to \$15 to \$20 per acre. Where burning alone is sufficient the cost is somewhat under \$5 per acre. Most of the range land subjected to this kind of reclamation produces about 40 pounds of beef per acre per year as compared to a production of 10 to 20 pounds prior to treatment. The net increase of 20 to 30 pounds of beef per year has a market value of \$4 to \$6. Since the treatment remains effective for ten or more years it is evident that range improvement of this sort can return from 20 percent to 100 percent per year on the investment over a period of many years.

Most of us who work with agricultural weed control do not fully realize the magnitude of the weed problem encountered by industry. Although I can find no reliable figures or even good estimates of the total consumption of herbicides by industry, it is clear that this use of chemical weed killers is substantial. There are advantages to industrial weed control that are difficult to evaluate on a strictly monetary basis. For example, what is it worth to a company to have a weed-free parking lot, working area, or storage yard? This can result in improved customer relations and employee morale, as well as generally more efficient operation that would be difficult to evaluate in dollars and cents. For example, I do not see how we can assign a monetary value for the beautification of our highways that can be obtained by proper vegetation control. (Otherwise, unsightly weed growth keeps us from seeing the layer of beer cans.) In most cases a well-planned and executed program of weed control on industrial sites is reflected in direct economic benefits. For example, reduction in fire hazard through weed control can result in reduced insurance rates to the company.

For a specific example, let us take the railroads. It is sound economy to keep roadbeds free of weeds and control vegetation around timber trestles, buildings, telegraph poles, switches, and in yards and around loading installations. If weeds are allowed to grow in the roadbed they serve to collect wind-borne dust and debris in the ballast; also as weeds mature and die organic material is continually being incorporated into the ballast. Accumulation of this debris causes a condition called "fouled ballast". This impairs drainage which in turn causes a spongy roadbed making it necessary to put a "slow order" on the affected section of track. This means that fewer trains can be operated, these giving slower service. The accumulation of soil and organic material in the ballast creates a condition increasingly suitable for further plant growth. The impaired

drainage and moist vegetation create conditions conducive to the rotting of ties and the corrosion of rails and tie plates. Dry vegetation accumulates becoming a fire hazard to trestles, communication facilities, and adjacent property. In addition to the direct losses from such fires, service is interrupted causing operational delays and further economic losses.

A mile of mainline track on a class I railroad requires an initial investment of \$50,000 to \$75,000. To clean and replace fouled ballast costs approximately \$4,000 to \$5,000 per mile. Without proper weed control this expense becomes necessary every four to ten years depending upon local conditions. The cost of herbicide treatment varies from \$20 to \$200 per two-acre track mile. The degree of weed control and residual activity of the herbicides is usually directly related to the cost. Contact sprays cost approximately \$20 per mile and this treatment may be made two to four times per year totaling \$40 to \$80 per mile. If a relatively permanent type of soil sterilant is used the cost is about \$200 per mile. Perhaps four such treatments would be necessary over a ten-year period, or possibly one treatment may be applied initially followed by several lighter, replenishing treatments at a cost of about \$100 each. Again the total cost amounts to about \$80 per year or \$800 over a ten-year period. Obviously, this cost compares very favorable with the alternative of cleaning and replacing the ballast every ten years requiring an expenditure of \$4,000 to \$5,000 per mile.

The old method of controlling weeds around timber trestles by hand cutting costs about \$1.75 to \$2.50 per lineal foot of bridge. This includes cutting and removing the vegetation under the trestle far enough on either side to eliminate the fire hazard. By employing soil sterilants this cost has been reduced to approximately 10¢ to 15¢ per lineal foot of bridge. This cost differential of 10- to 25-fold can probably be generally applied to compare the economic benefits of soil sterilants with hand methods at industrial sites.

There are about 40,000 miles of railroad in the eleven western states. It is estimated that 90 percent of this trackage is treated with herbicides. If the cost estimates previously mentioned are approximately correct railroads in the Western Weed Conference area spend about \$3,000,000 annually for weed control and profit by this expenditure to the extent of four to five times this amount.

Although there are a great deal more miles of highway than railroad in the West it appears that weed control measures are applied along the highways less uniformly and less rigorously than on the railroads. Nevertheless, if we include the highways, utilities lines, and industrial sites, I should think that an annual expenditure of \$10,000,000 would be a conservative estimate for money spent on weed control by these other industrial applications. Perhaps also we might include weed control in irrigation, drainage, and flood control systems in this same category of industrial weed control. However, few cost figures are available in these areas.

In answer to my questionnaire I received forty estimates on the costs of modern weed control methods as compared to the savings made over methods formerly used, if any. I averaged the ratios of all of these figures and found that on the average for every dollar spent on the purchase and

application of modern herbicides the grower gets a return of \$3.90 for his expenditure. This gives him a net profit of \$2.90 on every dollar that he invests in the products of weed control research. This is a direct profit from research. I ask you, where else can the investor secure such a return on his money?

My overall estimate for agriculture and industry in the eleven western states comes to \$130,000,000 annual net savings that derive directly from the use of weed control methods developed by research within the last 15 years. Perhaps this profit has amounted to \$700,000,000 over the past 10 years. I think that the various weed-control research budgets for the eleven western states during this period including work done by the universities, governmental agencies, and the chemical industry has amounted to no more than \$7,000,000--or at most one percent of the benefits derived from work.

Although the figures I have given you are speculative and represent at best only orders of magnitude, it nevertheless appears that research has repaid its investment on the order of one hundredfold. There is no reason to believe that research in weed control cannot be equally productive in the future.

I wish to give thanks to my friends and colleagues for supplying most of the figures and other information given.

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PROFITS FROM EXTENSION WEED CONTROL

E. P. Sylwester, Extension Weed Specialist
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First of all I want to thank all of you, especially your program planning committee for inviting me to speak at your conference. In point of time, this conference is the senior member of the 4 regional weed control conferences now in existence. It is indeed remarkable to pause and reflect as to how far we have come in the entire realm of weed control in research in extension, in regulatory and industrial aspects. Again I'm grateful to you to be able to participate in this conference. Thank you for your kind invitation. It's nice to be wanted and invited.

The title, "Profits From Extension Weed Control" which has been assigned to me as the subject for this talk has made it necessary for me to compile some material, which I know I would not have taken time to assemble, had it not been for this assignment. All educational insitutions have essentially three responsibilities; resident teaching, research, and extension. The same essentially applies to industrial concerns. They must teach their employees the know how that goes with the job, they must continually seek to improve their product and methods of production, and they must advertise or extend their knowledge and sell their product, if they are to succeed and survive. The most astounding discovery in any field of endeavor is more or less useless unless its value is explained, and its use put into practice for the welfare of the individual, and mankind. The greatest

discovery is of no use for the betterment of humanity unless it is put into active use. It is true that some of these discoveries may have no immediate or practical aspect. Many discoveries often remain laboratory curiosities unless someone can foresee their usefulness for society. All of us can name examples. But just as bad, as not extending the usefulness of a material or discovery is the art of extending it to fast, before all facts and facts of its use have been thoroughly tested. In our research, extension, regulatory, and industrial work all of us have the responsibility of acting as "balance wheels", not going overboard on certain things, yet being sure that the worthwhile things are properly emphasized. In our dealings with the public, there is much work that should be relegated to the area of science for the sake of science, but such discoveries are valuable building stones for future endeavor.

Lets look at Extension weed control work, first of all from the monetary profit angle. Better weed control, cultural and chemical. is reflected in more efficient farming, greater production, and consequently greater profit. This in short is reflected in a higher standard of living. We could compile figures as to how much the use of chemicals, all chemicals, for weed control, in all areas, has increased. Such a compilation would tell only a part of the story, because right along with that increased use of chemicals has come better cultural "know how", in weed control, better stewardship of the land, more effective use of competitive and smother crops, more agricultural readjustment. So we must look at the entire picture of good conscientious weed control.

We have in Iowa slightly less than 35,000,000 acres of agricultural land.

Let's take corn. In Iowa that is our basic crop. It's important in other states too. We had last year 10,168,000 acres of corn with a 60.5 bushel average and a total production of 615,164,000 bushels. About $\frac{1}{4}$ of that corn was sprayed for the control of weeds. If we take the minimum figures for average weed losses which we know exist in Iowa, and this is 5%, such spraying could conceivably have increased production by at least 689,550 bushels. In addition you get increased yields from cultural weed control. Those are minimum figures. Yet only our best farmers are using better chemicals and better cultural weed control, the "innovators", the modern, up to date farmers, actually the ones who have the least need for it. If the poorer operators would adopt these practices, the increased yields would be even more stupendous. Even 2-3/4 million bushels increased yield, at \$1.00 per bushel means a lot of music lessons, refrigerators, new clothes and a better standard of living, had all of them sprayed to receive minimum increases.

Let's take our next biggest crop, oats, with 5,234,000 acres, 41 bushels per acre average yield, with a total production 217,252,000 bushels, Good crop rotation and spraying for the control of broadleaved weeds in oats enables us to raise the crop free of broadleaved weeds. About $\frac{1}{4}$ of our oat average is sprayed every year. By eliminating the minimum 5% loss we could conceivably estimate that oat production has gone up 2,715,650 bushels due to spraying for the control of broadleaved weeds. Again only the best farmers use it, the ones that need it the least. The results would again be much more astounding if the poorer operators used it, and if all of them used more of it. Again this increased production, means a higher standard of living.

Let's take soybeans. We have 2,792,000 acres with an average yield of 26 bushels per acre or a total production of 72,592,000 bushels. We advocate some pre-emergent spraying on critical areas, we advocate no post emergence spraying. But we emphasize good cultural weed control. Again if we take the minimum weed loss of 5%, we are positive that increased stewardship of the land and better cultural, supplemented by better chemical weed control in the critical areas has resulted in 907,400 increased bushels. This transformed into money at \$2.00 per bushel means a very minimum of \$1,814,800 for an increased standard of living. Again this was harvested by the more aggressive and better farmers.

If we take flax the story is much the same. We don't raise very much flax. It is notoriously a poor weed competitor. We raise only 14,000 acres of flax with an average yield of 13.5 bushels and a total yield of 189,000 bushels. But about $\frac{1}{2}$ of this is sprayed, and good cultural weed control is practiced on at least half the area. By experience we know that Iowa farmers take a two bushel per acre average loss on flax because of weeds. Thus conceivably on $\frac{1}{2}$ the area, good weed control has resulted in 14,000 bushels increase due to weed control, again harvested by the best farmers.

Let's take pastures. We have about 9,000,000 acres in rotation and permanent pastures. Due to presence of legumes, weed control in rotation pasture land is not too serious and is done entirely by cultural practices. We have however about 6,000,000 acres of permanent blue grass pasture land. All of it needs fertilization in addition to weed control. About 4,000,000 of the 6,000,000 acres need spraying for the control of ragweed, ironweed, goldenrod, Vervain, whorled milkweed etc. We know experimentally that carrying capacity can be increased by 1/3 by a good weed control program. Farmers will pay around 10.00 per acre for good clean bluegrass pasture, but only half that much for poor pasture. If it's worth that on a rental basis, it is worth that much to the owner for pasturage. A \$5.00 per acre loss on 4,000,000 acres means decreased carrying capacity, and a monetary loss of \$20,000,000 a year. This loss is suffered primarily by farmers who would benefit much by good weed control and increased carrying capacity in pastures. In fact, it is primarily borne by those least able to afford it.

Now lets take brush control specifically under Northwestern Bell Telephone lines in Iowa. Brush control under those lines has progressed to the point, where only annual "policing" action is necessary. Service dependability has increased to the point where dial phones are being installed on rural lines, an impossible thing 10 years ago because of brush under lines interfering with dial impulses. From Ted Sullivan, former outside plant manager of the N.W. Bell Telephone Company in Iowa (now retired) comes this statement.

"There are about 18,000 route miles of pole line carrying wires, cables, or both. This breaks down to 8,000 miles of long distance and 10,000 miles of pole line serving farm customers. Spraying was done along 12,000 miles both types of line, the rest being brush free. The average cost of spraying per mile was 1/3 of the cost of hand cutting. This is in line with other utility Co. reports. There is no question about the overall effect of reduced maintenance costs, labor conservation and trouble free lines resulting in a decided service improvement. Had there been no spraying program for the past 10-12 years it could be that the available limited

manpower could not have kept up with the brush growth and service would be at a lower level. The gains from brush control are (1) improved service through trouble free brush interference and (2) financial improvement where hand cutting would cost three times as much and be less effective. Our brush control program is such that it required only periodic maintenance treatment. As Charles Laverty, our biggest custom sprayer said at the North Central Weed Control Conference last December he has about worked himself out of a job with the Northwestern Telephone Company. There are no major brush control problems under N. W. Bell Telephone lines in Iowa today.

Brush under lines, elm and boxelder, so thick you can't see the lines, drains off and ground the line currents and interferes with dial impulses. During wind the brush "bats" the wires together sending dial impulses into the switching equipment, making it almost useless for normal operation.

Similar statements have come from Independent telephone lines and from REA. Saving have been similar. County roadside weed and brush control programs have eventually paid off in cleaner roadsides, more vision, greater traffic safety, greater cleanliness, easier maintenance in upkeep and snow removal, and lower maintenance and upkeep costs by 1/3-1/2 of the former costs.

The one single disheartening thing in the whole weed control Extension work is the slowness with which people adopt ideas. Dandelion control is simple and effective with 2,4-D, yet less than 10% of the people use it. As a result our parks, cemeteries, airfields, etc. are masses of unsightly dandelions. The same may be said of ragweed infested permanent bluegrass pastures where \$.50 worth of 2,4-D per acre in 10 gal. of water per acre, would kill every single last ragweed plant in the area for that season. The same thing may be said about cockleburs, velvetweeds and sunflowers in corn. In small grain 12½ cents worth of 2,4-D per acre will control wild mustard to the extent of 95% in one treatment and 25¢ worth will control it 100%--and yet we have fields yellow with wild mustard. However, agricultural adjustment is gradually taking its slow inexorable toll. In Washington County in Iowa, 15-20 farmers are leaving the farming business every year. In Buena Vista County, Iowa, there were 406 fewer farms in 1954 and compared to 1940. In Emmet County, Iowa, there were 116 fewer farms in 1954 as compared to 1940. When I first got into Extension work in 1935, we used to speak of 225,000 Iowa farmers. Around 1950 we used to speak of 200,000 Iowa farmers. Now we speak of 190,000 Iowa farmers and the prediction is that around 1975 there will be in the neighborhood of 175,000 Iowa farmers, with larger, more economical, more efficient units. The borderline operator, who doesn't care, for whom weed control meetings, insect control meetings, soil erosion control meeting, better livestock production meetings, etc. have been a waste of time, for whom farming as a way of life has been good enough under an ever rising economy, is suddenly finding himself in an economic squeeze. You just cannot pay tribute of 10% to weeds, 10% to insects, 10% to soil erosion, and expect to stay in business. So the people who remain, automatically are the more progressive farmers and operators. So in the long run with fewer, better informed farmers, we will see a more rapid adoption of modern weed control methods. Heavy stands of weeds have seldom bought a better standard of living, more music lessons, or a better way of life.

We have looked momentarily at Monetary Values of Extension Weed Control. Let's look briefly at Aesthetic Values of weed control. What price can you

put on cleaner fence rows, cleaner roadsides, roadsides where more vision may mean the saving of lives etc. The man, woman or child, whose life is saved by better highway vision will never thank anyone, because they don't know their life has been saved. No one knows exactly how much value can you put on a ragweed free roadside which in turn helps alleviate hay-fever. How are you going to assess the value of having fewer cases of poison ivy poisoning among youngsters and adults alike, whose play and work bring them into contact with this nefarious plant. But out of all this cultural and chemical weed control work is coming, slowly but surely a better land stewardship, a new outlook for the weed besieged farmer, a feeling that the time is now when we no longer have to take weeds for granted, when we have to live with them, and when we can do nothing about them.

Many well informed farm owners and operators are taking steps which slowly and surely are bringing these weed saboteurs under control. You have difficulty putting a monetary price tag on a clean lawn or clean cemetery, or clean fence row or roadside. But in Iowa as elsewhere, we are at a place when we have to put a premium on good stewardship in all forms, on more conscientious effort, on a better way of life, on a philosophy where we want to make the best better, where we want to improve, where we are not satisfied with business as usual, or the philosophy that its "good enough." We need to instill in our citizens a new sense of stewardship and responsibility, and clean fields, weed free fence rows, roadsides, lawns, and gardens is as good a place to start as any. And we are making progress, slow but sure and it is coming more rapidly the last few years than ever before. It's hard to put a money tag or profit tag on it but it is there.

And besides these nebulous aesthetic values, there are some miscellaneous profits, some intrinsic profits or values which arise from Extension weed control. It makes you glad and happy to know that in some small way you have been able to be of help to a weed besieged individual, to whom 20 short years ago, the fight against weeds seemed like an endless, back breaking never ending laborious effort. In the control of weeds, lessons can be learned which have intrinsic values to the participants, the rest of their lives. The control of many of our "weeds not of the soil," falls into about the same cultural and chemical control patterns as the control of weeds "of the soil". Many such perennial problems are like the control of noxious perennial weeds. In the pursuance of extension work over the years there are other personal satisfactions that accrue. You are trying to help make the lives of people easier and more comfortable. Many of them realize that with less back breaking work they can control weeds easier, than has ever been the case before. To many of them the vision of a farm, roadside, county and state where weeds are easily and adequately controlled, is no longer just a figment of the imagination, but a reality. And there is a lot of personal satisfaction in having been a part of such work, and you can't put a price tag on it. And another profit angle, not measured monetarily, is the fact that after 20 years of work in a state, you are never alone. Someone knows you wherever you go and appreciates what you are trying to do. And you can't put a profit tag on that.

It's been my privilege and pleasure to talk to you on the subject the Profit Aspects of Extension Weed Control work. I am deeply grateful for the privilege and opportunity. Thank you.

PROFITS FROM WEED CONTROL IN THE REGULATORY FIELD

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As an ex-regulatory man, I should be able to defend their activities from a dollars and cents point of view, and this was probably the thinking behind the invitation to speak here today. I have chosen to look at it as an invitation to publicly justify my existence during the nine years I headed the weed branch of the Washington State Department of Agriculture.

As if plain justification were not enough, the title "Profits from Weed Control in the Regulatory Field" would also indicate that I am expected to point out where the State profited from its expenditure. I am certainly glad I have another job now for any of you in regulatory work may suffer as a result of my remarks if the people who hold the purse strings happen to hear of what I have to say. Never fear, though, for I will do my best to justify your existence, even if it is mostly in self-defense.

When I started to prepare this talk, I went back in my file of reports to some of the first written after I joined the Department of Agriculture. Here I found this information: "This year the number of March meetings was increased, due to extreme bad winter weather and it seemed that all the weed-minded wanted to get together in the month of March. During that month I attended meetings of an educational nature in six counties, helped with the programming and arrangements for the first Washington State Weed Conference and assisted in organization of two weed districts." This rather set the pattern during the first few months of my tenure and, as I recall, those were the years when 2,4-D was new. The State of Washington did not then have an extension weed specialist so it seemed I was called on the fill that job's requirements as well as those of regulatory import. This, as you know, is a type of work that requires a lot of time and which Mr. E. P. Sylwester has just covered in his speech on Profits From Weed Control in the Extension Field.

In those days we used to remind all utility districts, railroad maintenance officials, highway maintenance people and any others having rights of way through weed districts or weed areas (the designation for a county-wide compulsory control program in the State of Washington) that within these areas it was illegal not to control specific weeds. These notices were so timed as to arrive just prior to the dates at which these weeds could be controlled and also suggested mean of control. In this type of work, who can assess a dollars-and -cents value?

In my first six months progress report to the director of agriculture, I found the following statement written as of June, 1950: "Weeds, when growing in competition with agricultural crops, add considerable to the cost of production." I must have copied that directly from Robbins, Crafts and Raynor. This report goes to condemn the pestiferous group of perennials I found infesting large areas of good agricultural lands and costing farmers the expense of control, loss of production and the expense of farming an area from which they gained nothing. How is it possible to develop a topic of profits gained through regulatory work in weed control based on this type of information?

As I continued to peruse the reports which constituted almost a weekly diary of my work with the Department, I found that basically it included meetings, passing on advice, and working with weed districts formulating programs.

I then began to wonder about the economic value of compulsory weed control. I recalled having been told by a number of weed district directors that whenever the per-acre assessments to finance a weed district exceeded 10¢ the complaints from the land owners increased considerably. Was this justified?

I also recall that in one area in the state there was a number of weed districts with an average estimated annual budget of about \$8,000 to \$12,000. This budget was financed through a millage levy included with the other so-called junior district levys and was rather well hidden within the tax statements. Then a few years ago the state legislature changed the method of financing for weed districts to a flat per-acre assessment and thus there was a separate statement included within the tax statement, showing exactly what the weed district was costing the land owner. Although budgets in all the cases remained approximately the same and in no case did they assess more than 20¢ per acre, yet the year after this change the farm people in that community began to complain about the cost of their weed districts and, as a result, they have nearly all become inoperative. I am really in no position to evaluate these districts but in this particular county the county commissioners have continued to maintain a fairly efficient program on roadsides and this is probably the only place in the state that roadsides are more free of weeds than are the farmers' fields.

This county's roadside program has consisted primarily of spraying with 2,4-D. Many acres of cereal crops adjacent to these roads are either left unharvested or fail to pay the costs because of the patches of Canada Thistle within the fields. Since we all know that thistle can be sprayed in cereals or pastures, I believe this comparison of field and roadside serves to indicate what could have been done, had a strict compulsory weed program been followed. The program had been gaining some headway before the difficulty over taxation and, as for the increase in revenue to the farmers of that area, for what could have been gained we will let you compare the aforementioned cost of the weed districts with information yet to be given this afternoon by Mr. Friesen in his speech on The Effects of Weed Competition in Cereals.

In connection with compulsory weed work, I began to think in terms of what other states have accomplished, as the work under existing laws in the State of Washington is somewhat different from that found elsewhere. I recall talking with Walter Ball of California about a shipment of oats that were so weedy they would not allow them to be utilized for feed in California until they were processed and laboratory checks showed them to be free of live weed seed of the so-called noxious species. How much did this one act of regulatory nature save the State of California? Of course, no one knows for sure and I doubt if Mr. Ball remembers what weeds and how many seeds were in that oat shipment, but let us, for the sake of example, presume that these oats were to be fed in a feed lot and there was enough Canada Thistle seed to infest every acre on which the manure from the feed lot was spread. This, we will say, could be at least 80 acres and with a little figuring on this basis it is not at all difficult to determine that

on fairly good agricultural land the total loss could add up to at least \$5,000 per year on this 80 acres.

Now, considering that the regulatory act of stopping the sale of one shipment of weed-infested oats resulted in a \$5,000 per year saving to the people in the State of California, and that the \$5,000 would at least pay half the salary and expenses of most regulatory men for a year, you can see that a regulatory man does not have to work too hard to justify his existence.

Another intangible result of regulatory work is the stopping of imports of new weed species and hampering of their spread. I understand that Halogeton has a foothold in Northeastern California but without a regulatory program, both federal and state I believe in this case, there would probably be many more acres infested than now. I doubt that many of you would disagree with me in this statement that "the infestation would be greater without regulatory measures" and I also doubt that any of you will hazard a guess as to how much greater, so why should I be different?

Another area in which regulatory work is of benefit and helps build profits is in the control of the use of herbicides that are hazardous to either crops or people. We might even include the control of sale as well as the control of use, as all of you know there are those who will sell herbicides with utter disregard for possible benefits from their use. Such a fellow went through the Palouse a few years ago selling arsenic tri-oxide for selective weed control in wheat.

In my experience, I think probably the greatest trials with regard to regulating the use of herbicides came about as the result of damage to grapes and other susceptible crops from drift of 2,4-D. Realizing that these sensitive crops were a source of wealth, as was the increased wheat yields resulting from the weed control possible by utilizing 2,4-D, the Washington State Department of Agriculture attacked the problem with the view that both groups should be allowed to produce their maximum returns as long as they did not jeopardize the production of others. With this approach and after a few years of trial and error, a program was evolved under which most of the wheat area could be sprayed with but an insignificant amount of symptom appearing on the grapes. To assay the profits from these regulations is nearly impossible, yet certainly the increase in grape production where 2,4-D injury is at a minimum and the increased wheat production due to utilization of 2,4-D within those regulated areas must be at least partially attributed to a regulatory benefit.

Throughout this talk I have been bringing in intangible profits that result from regulatory work and to which I doubt that any set dollars and cents value can be attributed. I know of no better way to develop this topic, therefor another example from the State of Washington. This, the control of imports of Canadian screenings. Granted they were still coming in when I left the employ of the Department but the amount was much reduced, the quality was much better from the standpoint of feed values and the control over their handling was much better than was the case when a regulatory program was initiated. This was all accomplished without additional laws or, I might add, without adequate laws to entirely cover the problem, and though it is not 100% effective, I am certain that the program has been beneficial.

I could go on giving examples and maybe should mention as an additional example the Federal quarantine on Striga (witch weed), the parasite that attacks corn. It is useless, however, to continue sighting these examples to which I cannot attach a dollars and cents value, but taking my previous example of a \$5,000 gain from one regulatory act and realizing that these figures may be far from accurate, I still believe I have demonstrated that a tremendous good is derived from regulatory type of work.

I used to explain to weed supervisors that in my thinking the good they did was best represented by grafically portraying the decrease in weed infestation over what would have been, had there been no one working on the problem. I would give them this illustration when tole, as is so often the case, that no progress was being made and that the areas infested were increasing each year. There are few areas of weed control that include a broader scope than a good regulatory program.

Let us go back and again review a few of these points of approach. They include regulation of sales of herbicides, use of herbicides, compulsory weed control programs, quarantine approaches such as control of importations, and within each of these must be included an education program in cooperation with other weed-minded people to make sure that the values derived from such programs are sufficiently understood to be accepted by the general public.

Probably one of the best examples as to what the public can do to a program even though we know it to be beneficial is represented by the decreased roadside spray program in effect because of the relatively few but potent complaints that sprayed dead weeds and brush along roadsides are unsightly and thus create poor tourist attraction. We who are gathered here all know that if these people were educated sufficiently on weed control they would realize that with a year or so of spraying the asthetic values would improve and they as well as every one else would benefit from such a program.

If I get started on this vein, I am sure to exceed my allotted time. However, I would like for you to think about pyramiding profits resulting from a weed control program on roadsides as opposed to the tremendous cost to a community due to failure to curb a single seed-producing plant growing from a seed that has been transported by truck, car or some other conveyance and happens to reproduce in an area where, though previously unknown, it is exceptionally well-adapted. An example of what I mean might be the starting of Witch Weed or Striga in the middle of the corn belt, due to failure to control a single plant developing on wild millet. Characteristically, a fairly large corn-growing area could become infested before the plant was identified and brought to the attention of proper authorities. Thus a great deal of time and money would be spent in curbing a menace that could have been stopped for a very nominal expense if killed where it first started in a roadside barrow pit.

I hope I have managed to at least partically fulfill the responsibility handed me with the assignment of this topic, and if it helps to encourage a single worthwhile regulatory act, be it legislative or otherwise, I shall feel that the time and effort put into developing the topic and coming to Spokane for this meeting has been well repaid.

Thank you.

EFFECTS OF WEED COMPETITION IN CEREAL GRAINS AND FLAX

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In most published data on losses caused by weeds the greatest single loss is attributed to reduced crop yields. Estimates and surveys on crop losses due to weed competition have varied from 10 to 20 percent of the total crop value.

Crop competition studies initiated at The University of Manitoba in 1952 were designed to (a) determine how many mustard plants per square yard may be tolerated before yields of wheat, oats, barley and flax are significantly reduced, (b) demonstrate that spraying with a suitable herbicide prevents loss of yield, (c) obtain information on when in the growth of cereal crops and flax does weed competition begin to take place, and (d) determine the losses caused by weed competition on farm fields over a wide area.

Experiments were designed wherein wheat, barley, oats and flax were grown alone or in association with varying densities of wild mustard plants per square yard. It was found that as few as 10 mustard plants per square yard were sufficient to significantly reduce yields of flax. Oat yields were reduced by 24 mustard plants per square yard, whereas 50 mustard plants per square yard were required to reduce significantly yields of wheat or barley. In addition the value of destroying mustard with 2,4-D or MCPA in these crops was carefully assessed. For the sake of brevity the 1952 results with flax and the 1953 results with wheat are presented here.

Table I. Effect of mustard competition and 2,4-D treatment on flax and wheat yields.

Mustard plants per square yard	Bushels per acre			
	Flax 1952		Wheat 1953	
	Treated	Untreated	Treated	Untreated
0	19.3	22.0	22.6	22.9
10	17.7	8.1	-	-
25	17.1	6.2	-	-
50	16.6	5.9	22.6	18.4
100	15.3	3.6	23.2	15.7
200	13.8	3.2	22.4	13.4

As shown in the table, and considering the very low cost of 2,4-D or MCPA, it obviously pays to spray grain crops even with very light infestations of wild mustard.

Further experiments were designed to obtain more information on when in the growth of wheat, barley and oats does mustard competition begin to reduce yields. These crops were grown free of weeds and in association with 100 and 200 wild mustard plants per square yard. The wild mustard

was then removed at several stages of crop growth using 2,4-D ester at 4 oz. per acre. For the sake of brevity only the results with wheat in 1954 are presented in Table II.

Table II. Effect of time of removal of wild mustard competition on wheat yields.

Weed density per sq. yard.	No. treatment bus/ac.	Stage of crop when 2,4-D treated		
		4-leaf bus/ac.	6-leaf bus/ac.	Shot-blade bus/ac.
0	42.0	45.8	48.9	44.3
100	18.0	47.1	39.1	18.8
200	16.0	40.2	40.5	15.4

Similar results were obtained with oats and barley. Evidence from four years' experimentation indicates that the time competition may become effective varies from year to year (in 1952 the full competitive effect of mustard was expressed even before wheat reached the 5-leaf stage), but when weeds begin to take their toll, they do so very quickly. In the above table the full impact of competition was realized between the 6-leaf and shot-blade stages--a period of six days. The importance of early spraying for weed control is therefore demonstrated.

The magnitude of crop losses due to weed competition must of necessity depend largely on the species present and their concentration. Percentage reductions in yield obtained in carefully controlled experiments, involving in most cases only one or two weed species, may be very different from the actual losses occurring on the farm. The need for a method of determining the losses on farm fields over a wide area and an accurate assessment of these losses prompted the initiation on the following project two years ago.

In 1956 and 1957 fifty fields were selected at random in an area within a 60-mile radius of Winnipeg. The fields were suitable for study if (1) they were seeded to wheat, oats, barley or flax, (2) the farmer's permission could be obtained, and (3) they were at least 20 acres in size. Immediately after seeding, 10 paired plots each 4' X 4' in size were staked in the fields. One plot of each pair was kept weed-free by hand weeding. The species of weeds present and the relative numbers were recorded. When the crops reached maturity a one square yard sample from each plot was harvested and yield determinations made.

Weed Counts

A total of over 30 different weed species were found growing in these fields. The "cleanest" field had only 13 weeds per square yard while the "weediest" field had over 2,000. The average weed counts per square yard for all fields were 283 in 1956 and 235 in 1957. Crops grown on stubble land were 40 percent higher in weed count than crops grown on fallow land.

Weed Competition on Crop Yields

Yield reductions due to weed competition ranged from 0.1 to 47.2 percent in 1956 and from 0 to 61.5 percent in 1957. As would be expected, lowest reductions were recorded in fields having low weed counts. In general, low weed counts followed a year of (1) highly competitive crops such as sweet clover, (2) sugar beets or other intertilled crops, (3) summer-fallow or (4) resulted from early spraying of the current crop. The greatest losses and highest weed counts occurred in crops grown on stubble land or where spraying was not a regular farm practice.

Yield reductions due to weed competition in the various crops are presented in Table III:

Table III. Yield reductions (bus/acre) due to weed competition, 1956 and 1957.

Crop	1956				1957			
	No. of fields	Weed-free plots bus/A.	Weedy plots bus/A.	Losses due to weeds bus/A.	No. of fields	Weed-free plots bus/A.	Weedy plots bus/A.	Losses due to weeds bus/A.
Wheat	26	33.3	27.1	6.2	22	29.8	26.1	3.7
Barley	3	35.1	31.0	4.1	12	27.6	22.8	4.8
Oats	19	65.1	58.0	7.1	5	48.5	45.5	3.0
Flax	2	14.1	10.8	3.3	8	7.4	5.2	2.2

The presence of many different weed species in most fields made it difficult to measure the competitive effects of a single species. However, in several fields where a single weed species predominated a rough estimate has been made. Wild oats, wild mustard, and possible wild buckwheat showed serious competitive effects. Green foxtail, on the other hand, was not a serious competitor in wheat, oats or barley. Flax, on the other hand was seriously affected by the presence of green foxtail.

Effect of Spraying on Weed Competition

To observe the effectiveness of 2,4-D and MCPA in reducing weed competition, the cooperating farmer was asked to spray 5 paired plots and miss the other five, providing he intended to treat the balance of the field. In the two years 19 cooperators actually sprayed as instructed. Overall losses due to weeds in sprayed and unsprayed plots were as follows:

Table IV. Effect of 2,4-D and MCPA on weed competition

	Losses due to weeds (bushels per acre)			
	Wheat(10)*	Barley(3)	Oats(4)	Flax (2)
Sprayed plots	1.6	3.0	4.8	1.4
Unsprayed plots	5.0	3.4	7.9	1.2

* number of fields in brackets.

It will be noted that spraying reduced weed losses to a considerable extent, particularly in wheat and oats. However, yeild reductions were not completely eliminated, probably for the following reasons: (1) spraying too late, and (2) presence of resistant weeds. In both flax fields the predominating weed was wild oats and consequently no yield benefit could be demonstrated from spraying.

Weed Competition on Crop Quality

In 1957, the percent protein was determined on wheat and barley from paired weeded and non-weeded plots. To date, proteins have been run on the grain samples collected from 10 fields and data is presented in table V.

Table V. Effect of weed competition on protein.

Location	Wheat		Barley	
	Yield increase (weeds removed) bu/acre	Protein increase (weeds removed) percent	Yield increase (weeds removed) bu/acre	Protein increase (weeds removed) percent
1	2.9*	.412*	9.7*	.549**
2	4.5*	.103	9.1**	-.043
3	8.5**	.062	3.1	.114*
4	8.2**	.969*	8.5*	.428**
5	10.7**	.002	2.2*	.423*

* significant at 5% level of probability

** significant at 1% level of probability

The limited data available indicates that controlling weeds not only helps to increase yield, but often should increase protein content as well.

Summary

If we project the losses caused by weed competition on these fields to the whole of Manitoba, then the overall losses for the province can be calculated. The crop yields in the area under study have been about average for the province, and therefore such a calculation may be justified. It is also assumed that weed populations in the balance of the province are not greatly different from the area included in the study.

Using the loss figures in table III the following losses for the province have been calculated.

Table VI. Losses due to weed competition in Manitoba Grain fields.

Crop	1956		1957	
	Total bushels lost*	Value of crop lost**	Total bushels lost*	Value of crop lost**
Wheat	13,633,800	\$20,450,700	7,821,800	\$11,732,700
Barley	6,346,800	5,712,120	8,179,200	7,361,280
Oats	14,576,300	8,845,780	5,400,000	3,240,000
Flax	2,603,700	7,811,100	1,903,000	5,709,000
		\$42,719,700		\$28,042,980

* Calculated from the number of acres seeded in the province and bushels per acre lost through weed competition.

** Based on the following value per bushel: wheat \$1.50, barley \$.90, oats \$.60, flax \$3.00.

This data does not measure accurately the losses due to perennial weeds, such as Canada thistle, sow thistle and couch grass, all of which are wide-spread in the province. Furthermore the staggering losses presented include only the four major crops; wheat, barley, oats and flax. Undoubtedly weed competition is also significant in other crops grown in the province, i.e. peas, sunflowers, sugar beets, potatoes, rye, corn, soybeans, etc. If we add to reduced yields, a decrease in crop quality, the annual losses caused by weed competition become even more significant. Fortunately these losses can, to some extent, be reduced by timely and proper use of 2,4-D or MCPA.

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THE CHEMISTRY AND REACTIONS OF HERBICIDES AS RELATED TO THEIR USE

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A cardinal precept of scientific investigation is that any process or system follows well-defined physical laws. It is the job of the investigator to discover what laws are operable on the system with which he is dealing. In general, this knowledge comes through a series of successive approximations. The investigators of a particular phenomenon first advance a theory that appears to cover the general facts. Successive refinements are then made in the theory until there is a close approach between what is predicted by theory and the data obtained by experiment.

For a number of years we have been well aware of the subtle interaction of herbicides with the environment in which they are used. Many experiments have demonstrated the interaction of the chemical with the

environment. This started with some of the classical adsorption work done by the group in California and others in the nineteen-twenties and has proceeded to the rather general investigation by most research workers of the relation of environment to the response of weeds to the particular herbicide in which they are interested. However, attempts to relate the observed behavior to the chemistry of the compound and particularly as this chemistry reflects the physical properties involved have been at best cursory.

In this particular discussion we wish to begin considering the relationship of the chemistry of the compound to its behavior as a herbicide under different environmental conditions. If we are successful in developing some working concepts of this problem, it should make the work of the field experimenter much easier. If our theories are correct, we should be able to successfully explain some of the observed phenomena and be able to predict the probable behavior of herbicides under certain conditions.

We should not expect that in these early stages that we will have exactly the right form or the most quantitative estimate of our problem. Rather, we should recognize that we will need to improve our working concepts by successive approximation as more and better data become available. However, our excursion into the "outer space" of the field of herbicides should be well worth while. It is only reasonable to expect that it will provide us with more effective means of dealing with the problems encountered with these chemicals.

The concept of relating the behavior of a drug on or in a biological system to physical laws has long been employed in certain realms of biology. A classical illustration of this is to be found in Ferguson's principle of the variation of biological activity of chemicals with their partial saturation in a gas or liquid phase. In dealing with solutions, we find that there is a certain partial saturation solubility required for a given system in order to obtain a certain level of biological activity from the chemical. As a result of this principle, we should be able to postulate that as the water solubility of a compound increases the biological activity on a weight basis should decrease. It should be recognized that there will be limitations and exceptions to this postulate, but its validity will obtain in a large number of cases. The validity of this postulate for a number of herbicides used in selective weed control is demonstrated in figure 1. Here, the dosage in pounds per acre is plotted against water solubility in moles per liter and the best straight line through these points, based on the least squares calculation, is drawn. The correlation coefficient for this relationship was found to be .605 which is significant at the 5% level.

Turning our attention now from the more general phenomena, let us consider some of the specific problems with which we have to deal. One of these problems is the behavior of chemicals in soil. This is of paramount interest to us in both soil sterilization and pre-emergence weed control where soil active chemicals are used.

As most of the chemicals used for the purpose of acting through the soil are applied to the surface of the soil in the form of a spray, let us start with a consideration of the problem at the soil surface.

In asking ourselves what phenomena are of importance in achieving maximum effectiveness, starting at the surface, we find that solubility is of prime consideration. In other words, is the chemical being dissolved by the water entering the soil or by the water already present as soil moisture? In this case we are forced to turn our attention to two equations describing the solubility phenomena. These are as follows:

$$(1) \ln \frac{S}{S_0} = \frac{-\Delta H}{R} \frac{\Delta T}{T_1 T_2}$$

$$(2) \text{ rate of dissolving} = C_e \frac{-\Delta H}{RT}$$

In consideration of the consequences of these equations, we find that they tell us that more chemical goes into solution with increasing temperature. Further, that we more nearly approach the saturation point of the solution as the surface concentration of the chemical increases. This means that more chemical should arrive into the active zone of the soil. Moreover, we find that if the velocity of percolation or entry of water into the soil is more rapid than the time rate of solution, there will be less chemical entering the soil.

Once a chemical has reached the soil in solution, there is a tendency for it to be adsorbed. The tendency for a given chemical to be adsorbed is a function of some of the peculiarities of that chemical. We find great differences in adsorption among chemicals. Certain of them will be adsorbed physically by the soil colloids and organic matter. Others will be rather specifically adsorbed, some of them through chemical bonds as is the case with arsenicals. The strength by which the chemical is bound to the soil can be determined by letting soil and a solution of the chemical equilibrate. Knowing the amount of chemical available per gram of soil for adsorption, we can then determine the equilibrium concentration and calculate the energy by which the chemical is bound to the soil to a first approximation. Determination of the amount of chemical adsorbed per gram of soil with varying concentrations is shown for Amitrol in figure 2. The relationships involved in the calculations are as follows:

$$(3) \frac{\text{chemical adsorbed}}{\text{chemical in solu.}} = K$$

$$(4) \text{ apparent bond energy} = -RT \ln K + T \left(\frac{\partial RT \ln K}{\partial T} \right)$$

Now, the foregoing situation is actually much too simplified; because we have a heterogeneous system these relationships do not give the whole picture. Recent refinements in the consideration of this problem have led to the use of what is called the integral heat of adsorption. However, for purposes of our discussion, let us continue with the more simplified concept.

The bond energy calculated from some of the foregoing considerations gives us an index of the strength or degree of adsorption of the various chemicals. As the chemical passes through the soil we find an alternate adsorption-desorption process going on similar to that encountered in stationary solid phase chromatography. Since we are primarily concerned with the process of leaching or the movement of the chemical into the soil and

into the zone where it will be active, we must rightfully consider adsorption in relation to leaching. Moreover, since continued leaching may remove the chemical to a depth to where it is no longer effective, it is more important than ever that we have a better understanding of this process.

A few years ago in studying the problem of leaching of CMU in the soil, we found the wave front phenomena that would be required by this line of reasoning. We were able to calculate the depth at which we would find the maximum concentration of chemical by the following equation:

$$y = x e^{\frac{-\Delta H}{RTx}}$$

You will note that in this equation we have introduced a term ΔH , which is actually the bond energy between the soil colloid and the chemical. Thus, we are able to relate the adsorption phenomena to the leaching process. Manipulation of this equation tells us that the amount of chemical entering into the soil and to be found at the depth under consideration will be a function of the surface concentration as shown by figure 3, and the rate of water percolation or the amount of water passing the point under consideration which is illustrated by figure 4. We find also that this process will be influenced by temperature. Now in all cases we find that the partial saturation of the solution by the chemical is important. Thus, while we may say that a compound of low water solubility is more poorly leached than one of a higher solubility yet under a given set of conditions, it is possible for a compound of low water solubility to be of greater effectiveness because of its higher partial saturation.

Another phenomenon of interest in considering the soil behavior of chemicals is the breakdown of these chemicals in the soil. We are generally agreed that there are several pathways by which the chemicals might be destroyed in the soil and thus result in a loss of activity, but I think again it is generally agreed that one of the major pathways of loss of activity in the soil is by attack of the chemical by micro-organisms. Study of this attack by micro-organisms has revealed that it may be described by certain well-defined and meaningful equations. For our purposes, we are primarily concerned with the rate at which the chemical breaks down and we would like to be in a position to predict ahead of time how long a chemical will last in the soil from rather generalized information. If we will examine the Arrhenius relationship which is given in the following equation, we see that if we measure the rate of breakdown of a chemical at two different temperatures, we should be able to calculate a constant characteristic for that chemical known as the enthalpy of activation:

$$\ln \frac{k_2}{k_1} = \frac{-\Delta H_a (T_2^{-1} - T_1^{-1})}{R}$$

The soil microbiologists tell us that the flora of the soil is relatively constant qualitatively and that quantitative changes may occur rapidly. The microbiological reactions from place to place should therefore follow the same pattern, hence the enthalpy of activation should give us a reasonable estimate as to the length of time required to break down a given amount of chemical under conditions of soil moisture adequate

for the action of these micro-organisms. This would probably cover a range of 20 to 80% saturation. Measurement of the rates of breakdown of three different chemicals in the soil at two temperatures has been made and the enthalpy of activation calculated. It was very gratifying to find that these laboratory determinations when used to calculate the soil life of chemicals in the field gave very good agreement with field experience and showed a high correlation coefficient therewith. The results are shown in figure 5.

Turning our attention now to the behavior of the chemical on the plant above the soil surface, we consider first the matter of volatility of the chemical. It should be remembered that the discussion on volatility is also pertinent to the behavior at the solid surface as it is one of the means by which a chemical may be lost. We can start out by saying that all chemicals have a vapor pressure. However, certain of them have such a low vapor pressure that for all practical purposes it may be ignored. It is in connection with the growth regulating and non-polar herbicides that we become more interested in this phenomena, since they tend to be active as a vapor. Vapor pressure is described rather neatly for us by the equation given below:

$$\frac{d \ln P}{dT} = \frac{\Delta H}{RT^2}$$

Again we encounter our old friend ΔH , which in this case is the amount of heat required to change a molecule from a liquid to a gas. For all practical purposes we can treat this as being an invariable parameter of the molecule although in more refined work it actually is found to vary with temperature. This equation tells us that if ΔH is large there will be a large change in vapor pressure with an increase or decrease in temperature. This suggests to us immediately that the vapor pressure measured at only one temperature does not give us much information about the probable behavior of a compound at another temperature unless we also have the heat of evaporation. Thus, we may have the seemingly anomalous situation of two compounds at a low temperature where compound A may have a higher vapor pressure than B, but at another temperature finding that compound A has a lower vapor pressure than compound B. We encountered this situation with some of the esters of 2,4-D. This is shown in figure 6.

The constant ΔH or enthalpy of activation is an important item in our consideration of the volatility of compounds. Actually, the rate of evaporation of a compound is a function of the enthalpy of evaporation. Having this information at hand, together with the vapor pressure of the compound at the temperature at which we are interested plus information on the surface concentration of the chemical, we are able to approximate the rate of evaporation. Indeed, we have calculated the rate of evaporation of the herbicide EPTC from its own surface at 25°C and compared this to the measured rate of evaporation at this temperature and found agreement within about 5%. Another point of consideration in dealing with vapor pressures is the relationship of vapor pressures of different particle sizes as expressed in the Kelvin equation given below:

$$\ln \frac{P}{P_0} = \frac{2M \gamma}{rd RT}$$

This equation suggests to us that as particle size becomes very small, the vapor pressure of the chemical in this particle will increase. This conclusion is of considerable importance in the application of 2,4-D and other growth-regulating chemicals in as much as small droplets are found in spraying.

Another law of considerable interest to us in dealing with herbicides is the one known as Raoult's Law which is expressed in the equation below:

$$P = P_0N$$

This equation tells us that if we decrease the mole fraction at the surface of the chemical which we wish to apply by the addition of the non-volatile substance, the vapor pressure of the chemical will be reduced proportionately. It also tells us that if we do reduce the mole fraction of the herbicide that the evaporation losses will be less. Thus, we should be able to extend the effective life of a volatile herbicide by introducing a non-volatile diluent. Advantage has been taken of this in the use of insecticides and I am sure that it can be of some significance to us in the future in the formulation of more effective herbicides. This principle is shown to apply in the case of herbicides by the data in figure 7.

A final consideration of vapor pressure is the relationship of vapor pressure to volatility with steam. This relationship is expressed below in a very common equation and illustrates to us how steam distillation from the soil surface of the plant surface might occur. It should be noted, however, that this principle of distillation involves not only steam as a gas but it may also involve other gases such as air as well.

$$\frac{W_1}{W_2} = \frac{M_1 VP_1}{M_2 VP_2}$$

Another phenomenon of extreme importance in the effectiveness of herbicides is that of the ionic behavior of the materials. Where we have non-ionic molecules or non-polar molecules, this is of little consequence, but where we are dealing with salts, acids or bases, ionic behavior becomes important. This behavior is involved in solubility, formation of crystals, hygroscopicity and numerous other ramifications. Many have had the experience at one time or another of seeing the loss of effectiveness of an amine or sodium salt of 2,4-D due to the presence of calcium or magnesium ions. Ionic behavior is also associated with the development of electromotive force. In connection with the study of the toxicity of sodium chlorate some time back, it occurred to us to calculate the EMF of the sodium chlorate as a function of pH. We found marked differences as a function of pH and asked ourselves whether this would have any bearing on the toxicity of sodium chlorate, particularly in view of the observation that sodium chlorate is generally less toxic on an alkali spot than elsewhere. Upon testing this theory, we found a marked drop in biological activity as the pH increased above 8, which is shown in figure 8.

Finally, we turn our attention to the phenomenon of absorption of the chemical by the plant. Herein, we find a number of working concepts

that can guide us to more effective utilization of the chemical as well as suggesting modification of formulations that may increase the effectiveness of the herbicide. First of all, in examining the rate of disappearance of a chemical from a leaf surface and assuming this disappearance to be due to the absorption by the plant we find that the process follows what we know as first order laws. This may be expressed by the following symbolism:

$$\frac{-dn}{dt} = kM_0$$

and

$$k \approx Ae^{-\frac{\Delta E}{RT}}$$

This relationship immediately indicates to us that the amount of chemical absorbed per unit time is a function of the amount per unit surface area on the leaf, and that this surface concentration must be expressed in terms of an active form of the chemical. By further examination of the relationships shown here, we see that absorption is an energy-requiring process, or in other words has a so-called energy barrier. In order to make most effective utilization of the chemicals it is necessary for us, then, to find ways and means of reducing this energy barrier. This can be done by keeping the chemical in a liquid state since more energy is required to absorb the chemical from a crystalline state. Moreover, we are required to provide an additive that will help to overcome the barrier to absorption at the leaf surface. This we do by the addition of surfactants that not only tend to condition the chemical to permit maximum absorption, but also increase the area of contact or effective surface concentration of our chemical.

In summary, then, we can say that there are a number of physical relationships governing the behavior of the herbicide under field conditions. Knowing this, we can exploit the knowledge derivable from these relationships to increase our understanding of herbicidal action, to increase the effectiveness of our chemical and to reduce the amount of work necessary in the development and use of new chemicals.

Figure 1

Relationship Between Dosages Used in Field Application and Solubility in Water of Selective Herbicides

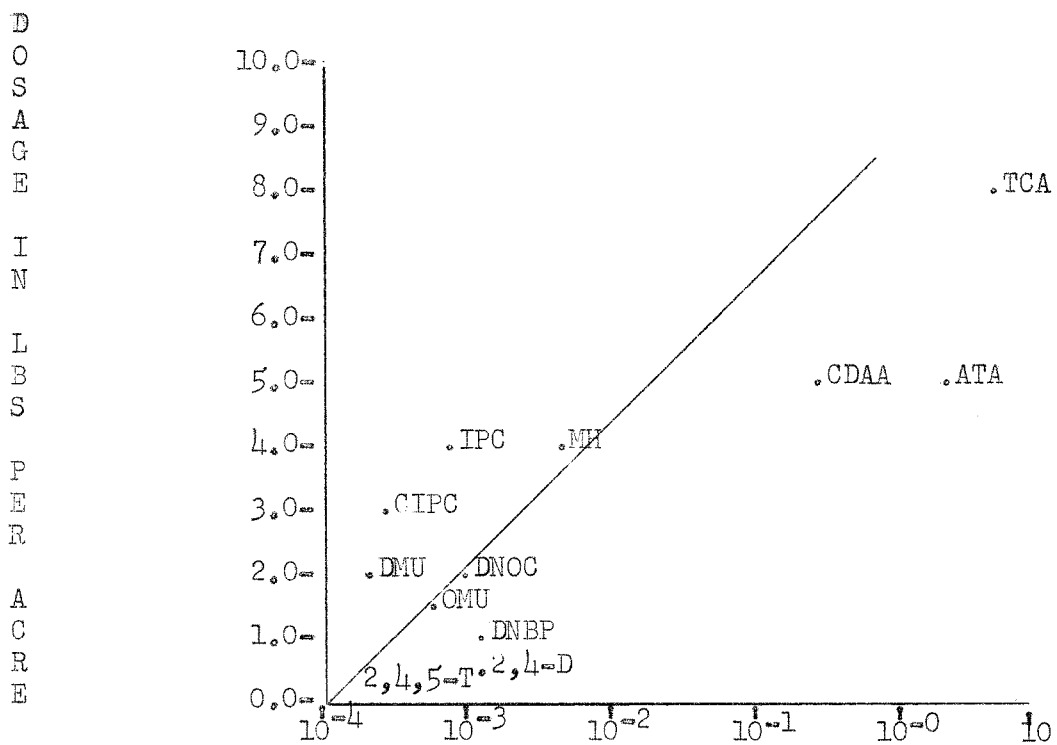


Figure 2

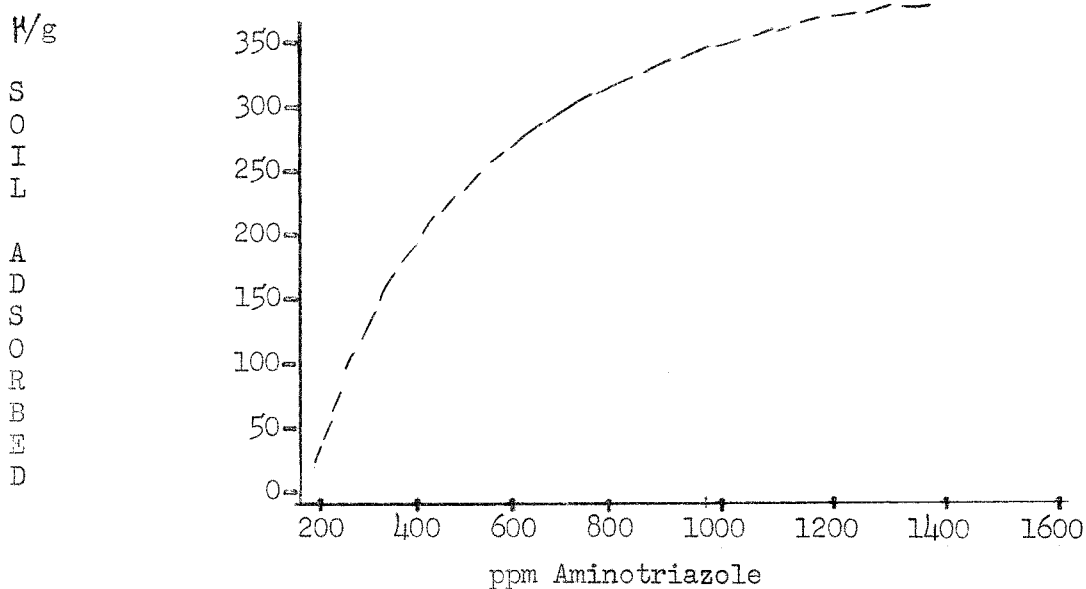


Figure 3

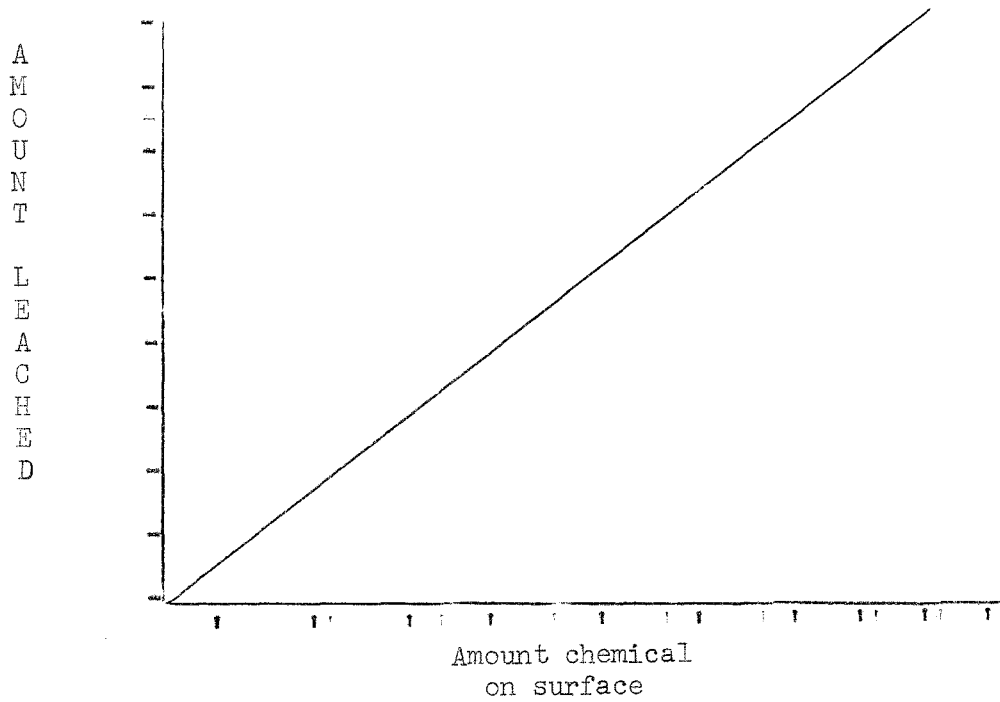


Figure 4

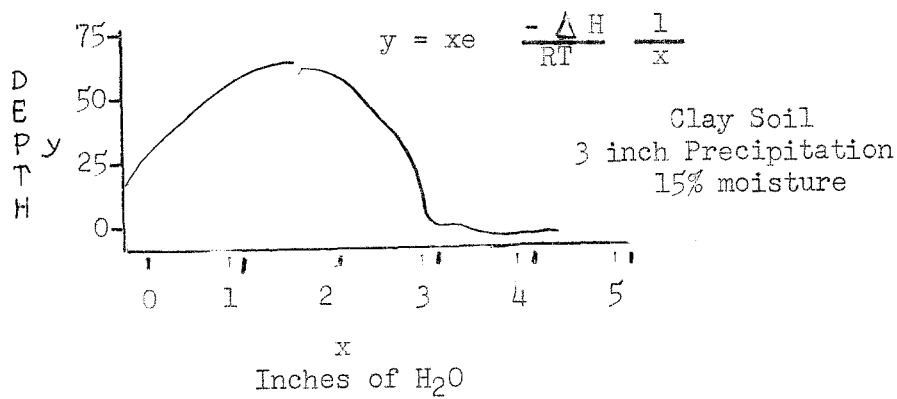


Figure 5

Comp.	k Temp	ΔH	
		k (day ⁻¹)	ΔH
ATA	15° C	2.25 x 10 ⁻²	5,374
	29° C	1.47 x 10 ⁻²	
IPC	15° C	4.67 x 10 ⁻²	7,768
	29° C	8.79 x 10 ⁻²	
CIPC	15° C	4.25 x 10 ⁻³	21,237
	29° C	2.39 x 10 ⁻²	

Figure 6

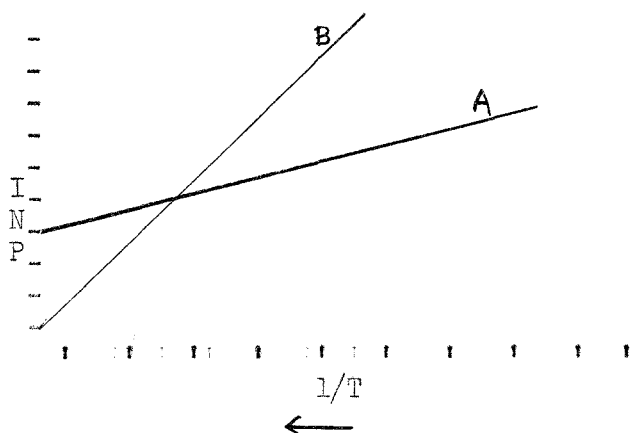


Figure 7

P = P₀N
Evaporation of Isopropyl
Ester of 2,4-D at 40°C

	24 hrs.	48 hrs.
Ester alone	1.8%	8.6%
Ester & chlorinated biphenyl	0.4%	4.2%

Figure 8

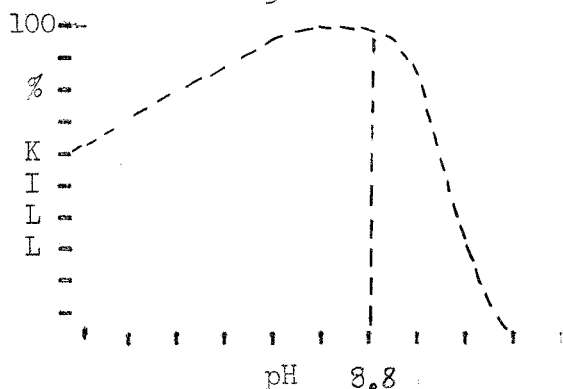
Kill by NaClO₃ vs. pH

Figure 9

Absorption of 2,4-D in
Presence of Surfactant

% Surfactant	% 2,4-D Absorbed
0.0	10.1
0.1	36.5
1.0	38.8

Note: Meaning of symbols used in this paper:

ln = natural logarithm, logarithm to the base e
 s_0 = solubility of solute at temperature T, (abs.)
 S_0 = solubility of solute at temperature T₂
 T, T₂...T = Temperature, degrees absolute
 R = Molar gas constant
 ΔH = change of heat (energy) content or enthalpy
 for a given process
 y = depth of leaching (inches)
 x = inches of water passing a given point in the
 soil horizon
 k_1, k_2 = rate constants for a given process at T₁,
 T₂

t = time
 e = 2.71828
 C = a constant
 K = equilibrium constant
 P = pressure of a gas
 M = molecular weight
 γ = surface tension
 r = radius of a drop
 d = density
 N = mole fraction
 $W_1 W_2$ = weight of sub-
 stance $\frac{1}{2}$,
 V_p = vapor pressure
 m = mass per unit area

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THE SELECTIVE ACTION OF CHLORDANE AND RELATED COMPOUNDS FOR THE
CONTROL OF CRABGRASS

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One of the first reports that the insecticide chlordane (1,2,4,5,6,7,8,8-octochloro-4-7-methano-3a,4,7,7a-tetrahydro-indane) can delay emergence and prevent the germination of crabgrass with only slight effects on the growth of established turf grasses was that of B. H. Grigsby of Michigan in 1951. Since that time other weed control specialists have tested chlordane as a selective herbicide against crabgrass and have reported their results in various journals and weed conference research reports. Some of these workers are R. D. Shenefelt in 1952, M. R. Carleton in 1953, D. Dybing, J. L. Fults and R. Blouch in 1954, and W. C. Shaw, C. R. Swanson and R. L. Lovvorn in 1953.

In the tests so far reported, rates indicated to be effective have been based on either the agricultural grade of chlordane or of the technical grade. Rates originally indicated by Grigsby were 5 to 25 pounds per acre for pre-emergence control of germinating crabgrass and 5 to 10 pounds per acre in kerosene for post-emergence control of crabgrass seedlings. A preliminary report of Shaw, Swanson and Lovvorn indicated that chlordane applied as a water emulsion, pre-emergence spray did not produce observable herbicidal or growth effects upon a number of crop plants and weeds including crabgrass. However, later work by Shaw (correspondence) indicated that 90 lbs. per acre of agricultural grade chlordane was necessary for adequate crabgrass control with a single pre-emergence application. The work of Dybing, Fults and Blouch was based on pounds of active ingredient per acre and not on pounds of formulation per acre. Tests were made under critical greenhouse conditions with seedlings grown in flats and where turf of established perennial grasses was not a factor affecting the distribution of the chemical. Under these conditions chlordane at a rate of both 15 and 30 pounds per acre did not inhibit the first stages of germination of crabgrass. At both rates as well as the untreated controls, the primary root, the coleoptile and the first leaf grew. However, after the initial appearance of the primary leaf and the primary root, growth stopped. Subsequent observations have since indicated that the primary leaf then becomes chlorotic and later turns red, then brown. Tissue at the first stem node becomes swollen, secondary root formation is inhibited.

In numerous field tests made on home owners bluegrass lawns and on plots established on the Colorado State University campus at Fort Collins, Colorado, during the seasons of 1954, 1955, 1956, and 1957, it has been found that a minimum of 60 pounds per acre of actual chlordane were necessary for successful pre-emergence control of crabgrass. This rate is equivalent to 111 pounds per acre of 45 percent agricultural grade chlordane as compared to the 90 pounds per acre indicated as necessary in tests by W. C. Shaw. The equivalent of 111 pounds per acre is 2.8 pints of agricultural grade chlordane per 1000 square feet.

When these rates are compared to amounts of other crabgrass herbicides being used, it is apparent that they are much too high. This suggested that either chlordane had a low toxicity toward crabgrass or

^{1/} The critical work reported in this paper is based on tests with smooth crabgrass, (Digitaria ischaemum).

that the agricultural grade chlordane contained small amounts of highly selective chemical toxic to crabgrass. If it were possible to isolate and test such a material it might have a great deal of value.

The trend of these facts was apparent as early as the spring of 1955. If chlordane was to be successfully used and developed as a selective crabgrass herbicide for wide use in competition with the several other good to excellent chemicals now on the market, the actual chemical in agricultural grade chlordane responsible for its selective toxicity to crabgrass would have to be isolated and tested.

The objectives of the present investigation have been: (a) to discover the chemical or chemicals present in agricultural grade chlordane which give it selective pre-emergence crabgrass herbicidal properties, (b) to compare the toxicity of several different boiling point fractions of agricultural grade chlordane and, (c) to evaluate the toxicity of several isomers of crystalline chlordane and the related chemicals, chlordane epoxide, heptachlor and heptachlor epoxide.

Materials and Methods

The materials used in this investigation were furnished by the Velsicol Corporation of Chicago, Illinois and were received March 25, 1955. Twelve lots of chemicals were received which included reference grade chlordane, five boiling-point fractions of reference grade chlordane and crystalline materials of high purity labeled chlordane, alpha chlordane, gamma chlordane, chlordane epoxide, heptachlor and heptachlor epoxide.

All materials were tested under critical greenhouse conditions where the factors of soil, technique of application, temperature, light and soil moisture were kept as uniform as possible. Tests were made both pre-emergence and post-emergence and evaluations were based on plant counts, height measurements, arbitrary indexes of toxicity and photographic records. In all cases three controls for each test were used. These were deobase + Triton X-51 + water, Triton X-51 + water and water controls.

Summary and Conclusions

Pre-emergence tests

This summary and these conclusions are based on tests made in both July and October, 1955.

1. The pure crystalline "chlordane" is entirely non-toxic to both crabgrass and pigeon grass @ 90, 60, 30, and 15 lbs/acre--if anything, the 30 and 15 lb. rates are growth stimulating to these grasses.

2. When technical chlordane is fractionated, cut A, i.e., lowest boiling fraction (55-CS-12A), Cut B (55-CS-12B), and Cut C (55-CS-12C) are about equal in toxicity and equal to the toxicity of Reference grade chlordane (55-CS-4); Cut D (55-CS-12D) and Cut E (55-CS-12E) are definitely less toxic than the first 3 cuts or the Reference grade chlordane.

3. Cut E has very much the best selective toxicity against crabgrass of any of the 5 cuts or of Reference grade chlordane.

4. Heptachlor is fairly toxic to crabgrass @ 90 lbs/acre but is only very slightly toxic @ 60, 30, and 15 lbs/acre. It is not toxic to pigeon

grass at all @ 15 lbs to 90 lbs/acre.

5. Heptachlor epoxide is toxic to both crabgrass and pigeon grass; its relative toxicity is about the same as reference grade chlordane and Cuts A, B, and C. It has no selective toxicity against crabgrass as compared to pigeon grass.

6. Alpha chlordane is almost entirely non-toxic to both crabgrass and pigeon grass @ 15 to 90 lbs/acre; just very slightly more toxic than chlordane (crystalline).

7. Both gamma chlordane and chlordane epoxide are more toxic to both crabgrass and pigeon grass than alpha chlordane or chlordane. However, the degree of toxicity is only moderate as compared to Reference grade chlordane.

8. All three controls used in these tests were entirely non-toxic to both crabgrass and pigeon grass with the exception of a very slight toxicity toward pigeon grass in one series of tests. The three controls were:

- (a) H₂O + Deobase + Triton X-51
- (b) H₂O + Triton X-51
- (c) H₂O

It was not possible to check H₂O + Deobase because they are not miscible without the Triton X-51. A pure Deobase control was not used because it was only a small part of all formulations tested. Tests on bean leaves of pure Deobase indicated it to have a little less contact toxicity than kerosene.

Summary and Conclusions--Post-emergence Tests

1. None of the 12 formulations tested appeared to have strong selective toxicity against crabgrass as compared to pigeon grass. In fact, there was greater toxicity against the pigeon grass than the crabgrass in the case of Reference grade chlordane, chlordane-Cut A, chlordane-Cut B, chlordane-Cut C, chlordane-Cut D, chlordane-Cut E. In the case of the pure crystalline compounds, after they were discounted for toxicity of the deobase plus Triton, the trend was also toward greater toxicity against pigeon grass as compared to crabgrass.

2. The chlordane-Cut E appeared to have the greatest toxicity of the five fractions tested and was somewhat more toxic than the Reference grade chlordane.

3. All six of the crystalline compounds were strongly toxic to both crabgrass and pigeon grass at the 60 and 90 pound rates. One unit of these materials was also much more toxic than one unit of reference grade chlordane or any of its 5 fractions.

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AMINO ACID METABOLISM IN BEAN ROOTS AS AFFECTED BY DRYING AND 2,4-D

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Bean plants, Phaseolus vulgaris L. var. Black Valentine were sprayed with 2,4-D at the rates of 1 lb., 2 lb., and 4 lb. per acre. Control plants were either (1) untreated and allowed to grow naturally or (2) uprooted and laid on the greenhouse bench. The plants were treated at three weeks of age and the roots harvested at 1, 4, 11, and 18 days after treatment for study of the nitrogen fractions. Both the protein nitrogen, the free amino nitrogen and the individual free amino acids decreased much more rapidly in the roots of the 2,4-D treated plants than in the control plants growing without treatment. The change was however, as much or more striking in the roots of the uprooted plants, suggesting that the change is characteristic of damage or death and is not specific to 2,4-D. The pattern of individual amino acid changes did not vary between groups. (Washington Agricultural Experiment Station).

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THE INTERACTION OF GIBBERELLIC ACID AND 2,4-D

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Numerous studies have been made on the translocation of 2,4-D. It is generally accepted that 2,4-D is a more effective herbicide in plants which are in a high state of metabolic activity than those in a low state of metabolic activity and also more effective in plants which are growing rapidly than those which are growing slowly. This increased effect in the more active plants is thought to be related to an increase in translocation. Since gibberellic acid is a dramatic growth stimulant, a study of the effect of gibberellic acid on the translocation and toxicity of 2,4-D was undertaken.

Methods

Uniform red kidney bean plants (Phaseolus vulgaris L.) with the first trifoliate leaf just starting to unfold was selected for the experimental material. One half of the plants were sprayed to "run-off" with a 100 ppm solution of the potassium salt of gibberellic acid forty-eight hours prior to the 2,4-D application. Forty-eight hours after the gibberellic acid application a slight effect was noted by an increase in the rate of elongation of the bean plants. Twenty-four hours after the gibberellic acid application no increased elongation of the bean plants was noted. Ten micrograms of radioactive 2,4-D in 10 lambda of ethyl alcohol (95%) was applied to a six to eight square cm area in the center of the upper surface of one of the primary leaves of the bean plants. The 2,4-D was labeled with C¹⁴ in the carboxyl position and had a specific activity of 0.47 millicurie per millimole. The plants were harvested twenty-four, seventy-two, and one hundred and twenty hours after the 2,4-D

application. The plants were divided into two parts, the treated leaf and the remaining part of the plant. The experiment was replicated four times for each treatment and harvest time. Autoradiographs were also prepared from similarly treated plants.

The plants were harvested after the desired period of time by dividing the plants into the two parts and immediately placing them into boiling eighty percent ethyl alcohol. The sample was blended for five minutes in a micro Waring blender, filtered through number one Whatman filter paper and given two twenty-five ml washes with eighty percent alcohol. The alcoholic extract and washes were combined and heated on a steam bath until all of the alcohol had evaporated. The remaining aqueous portion (about three ml) was placed in a sixty ml separatory funnel; the beaker was washed with two small portions of water (about three ml) and added to the separatory funnel, the final volume was about ten ml. One drop of concentrated hydrochloric acid was added to the separatory funnel and shaken; the pH was 1.8. Ten ml of anhydrous diethyl ether was added to the separatory funnel. The mixture was shaken for five minutes. The 2,4-D quantitatively moved into the ether layer. When the two layers separated the aqueous phase was removed and discarded. Ten ml of a one per cent sodium bicarbonate solution was placed in the separatory funnel and shaken for five minutes. The 2,4-D quantitatively moved into the bicarbonate phase. When the two layers separated the sodium bicarbonate phase was placed in a fifteen ml centrifuge tube, four drops of concentrated hydrochloric acid was added, mixed and allowed to sit over night; the pH was 1.8. The overnight period is necessary to allow the carbon dioxide to escape prior to the addition of Norite A (activated carbon) and stoppered shaking; without this delay the developed pressure would dislodge the stopper. Ten mg of Norite was added, the centrifuge tube was stoppered and shaken ten minutes; the 2,4-D was quantitatively adsorbed on the Norite. The Norite was centrifuged down and the supernatant solution decanted off. The Norite containing 2,4-D was suspended in two ml of water and placed in a 6.25 square cm cupped planchet. The Norite was allowed to settle to the bottom of the planchet and dried without moving with an infra-red heat lamp; moving prior to drying disturbs the evenly distributed Norite and could give inconsistent counts. The planchets were counted with a thin window GM tube and suitable scaler.

The use of activated carbon to adsorb the radioactive 2,4-D in preparing planchets in very thin layers is an excellent method of obtaining relatively high counts on micro amounts of material. This technique gives a very uniform distribution of radioactive material on the planchet and the amount of Norite used reduces the counts only slightly, due to self adsorption.

It has been demonstrated that 2,4-D is the only radioactive substance isolated from bean plants treated with radioactive 2,4-D when this method is used. This has been shown by the appearance of only one spot on an autoradiograph of a two-dimensional co-chromatogram of the final 2,4-D fraction and pure radioactive 2,4-D.

Results and Discussion

Callus tissue was formed in the plants which were treated with gibberellic acid forty-eight hours before the 2,4-D application, no callus

tissue was formed in the plants which were not treated with gibberellic acid. This callus tissue formation was primarily in the growing point area, but some lateral buds were also affected.

The relative amount of 2,4-D in the non-treated area of the plants at the various harvest times is given in table 1. The percent of the total recoverable 2,4-D in the non-treated area of the plants at the various harvest times is presented in table 2. The relative amount of 2,4-D and the percent of 2,4-D in the non-treated areas of the plant decreased with time in both the gibberellic acid treated plants and the plants not treated with gibberellic acid; however, the decrease in the amount of 2,4-D was substantially less in the gibberellic acid treated plants. Twenty-four hours after the 2,4-D application, the amount of 2,4-D in the non-treated areas of the plant was essentially the same in both treatments, but after seventy-two hours the gibberellic acid treated plants contained twice the amount of 2,4-D, and after one hundred and twenty hours, three times the amount of 2,4-D.

These values are the result of two different processes, translocation and 2,4-D breakdown. It is difficult to determine, with any high degree of certainty, which of these two processes is acted upon by gibberellic acid from the data presented. The gibberellic acid either increases translocation or decreases 2,4-D breakdown in both. Perhaps gibberellic acid inhibits decarboxylation. Additional experiments are in progress to further elucidate the interaction of gibberellic acid and 2,4-D.

Summary

The non-treated areas of the gibberellic acid treated plants contained three times the amount of 2,4-D as the non-gibberellic acid plants five days after 2,4-D application. There was a callus formation at the growing point of the gibberellic acid treated plants. The larger amount of 2,4-D in the gibberellic acid treated plants is due to an increase in translocation, or a decrease in 2,4-D breakdown, or both.

Table 1. The relative amount of 2,4-D in the non-treated areas of the bean plant at various harvest times, expressed in counts per minute.

Harvest time	2,4-D	
	G.A.	No G.A.
24 hours	300 + 64	289 + 66
72 hours	204 + 46	111 + 27
120 hours	166 + 57	57 + 17

Table 2. Percent of total recoverable 2,4-D in non-treated area of plant at various harvest times.

Harvest time	percent of 2,4-D	
	G.A.	No G. A.
24 hours	16.9%	15.9%
72 hours	15.1	8.8
120 hours	12.8	5.1

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PHYSICAL AND CHEMICAL PROPERTIES INDICATIVE OF
 GOOD HYDROCARBON SOLVENTS FOR AQUATIC
 WEED CONTROL IN IRRIGATION SYSTEMS^{1/}

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Introduction

In 1947, personnel of the Bureau of Reclamation, United States Department of the Interior and the Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, working cooperatively at Denver, Colorado discovered that certain coal tar solvents exhibited a pronounced phytotoxic effect on cultures of submersed aquatic weeds. Further studies verified the initial findings in that these emulsified hydrocarbon solvents were effective at relatively low concentrations and for short contact times on troublesome species of aquatic weeds. As the preliminary investigations showed promising results, field trials were made with these solvents and the results corroborated the laboratory findings. From the results of the trial applications a joint report (8)* was issued which outlined the method and tentative recommendations on physical and chemical properties for use of these materials. A later report (9) describes the hydrocarbon solvent method used for control of aquatic weeds and the recommended requirements of the physical and chemical properties of these solvents.

It was recognized early in the development of the solvents for aquatic weed control that a high aromatic content was an important criterion in their effectiveness. Thus the term aromatic solvents^{2/} is commonly used in referring to these hydrocarbons. In their work on control of submersed aquatic weeds, Seale, Randolph, and Stephens reported (7) the herbicidal properties of aromatic solvents appeared to be directly associated with their aromatic content. It was also learned that all aromatic fractions did not produce the same degree of effectiveness. The more effective solvents were generally found to fall within a certain distillation range. Hence, requirements covering certain points in the distillation range were established so that they would include the most effective aromatic fractions.

The requirements of the physical and chemical properties of aromatic solvent water weed killers as they appeared in the initial publication (8) and in a later report by Bruns, Hodgson, Arle, and Timmons (4) have been reviewed closely and the considerable additional data obtained from

^{1/} Contribution of the Bureau of Reclamation, U. S. Department of Interior in cooperation with Agricultural Research Service, U. S. Department of Agriculture, Denver, Colorado.

^{2/} A mixture of hydrocarbons consisting primarily of aromatic hydrocarbon compounds.

* Numbers in parenthesis refer to literature cited at end of paper.

many analyses indicate certain changes would be desirable. Also, a new method of determining aromatics (2) has been adopted and a requirement covering water content has been added to the specifications. Therefore, this study has been made for the purpose of improving the specifications for the purchase of aromatic solvents used for control of submersed aquatic weeds in irrigation systems.

Materials and Methods

American Society for Testing Materials (ASTM) methods were used to determine the distillation range (1), hydrocarbon types (2) and flash point (3). A method from a Federal Specification (6) is used for the water content analysis.

The bio-assay test method used in evaluating the effectiveness of the solvents consisted of treating cultures of aquatic weeds (rooted and excised) with several closely spaced concentrations of the emulsified solvents for a contact time of 30 minutes. At the end of the 30-minute period, the treated water was emptied from the container and the plant material rinsed thoroughly with tap water. Then the container was refilled with tap water and allowed to stand for visual observations of the plant material. An estimated percentage of plant kill was the criterion used in the evaluation of the effectiveness of the solvents.

A suitable nonionic emulsifying agent was used at the rate of 2 percent by volume with each solvent in the bio-assay test.

Results and Discussions

The results of analysis of samples of proprietary hydrocarbon solvents for distillation range and hydrocarbon types are shown in Tables 1 and 2. The flash point determinations are also included.

The data included in Table 1 represent the properties of 10 samples which produced good-to-excellent kill in the bio-assay test. The distillation ranges varied considerably. However, they were rather consistent in that they are in the same general zone. The 80 percent fraction of 10%-90% of all 10 solvents falls within 266° to 382° F.

The percentage of aromatic hydrocarbons is at a high level in all samples. No sample fell below 88.8 percent; the average for the 10 was 92.7 percent.

It is interesting to note that the flash point values although not indicative of phytotoxicity are in close agreement with the average being 85°F.

Table 1. Properties of effective solvents

The distillation ranges including initial boiling point (IBP), end point (EP), and temperature at which 3 percentages by volume were recovered, hydrocarbon types, and flash point values of hydrocarbon solvents which showed good-to-excellent kill in the bio-assay test.

Hydro- carbon solvent No.	Distillation range					Hydrocarbon types			Flash point °F
	Temperature					(percent by volume)			
	°F at 760 mm pressure	IBP	10	50	90	EP	Saturates	Olefins	Aromatics
1	236	266	274	282	302	5.8	3.6	90.6	87
2	267	271	276	279	289	6.6	2.0	91.4	78
3	270	277	277	277	278	11.2	0.0	88.8	84
4	262	277	286	319	394	0.0	4.5	95.5	78
5	271	276	276	277	281	2.1	0.0	97.9	81
6	253	281	292	314	330	8.6	0.0	91.4	80
7	278	287	294	312	329	11.2	0.0	88.8	90
8	282	303	320	373	394	7.1	0.0	92.9	100
9	269	283	305	358	411	0.0	9.0	91.0	84
10	242	274	331	382	414	1.5	0.0	98.5	89

Table 2 contains data on 10 hydrocarbon solvents which produces poor-to-fair kill in the bio-assay test. The distillation ranges of this group varied greatly. A few of them were similar to those of the more effective solvents (table 1), but the majority of them had a higher range.

Also, there was quite a variation in the percentage of aromatics. The lower percentage of aromatics in those samples (Solvents No. 13, 16, and 17) which had a distillation range similar to the more effective solvents is believed responsible for the reduced effectiveness in the bio-assay test. The higher boiling aromatic fractions did not show the same degree of phytotoxicity as did the aromatics having lower boiling points (table 1).

Table 2. Properties of ineffective solvents

The distillation ranges, hydrocarbon types, and flash point values of hydrocarbon solvents which showed poor-to-fair kill in the bio-assay test.

Hydro carbon solvent No.	Distillation range					Hydrocarbon types			Flash point °F
	Temperature					(percent by volume)			
	°F at 760 mm pressure	IBP	10	50	90	EP	Saturates	Olefins	Aromatics
11	209	221	227	236	257	1.6	1.0	97.4	43
12	292	382	449	474	486	0.0	1.3	98.7	146
13	249	288	333	358	391	4.8	17.5	77.7	74
14	428	492	559	644	656	43.5	0.0	56.5	214
15	230	265	324	433	470	6.4	6.1	87.5	63
16	271	295	316	354	382	7.5	19.5	73.0	93
17	271	275	275	278	291	18.0	5.1	76.9	79
18	312	322	325	332	371	3.2	0.0	96.8	115
19	425	439	445	451	454	1.2	0.0	98.8	211
20	221	249	298	349	373	6.1	13.9	80.0	68

The revised tentative specifications recommended for us in purchase of aromatic hydrocarbon solvents for control of aquatic weeds in irrigation systems where short contact times are important to the economy of the method are included in table 3. Changes made in the distillation range requirements are based on data included in table 1 and those from other samples of solvents not included.

The minimum requirement for aromatic content is left at 85 percent, the same as that under Type A solvent (4, 8, and 9), because bio-assay test results indicate that there is a decrease in effectiveness when the aromatic content falls much below 90 percent and a significant reduction when it falls below 80 percent. The minimum requirement for aromatics (75 percent) under Type B solvent (4, 8, and 9) is considered too low, and therefore requirements for this type of solvent are omitted because it does not have any advantages over the requirements listed in table 3.

A requirement on water content was added to the specifications recently because field experiences have shown that excess water in the solvent may cause the emulsifying agent to separate from the solvent and settle out with the water in the form of a viscous liquid.

Table 3. Revised tentative specifications.

Revised tentative specifications recommended for use in purchase of aromatic hydrocarbon solvents for control of submersed aquatic weeds in irrigation systems.

Flash point (tag closed cup), not less than, °F	80
Distillation range, ASTM: D86-54, °F at 760 mm pressure	
Initial boiling point, not less than	240
Not more than 10 percent at	265
Not less than 50 percent at	320
Not less than 90 percent at	380
End point, not higher than	420
Aromatics, ASTM: D 1319-55T, not less than, percent	85
Water content, Method 408.1, Federal Specification TT-P-141b, not greater than, percent	0.2

In many biological tests where industrial or technical grade xylene was used as a standard, it has consistently shown good results in comparison with other hydrocarbon solvents. Its successful use in the field corroborates these findings. Therefore, it is recommended that the quantitative requirements listed for grade B xylene under Federal Specification TT-X-916 (5) be used to purchase industrial grade xylene for use in control of submersed aquatic weeds in irrigation systems (table 4)

Table 4. Specifications for Xylene.

Specifications recommended for use in purchase of industrial grade xylene for control of submersed aquatic weeds in irrigation systems.

Characteristics	Requirements	
	Grade B	
	MIN.	MAX.
Specific gravity at 60°/60°F	0.850	0.870
Distillation		
Initial boiling point at 760 mm pressure	235°F	-
Distillate below 266°F (percent by volume)	-	5
Distillate below 293°F (percent by volume)	90	-
Dry point at 760 mm pressure	-	311°F
Flash point (tag closed cup)	75°F	-

Summary

Studies were conducted to determine the correlation between the biological effectiveness, and the distillation range and percent aromatics of several samples of hydrocarbon solvents. The data presented represent the properties of ten solvents which produced good-to-excellent results in the bio-assay test and of ten solvents which were poor-to-fair in effectiveness.

Revised tentative specifications, based on the physical and chemical properties of the more effective solvents, are recommended for use in purchase of aromatic hydrocarbon solvents for submersed aquatic weed control in irrigation systems. Those hydrocarbon solvents producing the most satisfactory results in the bio-assay test had an aromatic content above 85 percent and a distillation range in which the 80 percent fraction of 10% to 90% fell within 266° to 382°F. Also, 50 percent or more of each of these solvents, except for one, was recovered at or before the 320°F boiling point. Those solvents having the lesser effect on the aquatic weeds either have a lower or higher distillation range, or a reduced aromatic content.

The flash point values for the better hydrocarbon solvents were relatively uniform, ranging from 78° to 100° F.

A water content requirement was added to the specifications to cover excess water in the solvent. Excess water (greater than 0.2%) may create a problem when the emulsifying agent is added to the solvent by causing a separation and settling of the emulsifier and water.

The consistently good kills produced by technical grade xylene in bio-assay tests indicate the effectiveness of this hydrocarbon for use in aquatic weed control. Federal Specifications covering industrial grade xylene are included and recommended for use in purchase of xylene for aquatic weed control in irrigation systems.

Acknowledgements

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OPERATION AND MAINTENANCE COST SAVINGS FROM USING AROMATIC SOLVENTS TO
CONTROL PONDWEEDS IN IRRIGATION SYSTEMS

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Saved \$374,000 in operation and maintenance costs, the result of chemical control of aquatic weeds during 1957. Fifteen cents of every dollar spent in the operation and maintenance of the 160,000-acre project operated by the North Side Canal Company at Jerome, Idaho, represents the cost of controlling pondweeds in laterals and canals according to a report made by Manager Carroll F. Wilcomb. This report was presented at the Region 1 Annual Irrigation Operators' Conference held at Boise, Idaho, February 13 and 14, 1957. Mr. Wilcomb's report compares the cost of controlling pondweeds with chemical treatment of aromatic solvent and by chaining. Chains, disks, and similar equipment, drawn along the bottoms of the streams by horses or tractors on each bank, have been used since the beginning of irrigation in the West in breaking pondweeds loose from the bottom of irrigation streams. Such weeds and other debris torn loose from the stream bed are floated to a central collecting point for removal by hand, dragline, or by flushing into some wasteway area. In the event laterals or canals are not provided with roads, which is often the case on some of the older projects, operating forces must resort to removal of the pondweeds by hand or by drying the ditch for 3 to 4 days. Chemical control is accomplished by introducing aromatic solvents into the infested stream at concentrations of 600 to 740 ppm over a period of 30 minutes. Disintegration and sloughing of the pondweed leaves and stems are usually slow, and consequently, removal from the stream is unnecessary. Under most conditions chemical control is more complete and lasts one-third longer.

In 1956, Mr. Wilcomb adopted the practice of controlling pondweeds with aromatic solvents in all laterals carrying 30 cubic feet per second or less, which required 7,335 gallons of aromatic solvent. The increased use of this chemical method made it possible to eliminate one complete chaining crew (2 caterpillar tractors and 7 men) during the entire mowing season and to release another chaining crew three weeks earlier than usual, all of which resulted in a saving of \$13,709.

In commenting on this saving, Mr. Wilcomb pointed out that, while this saving was substantial (approximately 28 percent of his total cost of removing pondweeds), probably the greatest savings and one which was difficult to measure in dollars was the improved service that he was able to give in the delivery of water, savings in water losses, and increased crop yields.

Savings of this kind through the use of aromatic solvent have resulted in the adoption of this practice by irrigation projects throughout the Pacific Northwest. While some projects continue to chain their larger laterals and canals, others use this method in controlling pondweeds in canals which carry as much as 100 to 150 cubic feet per second. Some projects rely entirely on chemicals for removal of these weeds from their laterals and canals.

If we assume that each of the 200,000 gallons of aromatic solvent used on irrigation projects in Idaho, Oregon, and Washington during 1957 was as effective as that used by the North Side Canal Company and resulted in an equal saving to the users, we have an estimated total saving of \$374,000, calculated as follows:

\$13,709 total saving, North Side Canal Co.	= \$1.87 saving p/gal. of aromatic solvent used.
<u>7,335 gal. aromatic solvent used</u>	

200,000 gal. used, Region 1, 1957
 x \$1.87 saving p/gal. of aromatic solvent used
\$374,000 estimated total saving to reclamation projects through the use of aromatic solvent in controlling pondweeds in irrigation laterals and canals in Region 1 (Oregon, Washington, Idaho, and western Montana.)

A word of caution.--Savings such as this can be had on most irrigation projects if due caution is taken in selecting and applying aromatic solvent. While methods used in selecting aromatic solvents for aquatic weed control are not infallible, if they are adhered to, an effective product can be selected. The best aromatic solvent on the market will not give good kills unless it is free of water and mixed with a top-grade emulsifier and, like other chemicals, it must be applied in a manner that will insure its reaching the plants in adequate quantities at the proper time. This \$374,000 saving through the adoption of this improved practice was made possible by research. (Bureau of Reclamation, Boise, Idaho)

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PROFITS FROM RESEARCH ON CONTROL OF AQUATIC
AND DITCHBANK WEEDS ON IRRIGATION SYSTEMS

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Profits from research on the control of aquatic and ditchbank weeds are much more difficult to measure than are profits from research on control of weeds in fields, horticultural and pasture crops. Profits from weed control in crops can be measured directly by the effect of improved control methods on crop yields or animal gains and by the effects on cost of production. The only "crop" produced by irrigation and drain canals and ditches is water, and water is difficult to translate directly into dollars and cents. Also losses of water from irrigation canals and reservoirs are hard to measure. It is difficult to determine accurately how much of the water losses are due to weeds. However, such an attempt was made by the Bureau of Reclamation in 1947. As the result of a survey conducted in that year by the Bureau of Reclamation, it was estimated that aquatic and ditchbank weeds in the 17 Western States were causing water and crop losses and requiring weed control costs amounting to 25½ million dollars on the approximately 130,000 miles of irrigation canals and ditches in the West.

Weeds cause losses on irrigation systems by reducing flow and delivery of water to cropland, by raising the water level and causing increased evaporation and seepage, by transpiring large quantities of water needed by crops, by interfering with the proper maintenance of canals, by causing overflows and canal bank breaks, and by various other means.

At the time of the Bureau of Reclamation's survey in 1947 the methods of weed control on irrigation systems were expensive, tedious, slow, and often not very effective. They included handcutting, forking and shoveling, mowing, burning with oil, disking and chaining to control water weeds, draglining and dredging to remove cattail and other aquatic growths and silt from channels, spot treatment of noxious perennial weeds with sodium chlorate and a few other soil sterilants. 2,4-D was used only on a limited trial basis. With these methods the best that irrigation districts and water user organizations could do was to fight a defensive battle against weeds. Despite their best efforts, weeds were gaining on many or perhaps most areas.

Research on control of aquatic and ditchbank weeds was begun in 1947 and 1948 by the Agricultural Research Service and by the Bureau of Reclamation, working cooperatively. Some research had been done before by a few state experiment stations. The research on aquatic and ditchbank weeds was only a small fraction of the research on cropland and range weeds but several improved methods were developed and immediately adopted by federal and private irrigation organizations. There has been great improvement in weed control on irrigation systems during the past 10 years and much of that improvement is due to better methods of control developed by research.

There are no overall figures available on the amount of water and crop losses that have been prevented by the better methods of weed control or on the reduced costs of weed control. However, at the present time our aquatic and non-cropland group of the Agricultural Research Service and the Bureau of Reclamation regional offices are conducting a survey to obtain information on the extent of different kinds of weed infestation on irrigation systems, on losses from different kinds of weeds, on comparative costs of different methods of control, and on the benefits from weed control. We hope to develop regional and national summaries from this information that will add greatly in evaluating the progress that has been made and in revealing problems that require further research. A year from now it should be possible to make a much better report on the profits from research on control of aquatic and ditchbank weeds on irrigation systems.

Despite the lack of overall statistics on present losses from weeds and on profits from improved methods of control, considerable information is available as examples of rather startling profits from improved methods of controlling weeds on irrigation systems. Sources of such information are the annual weed control reports of Bureau of Reclamation regional offices. Other sources are the reports of private irrigation companies that keep cost records on their operations.

One of the examples of the benefits and profits from improved methods of weed control on irrigation systems is provided by the Imperial Irrigation District of southern California. This District has 3,100 miles of canals and drain channels which irrigate and drain approximately 400,000 acres of land. Superintendent Oscar L. Fudge reported at the joint meeting of the 15th Western Weed Control Conference and the 8th Annual California Weed Conference at Sacramento, California, in February 1956, that during the 5-year period, 1945-1949 inclusive, when burning with oil burners was the only method of weed control, the Imperial District spent \$1,318,000 on weed control. The operation was confined to the inside of channels but it was still necessary to burn an average total of 22,000 acre-miles of ditchbanks each year because of the frequency of burning required. During the next 5-year period, 1950-1954, inclusive, the Imperial District spent \$1,388,500 on spraying with 2,4-D and with contact oils and on burning, with chemical treatment being the major operation. This combined operation was not confined to the inside of channels but covered a major part of the right-of-way. Despite the increased scope of the program, it was necessary to cover only 10,700 acre-miles per year because of the fewer treatments required.

Mr. Fudge stated that the improved chemical methods made it possible for his District to change from a defensive program to an offensive control program and to make important gains in eliminating aquatic and ditchbank weeds at very little increase in cost despite rising prices. During the years 1947-1954, rapid progress was made in eliminating the jungle-like growth of arrowweed, salt cedar, willows, Johnson grass, and other weeds from the ditchbanks and reducing cattail and water weeds in the channels. As Mr. Fudge expressed it, "We are now able to shut down our equipment for 60 days or more each year for a complete overhaul. We can drive down the roads and see the fields beyond our ditchbanks and we are helping the farmer to reduce his insecticide expenditures."

During 1955 to 1957 the Imperial Irrigation District was able to extend its improved chemical methods to begin the successful elimination of several serious weed problems that had resisted all control efforts before. The District sprayed an average of 4,729 acre-miles of cattail and woody growth with a 2,4-D-TCA mixture and sprayed an average of 3,729 miles of phragmites with dalapon. In 1957 only 602 acre-miles of ditchbank were burned as compared to 6,500 acre-miles in 1955 and 22,000 miles per year during 1945 to 1949. Thus, improved chemical methods have replaced oil burning and spraying almost completely. Mr. Fudge did not report any statistics on the amount of water and crop losses saved in his District due to the improved weed control but these savings must have been considerable.

The Bureau of Reclamation Region 1, which comprises the states of Washington, Idaho, most of Oregon, and a small part of Wyoming, has reported some outstanding reductions in weed control costs due to improved methods developed by research. Mr. Dean Boyle of Region 1 in his report at this meeting has shown that on the basis of accurate records kept by the North Side Canal Company at Jerome, Idaho, the estimated saving from the use of aromatic solvent for waterweed control in Region 1 during 1947 was \$374,000 as compared with mechanical methods of control. If we project the figures developed by the North Side Canal Company to the total usage of aromatic solvents in the entire country in 1957, we get an estimated savings of \$1,084,600 due to the use of 580,000 gallons of aromatic solvent.

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This saving in one year is approximately 18 times the total cost of all research expenditures by federal agencies during the period 1947-1952 when the aromatic solvent method of controlling submersed aquatic weeds in irrigation channels was discovered and perfected by laboratory and field research.

Cost figures compiled by the Bureau of Reclamation Region 1 showed the average cost of spraying ditchbank weeds with 2,4-D was \$4.55 per acre as compared to the cost of \$10.42 per acre for spring burning and \$24.67 for seasonal mowing. The cost figures compiled by the Bureau of Reclamation Region 2, which comprises most of California and part of southern Oregon, show the average cost of spraying ditchbank weeds with 2,4-D to be \$5.63 per acre as compared with the average cost of \$14.31 per acre for mowing, \$16 per acre for oil spraying, and \$20.23 per acre for spring burning. The average saving from using 2,4-D as compared to the older methods was \$9.88 per acre or \$23.82 per mile of irrigation ditchbank. If this average saving were projected to the total mileage of irrigation canals and laterals in Regions 1 and 2 it would indicate a potential total saving of \$1,187,856 annually in the cost of controlling ditchbank weeds in the two regions.

The average cost of controlling cattail with 2,4-D in oil-water emulsion spray in Regions 1 and 2 has been \$24.12 per mile. The average cost of cleaning cattails, tules, and other aquatic growths and accumulated silt out of canals and drains with a dragline was \$407 per mile. It was reported that in heavily infested channels it was necessary to dragline every 3 to 5 years and in some instances, every year to remove obstructive weed growth. Draglining was reported to be necessary at least twice as often where cattail and other weed growth was present as when no weed growth was present. Thus, even if chemical treatment of cattail were necessary once every three years, three such treatments at a total cost of \$72 per mile each 10 years would save one dragline treatment costing \$407 per mile. No statistics are available on the total mileage of canals and drains that are infested with cattail and tules but it is considerable in California and parts of the Pacific Northwest. Our survey now being made should provide information on that subject.

Cost figures compiled by the Bureau of Reclamation Region 4, which comprises Utah, Nevada, western Colorado, and southwestern Wyoming, revealed some interesting comparisons of costs of different methods of controlling aquatic and ditchbank weeds. The average cost of spraying with 2,4-D in that region has been \$7.16 per acre or \$15.28 per mile. The average cost of spraying with 2,4,5-T for control of woody plant growth has been \$31.36 per mile. The average cost of the common practice of spring burning to eliminate dead weed growth from the ditchbanks and accumulated weeds from the channels has been \$41.91 per mile. Experience has shown that where weeds are controlled with 2,4-D during the growing season it greatly reduces the amount of weed burning necessary the next spring. Comparable costs indicate that controlling ditchbank weeds with 2,4-D instead of letting them grow and then burning the dead growth each spring saves \$26.63 per mile in operating costs in addition to eliminating or greatly reducing weed seeds produced to reinfest ditchbanks and adjoining farmlands. If this average saving were projected to the total mileage of irrigation and drain canals in Region 4, it would suggest a total potential saving of \$469,598 annually in the cost of controlling ditchbank weeds in that region.

The average cost of draglining to remove aquatic weed growth and accumulated silt in Region 4 has been \$355 per mile. Chemical treatment of cattails has not been utilized much in Region 4, but experience in other regions indicates that chemical treatment would save at least \$300 per mile in draglining and dredging costs every 10 years in canals and drains infested by cattail.

The problem of controlling ditchbank weeds and woody plant growth on irrigation and drain canal banks in Bureau of Reclamation Regions 3 and 5 is considerably different from that in other parts of the West. These regions comprise the states of Arizona and New Mexico, southern California, western Texas, and western Oklahoma where cotton is the major crop. This prevents or greatly reduces the use of 2,4-D during the growing season and requires more expensive methods of control. However, research by the Agricultural Research Service in Arizona and by state experiment stations in New Mexico, Texas, and California has developed improved methods of weed control with aromatic oil, INBP- and PCP-fortified oils, and oil-water emulsions. Also research by the Bureau of Reclamation and industrial companies has resulted in improved equipment for mowing and burning ditchbank weeds and woody growth. These improved chemical and mechanical methods have made possible the effective control of Johnson grass, willows salt cedar, and other ditchbank weeds at costs of \$18-\$38 per mile where previously adequate control was almost impossible in this area of long growing seasons and high temperatures where weeds grow luxuriantly along irrigation systems. Now, with the development of amitrol and dalapon for the control of cattail and rank-growing grass species, the costs of draglining can be greatly reduced even in the cotton growing areas and the costs of controlling Johnson grass, phragmites, and Arundo donax can be reduced as compared to the cost of oil-spraying or burning.

Interesting information on profits from research on control of weeds on irrigation systems comes from Bureau of Reclamation 6, which comprises Montana, north central Wyoming, and the western part of the Dakotas. This region has attempted to determine the amount of water and crop losses which have been prevented by weed control on irrigation systems. In 1949 the ratio of benefits from weed control to costs was estimated at 7.4:1. On this basis the profits from weed control on irrigation systems operated by the Bureau of Reclamation in Region 6 was \$497,088. If we projected that ratio and that cost of weed control to all irrigation systems in the 4-state region, the total potential profit from weed control would be \$1,933,614. Since 1949 the reduction in costs of weed control probably has increased the ratio of benefits to costs of weed control.

The average cost of treating herbaceous ditchbank weeds with 2,4-D in Region 6 was \$6.93 per acre or \$10.03 per mile. The cost of spraying willows and wild rose was \$28.35 per mile. Rank growth of willows and wild rose along irrigation canals is one of the chief weed problems in Region 6. The average cost of clearing canals of such woody growth during the winter season by mechanical methods has been \$400 per mile. Spraying with 2,4-D and 2,4,5-T now provides a method of eradicating the woody plant regrowth and keeping canal banks clean after the expensive mechanical clearing operation.

Cattail is another serious problem in Region 6. Previous to the development by research of the method of using 2,4-D in oil-water emulsion

for cattail control, draglining at a cost of \$418 per mile was the only available method of removing cattail from drains and low velocity delivery channels. Now the cattail can be eliminated just as effectively with the 2,4-D in oil at an average cost of only \$43.42 per mile.

In the 1956 report from the Riverton, Wyoming, project it was stated that "One of the main benefits of 2,4-D spraying has been the virtual elimination of weed burning on the project. Weed burning has been costing as much as \$18,000 in one year. There has been much damage done to farms and other property in past years by fires that got out of control when burning weeds in ditches. The willow infestation which was a serious problem on the project in 1948 as now been completely eliminated by 2,4-D."

The limited cost figures from Bureau of Reclamation Region 7, comprising eastern Colorado, eastern Wyoming, western Nebraska, and western Kansas, indicate similar cost relationships between different methods of weed control to those reported for Region 6. The survey study now under way is expected to provide reliable information for Region 7.

The examples given were, in some instances, based upon direct comparisons and accurate records and in other instances were based on rather rough indirect comparisons. For the most part the measurements or estimates of profits from improved methods of weed control in irrigation systems were conservative. If all of the examples reported were projected to the total mileage of irrigation and drainage canals and ditches in the 17 Western States, it would indicate a potential annual profit from improved weed control methods developed by research of approximately 4 1/2 million dollars. This figure does not include the saving in costs from improved methods of controlling cattail and woody plants or the value of water and crop losses prevented by improved methods of weed control on irrigation systems. Even so, this amount is more than 18 times the total amount spent for research on control of aquatic and ditchbank weeds in the 17 Western States during the 10-year period, 1947-1956. It is more than 70 times the cost of the much expanded federal research program on aquatic and ditchbank weeds in the western region in 1958.

Despite the rapid progress during the past 10 years in improving methods of controlling weeds in irrigation systems, much remains to be done by research. Several methods of weed control still are too expensive and we lack effective methods for some problems. We need more effective and less expensive methods of controlling submersed aquatic weeds, especially in large canals with capacities above 100 cfs, including those of 1000 to 4500 cfs in California and Washington where serious submersed waterweed problems are developing in the extremely large canals. We need less expensive and more efficient chemical methods for cattail. We need much more effective chemical methods for controlling salt cedar without hazards to cotton. We need better adapted grasses for ditchbank seeding to provide competition with ditchbank weeds and better grasses for competition with weeds in seepage and other weed areas along irrigation systems. We have promising leads for answering many of these needs. It seems logical to predict that the profits from research on control of aquatic and ditchbank weeds on irrigation systems will be even greater in the future than they have been during the past 10 years.

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PROFITS FROM RESEARCH ON CHEMICAL CONTROL OF SAGEBRUSH

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The sagebrush-grassland type of range is one of the most extensive of the western region. Of the approximately 96½ million acres in the eleven western states, Wyoming is blessed with 20 million, or about one-fifth of the total.

Most of these sagebrush-grass type rangelands are potentially productive, but these large areas now support plants of low forage value. Increasing land values, shortage of additional rangeland, economic requirements for more efficient production, and increasing need for more livestock products point to the need for greater production on our sagebrush lands.

Considerable interest has been created in the control of sagebrush and many ranch operators are anxious to know what methods can be used and if such programs would be a paying proposition.

Prior to the advent of selective weed killers in 1944, eradication was accomplished by raiiling, spring-tooth harrowing, disc plowing, water spreading and burning. Many of the mechanical treatments were found to be costly, and could not be adapted to much of the sagebrush areas where control program could be an economical venture. Although it has been shown that an increase in forage yield of 200 to 300 percent can eventually be realized by burning, only the chemical control of sagebrush and its effect upon production and utilization of the associated native forage species will be discussed in this paper.

Research on control of sagebrush by chemical means began soon after World War II. As early as 1946 and 1947 Cornelius and Graham of the California Forest and Range Experiment Station showed that sagebrush was susceptible to various formulations and concentrations of 2,4-D with production of forage from sprayed plots averaging 2.5 times the yield that the same grasses produced on the unsprayed plots. Probably the first research project of any magnitude which has been reported was a cooperative investigation in Central Wyoming and Colorado by the U. S. Forest Service and Bureau of Land Management undertaken in 1949. The Wyoming experiment was located in an area which could be considered as marginal from the standpoint of a sagebrush eradication. Annual precipitation is approximately 14 inches per year with the herbaceous understory covering only 8 to 10 percent of the ground. Native grass production was increased 2 to 3 times its original production, or from 220 pounds of air-dry forage per acre on the unsprayed plots to 590 pounds per acre where 60 to 97 % of the sagebrush was killed.

There has been great improvement in control of sagebrush during the past 10 years and most of this improvement can be attributed to the development of research programs. No effort has been made to evaluate the research programs as to the first individuals or research stations engaged in such programs, but rather to bring together the overall program of the western range states as reported by the different organizations.

There appears to be no summarized information on the total amount of sagebrush which has been sprayed in the western region the past 10 years. A survey conducted in Wyoming in 1957 shows there has been approximately 60,000 acres of sagebrush-grass type rangeland sprayed since 1953. No doubt several of the other states have equal sized programs in progress.

Even with the lack of overall statistics on the present acreage under chemical control program, considerable information is available from which to draw numerous examples of the benefits derived from controlling sagebrush on our western ranges. Most of the sources of information have been reports by Experimental Stations, Bureau of Land Management, U. S. Forest Service and individual cooperators.

A good example of the benefits and profits from chemical sagebrush control is reported by A. E. Miller in the August 1957 Soil Conservation publication. Mr. Miller reported that sagebrush spraying on a Washington range resulted in a three-fold increase of grass forage. The sprayed area produced 780 pounds of grass forage and the unsprayed 185 pounds of grass per acre. To put it another way: He states, "If 50 percent of the total grass production is utilized, the comparative stocking rates should be one A. U. M. (animal unit month) of grazing for each two acres on the sprayed plot, and one A. U. M. grazing for 8.7 acres on the unsprayed plot." For each 500 acres sprayed this would mean there had been an increase in grazing capacity from 58 to 250 A. U. M.'s. It was also reported increased gains on yearlings from 5.6 to 17.6 pounds per acre. This gives an increase of 12 pounds of beef per acre. If we can value each pound of beef increase at 25 cents per pound this would be \$3 per acre return each year contributed to the chemical control program. The original cost of \$4 for chemical and application could be realized within a span of two years.

Mr. E. R. Jackman, Oregon State College, reporting in the August 1957 Farm Journal, lists several ways a rancher can spend \$1,000 to increase his grass production. Mr. Jackman states that \$1,000 would pay for the chemical spraying of 333 acres which would give an additional 40 tons of feed each year.

Range improvement studies at the U. S. Southern Great Plains Field Station, Woodward, Oklahoma show annual net returns of \$7.70 per acre from sand sagebrush controlled pastures while the untreated pastures made \$4.52. Brush control increased profits \$3.18 per acre.

The chemical control of sagebrush in various areas of the western region vary little from the programs which are being carried out in Wyoming.

Since I have been working with the Wyoming project the past five years, I should like to evaluate our sagebrush control program. Two areas in the Bighorn Mountains in northern Wyoming comprising approximately 310 acres was used to obtain data for the evaluation of a chemical sagebrush control program. The experiment was initiated in 1952 and production, utilization, and sagebrush seedling studies have been conducted each year since that time.

The common native grasses can be expected to increase production from 100 to 150 percent the first year following spray application. Production of these grasses have increased over a five-year period to where the range is showing a three-fold forage yield. Average of the five-year period shows the unsprayed areas producing 526 pounds of air-dry forage per acre as compared to 1,668 pounds where 75 percent or more of the sagebrush has been controlled. In addition, this increased production has been shown to be more accessible for livestock use. In such areas, livestock have utilized 60 percent of the forage production compared to only 25 percent where the sagebrush has not been controlled.

Average Pounds of Air-Dry Grass Production Per Acre ^{1/}

Date	Percentage Sagebrush Control Areas			
	0	50-75	76-95	96-100
1953	478	659	774	1128
1954	480	769	1013	1347
1955	331	1254	1950	1938
1956	590	960	1762	2340
1957	758	1104	2026	2413
Average	526	949	1505	1833

^{1/} Figures represent the total air-dry grass produced per acre within sagebrush controlled areas based upon random 2.5 sq. foot clipped quadrates.

In spite of the high percentage of utilization on the sprayed areas, more grass is left at the end of the grazing season than was originally on the area.

In evaluating a chemical control program, one must determine the economic value from the standpoint of whether the land is privately owned or whether the land is government controlled. The United States Forest Service, Bureau of Land Management and the Agricultural Stabilization and Conservation groups have accepted the use of herbicides to control sagebrush as a range-improvement technique and are cooperating with the individual operators throughout the western region. However, there is still some opposition by individual ranch operators. They cannot see investing \$3 to \$4 per acre into any control program when they only pay 19 cents per head of cattle per month for the privilege of grazing their livestock on these lands.

Grazing Fees on Government Controlled Land

Grazing Area	Acres/Mo ^{1/}	Return/A
Unsprayed	3.0	\$.06
Sprayed	.8	.23

^{1/} Refers to number of acres required to carry one cow and calf one month.

The cost of controlling sagebrush with 2,4-D compounds average \$3 to \$3.50 per acre. With the 3 and 4-fold increase in forage production on the experimental areas, it requires three acres of untreated land to carry a cow and calf for one month compared to .8 of an acre of treated land. This would represent a return to the government of 6 cents per acre from the unsprayed lands and 23 cents per acre from sprayed land, or an additional 17 cents per acre, per year credited to the chemical sagebrush control program. When other benefits are not taken into consideration, one can readily see where the remark, "It will take twenty years to pay for such a program," comes from.

Now let's look at the same situation only from the standpoint of private land-owners. Many of these operators have a limited amount of acres from which to base their operations. They are interested in increasing the carrying capacity of their lands and in many cases this is necessary for them to remain in business. If we project the results of the experimental data and that from private ventures we get a completely different picture than the one presented above.

Five-Year average forage production and return per acre.

Grazing Area	Pounds Forage Utilized	Pounds Gain/Day	Pounds Gain/Acre	Return/Acre Per Year
Unsprayed	263	10	20	\$ 5.00
Sprayed	916	36	72	18.00

If we work with average figures such as: two pounds of beef animal gain per day, a feed requirement of 25 pounds of air-dry forage per day, and a value of 25 cents per pound of beef, the following figures can be presented: (1) With livestock utilizing 50 percent of the available forage on both areas, the unsprayed range would yield 263 pounds of air-dry forage, as compared to 924 pounds on the sprayed range. (2) The requirement of 25 pounds of air-dry forage per head per day would give 10 and 36 days of grazing for the respective areas. (3) Two pounds of gain per day would show 20 pounds of beef produced on the uncontrolled area and 72 pounds on the controlled area. (4) With beef selling for 25 cents per pound, there would be a return of \$5 per acre and \$18 per acre, or an additional \$13 credited to the chemical sagebrush control program each year.

The examples I have given you have not been subjected to severe scrutiny or economic analysis. For the most part the estimates of profits resulting from sagebrush control programs are conservative and are not as fictitious as they may sound.

In closing I would like to include a March 1958 news release by D. W. Bohmont, Wyoming Agricultural Experiment Station, entitled, "Research Pays Dividends."

If someone were to offer you four dollars for each one dollar you have you would accept the offer and look for more. That is the situation which has resulted from the experiment station research project on sagebrush control. Of some 20 million acres of sagebrush in Wyoming, a large part would profit from the chemical removal of this low-productive and

unpalatable shrub. For an investment of \$3 to \$3.50 per acre the rancher can realize a forage yield increase of 200 to 400 percent each year. With an assumed value of \$10 per ton of forage increase, the total spray bill is paid in one year. The following years are pure profit. At present over 50,000 acres have been sprayed. This has given a profit, in any one year, of over \$4 for each \$1 originally invested in the research program, and the end is not in sight! Many ranchers have embarked upon a long-term spray program to improve a small part of their range each year. In addition, the federal management agencies have started to utilize the spray program as a means of improving spring-fall rangeland. Chemical sagebrush control is an example of the profitable improvement of our rangeland through research, as well as a lasting return.

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BIOCHEMICAL AND PHYSIOLOGICAL PROPERTIES OF BROWN AND BLACK
SEEDS OF HALOGETON GLOMERATUS

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Halogeton glomeratus is a poisonous member of the Chenopodiaceae which immigrated to the Western United States from Asia. Its dissemination has been extremely rapid. Drought and range misuse have combined to hasten its spread and halogeton has now invaded each of the 11 western states except Washington, Arizona, and New Mexico. Halogeton now infests an area exceeding $11\frac{1}{2}$ million acres and its spread continues at a rate of one-third million acres per year. The extremely high oxalate content, particularly in the leaves, makes this plant quite toxic. Losses in the sheep industry are now infrequent primarily because sheep no longer graze in heavily infested areas. The acreage rendered unsafe for grazing because of the presence of halogeton now constitutes a much more severe economic loss than the number of sheep killed.

Halogeton produces two types of achenes (hereafter referred to simply as seeds) commonly termed black and brown. The black are actually a dark chocolate brown and appear smaller than the brown seeds because the embryo is incased in only the integuments and ovary wall. The brown seeds have not only the integuments and ovary wall but 5 adherent bracts which entirely surround the ovary wall. The average black seed weighs 500 micrograms while the brown weighs 804 micrograms. The average black embryo weighs 390 micrograms, however, versus 352 micrograms in the brown. The black thus weighs 1.11 times the brown.

The black seeds exhibit strong viability and excellent germination. When seeds of this type are placed on moist filter paper at 8 a.m., emergence and uncoiling occur so rapidly that it is frequently possible to plant the resulting seedlings the same day. The brown seeds, on the other hand, have rarely been observed to germinate under laboratory conditions. They appear to swell only slightly in water and appear, for reasons yet unknown, unable to burst through the protective ovary wall. They do not, however, seem to absorb water as rapidly as the black types

even when excised. Upon excision and under light brown embryos rarely uncoil in fewer than 2 days. At this time a green pigment assumed to be chlorophyll begins to appear in the cotyledons. Excised black embryos uncoil at once. Red pigment forms rapidly in the hypocotyl if the seedlings are under light. Chlorophyll is present in the cotyledons before emergence.

Brown seed production by the plant is not, as some suppose, merely a last effort by the plant to produce another black seed--an effort which is untimely nipped by frost or some other factor causing the death of the plant. The brown seeds are produced first and are already hard and brown as soon as early September in Northern Utah. They cannot, therefore, be termed immature since they are able to complete their normal physiological growth before the black have fully matured. Yet the brown, though fully viable, are so weak, and exhibit such low germinability that it is unlikely that they are more than a slight factor in range infestation. Some have thought brown seeds were merely dormant and that this was nature's way of extending the number of years seed from a given plant could germinate. On the basis of germination of laboratory samples this appears unlikely. Both types of seeds lose their viability at the same rate. Our 1953 samples of brown seeds have no viability at the present time while 1953 black seeds still germinate 27 percent. Viability and longevity are being studied in more detail through a 10 year burial study in Nevada, Utah, Idaho, and Wyoming.

Germination and establishment trials with brown seeds have thus far ended in failure. Seeds harvested in 1954 which had a germination of 50 percent when excised were placed in metal flats at depths of $\frac{1}{4}$, $\frac{1}{2}$ and 0 inches in Curlew Valley during the spring and summer of 1957. The flats were perforated across the bottom and buried so that the tops were flush with the soil surface. The soil had been carefully sifted to remove seeds of any other species. No seedlings were observed in the flats at any time. This experiment is being repeated using seed from 1954 through 1957. In this latter test, however, the flats were placed between the greenhouses on the Utah State campus so that daily observations could be made. Since the trials were begun December 23, 1957, no brown seeds have been observed to germinate. Black seeds, planted under the same circumstances and at the same time began germinating during the Christmas holidays. As of February 18, germination in the black type has ranged from 22 percent in 1953 seeds to 80 percent in 1956. Establishment has been particularly good from black seeds placed $\frac{1}{4}$ inch beneath the soil surface.

Biochemical analyses of major embryonic constituents have been completed during the past year in an effort to determine the factor or factors responsible for the vast differences in appearance, germination, and establishment between the two types. The analysis for various elements was done by the Soil Laboratory at Utah State. The analyses for reducing sugars, sucrose, starch, protein and oxalic acid were accomplished by the author using standard colorometric methods or, in the case of oxalic acid, by calcium precipitation.

Brown and black seeds were soaked in distilled water until such a time as their embryos could be excised. Three grams of dried embryos of each type were digested separately in 1:1 mixtures of nitric and

perchloric acid, evaporated to near dryness, and brought to a final volume of 100 cc with distilled water. The samples were analyzed for sodium, potassium, calcium, magnesium, strontium and iron.

Table 1. Inorganic constituents of brown and black embryos of Halogeton glomeratus

	Parts per million in plant material					
	Na	K	Ca	Mg	Sr	Fe
Black embryos	1290	5800	2400	3460	7	24
Brown embryos	1580	5870	620	3400	15	53

The only difference of importance is in the calcium content of the two seeds. It would appear that this element is deficient in the brown seed. It is, of course, impossible to say whether this quantity is sufficiently low to interfere with the normal metabolism of the seed since there is no way of determining what minimum requirements are. Efforts to stimulate germination by placing the seeds in solutions containing soluble calcium were not successful.

In the remaining experiments, entire seeds were used. The reasons for this were twofold: The excision of embryos was laborious and costly, and the organic constituents to be analyzed were almost entirely confined to the embryo.

Since it seemed possible that poor germination in brown seeds could be traced to lack of carbohydrate materials, both types of seeds were tested for reducing sugars, sucrose, and starch. Standard colorimetric methods were used. The seed used was harvested in late October and early November 1957 from west of Snowville, Utah.

Table 2. Chemical analysis of brown and black seeds of Halogeton glomeratus for reducing sugars, sucrose, and starch

	Micrograms		Micrograms		Micrograms	
	reducing sugars	Ratio	sucrose	Ratio	starch	Ratio
	per seed		per seed		per seed	
*Black	3.93	1.78	37.5	2.05	26.8	
*Brown	2.20		18.3		68.3	2.55
*Mean of 5 samples					Black	Brown
Average % of sugars occurring as reducing sugars					7.01	9.80
Average % of sugars occurring as sucrose					92.99	91.20
Average % of carbohydrate reserves occurring as sucrose or reducing sugars					59.00	21.90
Average % of carbohydrate reserves occurring as starch					41.00	78.10
Average total carbohydrate reserves in micrograms per seed					64.40	86.60

Black seeds contain more than 1 3/4 times as much reducing sugars and twice as much sucrose as the brown. Since these sugars are available in great amounts in the black seeds, it is not surprising that they are able to respond so readily to favorable conditions for growth.

It was assumed that this favorable excess of reserves would be found when the seeds were analyzed for starch but the opposite results were obtained. The brown seeds contained more than twice as much starch and apparently store their reserves chiefly in this form. About 78 percent of the total carbohydrates in the brown seeds are found as starch and 22 percent as reducing sugars and sucrose, with the reducing sugars constituting a relatively small portion of the total. Black seeds, on the other hand, have sucrose as their principal reserve. Nearly 60 percent of the total reserves are in the form of sucrose or reducing sugars, and only 40 percent are found as starch. Again, reducing sugars constitute a relatively small portion of the total sugars initially available to the embryo.

Protein analysis of the two seed types again revealed striking differences. Black seeds usually had at least twice as much protein per seed as the brown and frequently samples exhibited even stronger ratios. Black seeds contained around 165 micrograms of protein per seed while the brown averaged 80 micrograms per seed.

A test was next run on both seeds to determine whether enzymatic catabolism of starch was slower in the brown seeds because of the smaller quantities of protein. Seeds were ground in a 0.02 M phosphate buffer, pH 6.9 and in a chilled mortar. The extract was incubated in an aqueous solution of soluble starch for 1, 2, and 3 minutes at 20 degrees C. One ml of solution was removed for analysis at each of the above times, 2 ml of Somogyi solution added at once, followed by 5 ml of distilled water. The remainder of the reaction was completed according to the standard analysis for glucose.

Table 3. B Amylase activity in brown and black seeds of Halogeton glomeratus

	Micrograms red. sugar 30 seeds	Increase in micrograms red. sugars 30 seeds	Micrograms red. sugars per mg protein
Black--control	106	--	40.77
Brown--control	54	--	50.90
Black--1 minute	164	58	63.07
Brown--1 minute	110	56	101.80
Black--2 minutes	176	70	67.67
Brown--2 minutes	116	62	107.20
Black--3 minutes	186	80	71.47
Brown--3 minutes	120	66	110.90

B. amylase from the brown seeds catabolized enough starch to result in an increase of 60 micrograms of reducing sugar per mg of protein while black seeds only produced 30.7 micrograms on a protein basis. This could be partly due to the fact that there is less starch in the black seeds, hence a smaller enzyme concentration. The brown seeds are sufficiently capable of breaking starch into reducing sugars to justify the conclusion that lack of enzyme activity, at least B amylase activity, is not the cause of low germinating vigor.

Both types of seeds are very low in oxalic acid. Some investigators have found as much as 8 percent in the seeds, but in the samples analyzed in this laboratory the oxalate content was much lower. Brown seeds averaged 1.80 percent water soluble oxalates while black had 2.13 percent. Correcting the brown seeds for weight and thus increasing the number of embryos, they would have contained 2.00 percent on this basis. This would be little different from the black.

To determine whether any of the differences noted between the two seed types is a significant factor in the inability of the brown seeds to germinate and grow vigorously is difficult to answer. We, of course, do not know the minimum requirements of a seed for these various elements and organic compounds. The brown seeds do not respond to additions of calcium, or calcium and gibberellic acid combinations. Sugar solutions have no effect on germination. Perhaps the most striking of the differences noted here is the nature of the carbohydrate reserves. Starch is the primary product in the brown seeds while sucrose is the major reserve in the black.

Several conclusions can be drawn as to the potential of brown seeds in natural revegetation of halogeton on the range. It is very doubtful that halogeton would survive under natural conditions if only brown seeds were produced. We almost never find embryos of brown seeds emerging in the laboratory and have yet to germinate them in soil either in flats on the desert or in the area between greenhouses. Seedlings started from embryos excised in the laboratory must be given about the same amount of attention as a human infant if they are to survive. One cannot rule out the possibility that they may remain viable for long periods of time under desert conditions but vigor of germination is so low that establishment is almost predestined to failure except under long periods of most favorable conditions.

Studies will be conducted during 1958 at this station to determine the effect of nutrition, light and salt concentration on the ratio of the production of brown and black seeds.

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PROFITS FROM RESEARCH ON CONTROL OF WEEDS IN PASTURES AND RANGELANDS

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Introduction

Weeds and brush infest most of the 536 million acres of grazing land in the 11 western states. Because the losses from these unwanted intruders have not been accurately assessed the data on total losses cannot be presented. However, we know that for each pound of dry matter produced by weeds about an equal amount of more desirable forage could be raised. Partial control of brush on rangelands has resulted in three to eight times as much forage as grown on comparable untreated sites. In addition, poisonous plants cause more financial loss by killing livestock than by crowding out useful forage plants. Limited areas of poisonous weeds kill livestock worth infinitely more than the useful forage the same area could produce.

Other losses from weeds include the reduction in efficiency of managing and handling livestock. In addition, there is less water from springs, wells and streams in many areas because of the brush on the watershed.

Weeds have some value. To maintain proper perspective one should recognize their usefulness. Weeds, except poisonous one, if they are eaten, contribute to the diet of livestock. Weeds cover denuded lands and provide some protection against wind and water erosion. Some weeds and brush even provide a measure of protection for native grasses and prevent their complete extinction by severe overgrazing. However, these values are not sufficient to justify perpetuation of weeds on rangelands. Indeed, in spite of our best possible control efforts, we probably shall continue to have more weeds and brush than are wanted on the rangelands.

Simply controlling weeds that have invaded a range will not correct injuries to vegetation resulting from mismanagement.

Poor range management reduces the vigor of desirable native vegetation and allows invasion of weeds. Vigor of these desirable species can be improved only by good grazing management.

Therefore, for efficient production of forage, good grazing management and production practices must accompany any brush or weed control program. Brush and weeds, however, have encroached even on areas given relatively good management. The infestation of brush and weeds in our grazing lands is a problem that must be solved.

Herbicides may be useful tools in shortening the time required for secondary succession from a weedy range to one of good or excellent condition. Selectively removing competing weeds and brush leaves more moisture, light, and nutrients available for desirable plants. Thus, the recovery and spread of desirable plants can be proportionately much more rapid. The effect of herbicides upon the rapidity of successional changes needs much more research.

The use of insects for control of range weeds should be further exploited. Interrelated studies of the need for revegetation or supplemental herbicidal treatments along with establishment of insects for weed control under some situations may give useful information.

Examples of Potential Returns from Weed Control

Weed control practices must be profitable before an operator will adopt them. However, finding adequate data from which to calculate returns from weed control practices is not simple. Eventually such data must be accumulated. The yield, quality, and other effects resulting from new weed control methods must be compared with those from methods presently used. Such data are essential for evaluation of new techniques.

By using information sent to me or by taking it from publications, I have developed a table giving some examples of potentially increased returns to ranchers who adopt the herbicide treatments available, Table 1. In this table the annual increase in yield of forage resulting from treatment, as well as the estimated costs of treatment, are shown. From this information are developed figures showing annual net gain converted to the annual return if all acres adapted to spraying were sprayed.

Data from D. N. Hyder and F. A. Sneva indicate that spraying big sagebrush increased production of forage 400 pounds per acre in Oregon. D. W. Bohmont and H. Alley got similar results in Wyoming. The value of the increased forage was assumed to be \$10 per ton. The cost of spraying was pro-rated over a 10-year period. The annual net gain was thus \$1.68 per acre. This multiplied by the 24 million acres of sagebrush land adapted to spraying equals an annual return of 40.2 million dollars.

Similarly, spraying low larkspur and sagebrush land potentially would return 1.8 million dollars annually. This value was determined by adding 15 cents per acre, the average loss from poisoning on these lands, to the annual net gain value indicated for spraying sagebrush. Spraying rabbit-brush would return 1.5 million dollars, spraying sand sagebrush (much of which is not in the 11 western states) 16.5 million dollars, and spraying mesquite 10.5 million dollars. Good returns in increased forage resulted from controlling juniper in Arizona, but a practical herbicide treatment has not yet been developed. Mechanical methods of burning have been used, but cost figures vary widely. Also, in mountain meadows a good annual net gain, \$1.89 per acre, was calculated for control of plantain leafed buttercup.

The examples are indicative of profits possible from weed control in grazing lands. Many weed problems have not been covered. Downy brome has invaded most of the rangeland in the northern two-thirds of the western region. What gain would result if it could be replaced with desirable perennial vegetation? What are the losses from halogeton, other poisonous plants, chaparral species, and many others? There are insufficient data to answer such questions.

Table 1. Some estimated potential returns for spraying.

Weeds	Annual Increased Yield (lb/A)	Cost For Treat- ment (\$/A)	Annual Net Gain ¹ / (\$/A)	Acres Adapted to Spraying (millions)	Annual Return (millions)
Big sagebrush (Oregon)	400 ² / ₁	\$3.25	\$1.68	24	\$40.2
Low larkspur & sagebrush (Oregon)		3.25	1.83	1	1.8
Rabbitbrush (Oregon)	400	5.00	1.50	1	1.5
Sand sagebrush (Oklahoma)	1,000	4.50 ³ / ₁	1.10	15	16.5
Mesquite (Arizona) ⁴ / ₁	170	7.00	0.15	70	10.5
Juniper (Arizona)	400			25	
Plantain leafed buttercup (Califor- nia)	442	3.25	1.89		

¹/ Increased gross return less the cost of treatment spread over 10 years. Assumed \$10 per ton dry weight for forage.

²/ D. W. Bohmont and H. Alley show about the same results for 2,4-D on big sagebrush in Wyoming.

³/ E. H. McIlvain has indicated \$2.50 for treatment and \$2.00 cost of deferred grazing for 2 years.

⁴/ Extrapolations from F. H. Tschirley's data. Climatic conditions differ widely in areas infested with mesquite.

Three methods of weed control are compared in an experiment conducted in Nebraska, Table 2. Results of this experiment may be representative of areas in favored sites of the West. All methods of control resulted in an increase of forage eaten by cattle. Mowing annually gave a net return of \$0.85 per acre annually; spraying with 2,4-D, \$2.60; and plowing, reseeding to a warm season grass mixture, plus spraying with 2,4-D for weed control returned \$8.90 annually. All methods gave good returns on the investment but the most expensive method (plowing, reseeding, plus 2,4-D), gave the highest net return. Comparisons such as these should be useful to operators. Actually there are more differences between the treatments than evidenced by the data. The condition of the pasture was tremendously improved by the last treatment. The second treatment, spraying with 2,4-D, also gave high percentages of killed weeds and improved grass that will continue to be manifested in yields after annual treatments are discontinued. There was little reduction in perennial weed

population by mowing, and benefits in pasture condition from this treatment were slight. Annual mowings will be required to realized even a small improvement in production.

What losses in establishment of new seedings of forage species can be attributed to weeds? It is well known that moisture supply is critical to seedling establishment. How many weeds does it take to exhaust the moisture and cause mortality of the seeded species? Even where moisture is plentiful, losses often result from shading by weeds.

Interacting effects of weeds upon seedling establishment of forage species need study.

Table 2. Estimated returns for weed control in a pasture in Nebraska (28-inch rainfall)

Treatment	Annual Increase in Forage Eaten (lb/A)	Annual Cost of Treatment (\$/A)	Annual Net Gain ^{1/} (\$/A)
Mowed	280	\$1.25	\$.85
Sprayed with 2,4-D	680	2.50	2.60
Plowed, seeded to warm season grasses + 2,4-D	1,830	4.85	8.90

^{1/}Increased gross return less the cost of treatment pro-rated over 10 years. Assumed \$15 per ton dry weight for forage eaten.

New specific herbicides that control broadleaved weeds in legume seedings with benefit to stands and vigor of the legume are becoming available. Certain other chemicals will selectively remove annual weed grasses from perennial grasses; for instance, downy brome from smooth brome grass. It may be possible eventually to remove selectively annual weed grasses from perennial pasture grass seedlings. However, such chemicals are not yet known. That this is within the realm of possibility is evidenced by the true tolerance of corn, an annual grass, to simazin. Most other grasses are severely injured by simazin.

In table 3 are shown data from Ithaca, New York, showing the relative returns from birdsfoot trefoil and alfalfa subjected to different methods of weed control. Similar data may be available for irrigated conditions in the western states. It is notable that in New York when both broadleaved weeds and weed grasses were killed there was a good net return. With birdsfoot trefoil 4 pounds per acre of 2,2-dichloropropionic acid (dalapon) plus 1½ pounds per acre of 4-(2,4-dichlorophenoxy)butyric acid (4-(2,4-DB) gave good control of weed grasses and broadleaved weeds. Increased yields of birdsfoot trefoil the first summer were 2,100 pounds per acre giving a net gain of \$13.25 per acre as compared with the untreated check. Increased yields were smaller for dalapon or 4-(2,4-DB) used alone.

Table 3. Return for weed control in seedling establishment, New York.

Crop plant	Treatment		Increase In Yield Over Check (lbs/A)	Cost/A ^{1/} (dollars)	Net Gain/A ^{2/} (dollars)
	Chemical	Lb/A			
Birdsfoot trefoil	Dalapon + 4(2,4-DB)	4 lb. 1½ lb.	2,100	\$20.75	\$13.25
Birdsfoot trefoil	Dalapon	4 lb.	700	12.00	1.00
Birdsfoot trefoil	4(2,4-DB)	1½ lb.	400	10.68	-2.18
Alfalfa	Dalapon + 4(2,4-DB)	2 lb. 1½ lb.	1,050	16.25	3.25
Alfalfa	Dalapon	2 lb.	-650	4.50	-13.58
Alfalfa	4(2,4-DB)	1½ lb.	400	11.94	-2.19

^{1/} Includes all costs of producing and harvesting crop.

^{2/} Net gain over return from check treatment. Hay valued at \$30 per ton.

Results from herbicidal weed control in alfalfa follow the same pattern as with birdsfoot trefoil in that it was important to control both the weed grasses and broadleaved weeds. These data pertain only to the hay yield during the seedling year. The advantages of weed control should be enhanced by improved performance in succeeding years.

Sometimes weed grasses are also a problem in established alfalfa. Results from experiments at Prosser, Washington, on the control of downy brome in alfalfa are shown in table 4. All herbicide treatments gave over 90 percent control in the two years reported. Returns are striking when the value of the hay is figured at \$30 per ton. However, if the value of hay were reduced to \$15, the return would be reduced more than one-half. For instance, the return for the first treatment would be reduced from \$17.60 to \$4.25. For the second treatment, the gain for treatment would be reduced from a gain of \$9.50 to a loss of \$2.15 for treatment.

The economics of weed control can fluctuate widely with prices. Also economists would be critical of the inadequate treatment of costs in this report. Therefore it is important for you to report enough basic data from your research so that new evaluations can be made by specialists in economics or so that new calculations can be made when economic conditions are changed.

Table 4. Downy brome grass control in alfalfa, two year average, Prosser, Washington.

Treatment	Rate (lb/A)	Yield in First Cutting (T/A)	Cost of Treatment (\$/A)	Gain ^{1/} (\$/A)
Endothal	6	3.33	9.10	17.60
Endothal	8	3.15	11.80	9.50
Dalapon	5	3.12	6.00	14.55
Dalapon	10	2.95	11.00	4.30
Check	0	2.44	0.00	0.00

^{1/}Increased yield times \$30 per ton, minus cost of treatment

Conclusion

Data on the profits from weed control on grazing lands indicate high potential return but available data are fragmentary.

Dollar profits from weed control to the producer must be a high consideration in taking research results to the rancher. Nevertheless, many other considerations are also deemed important by enlightened ranchers. Among these are: (1) the improved quality of forage, (2) the improved condition of the range, (3) the reduction in hazards from poisoning or mechanical injury, (4) the increased water yield on some watersheds from brush control, and (5) the increased ease of managing livestock on ranges relatively free of weeds and brush. All these are considered as profits from weed control.

A great deal of research must be planned and completed to develop information on the values of weed control. It is obvious that improved methods of control of serious weeds are of paramount importance. It is important that data be accumulated so that the economic profits and other benefits from use of control methods can be calculated. The effects of weed control on other vegetation and the interrelated ecological effects must be thoroughly assessed. In arid regions, changes in vegetation may come slowly and the margin of profit is small. A firm foundation of knowledge for decisions on expenditure of funds for improvement of range-lands is thus of major importance. Such foundation must depend upon careful research.

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PROFITABLY CONTROLLING CANADA THISTLE

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In keeping with the theme for this year's Weed Control Conference, "Profits from Weed Control Research," I would like to present some of our findings at the Oregon State College Experiment Station on chemical

control of Canada thistle. The title of this report is rather broad; however, I would like to limit the scope of this presentation to results with ATA and comparisons of ATA with 2,4-D.

In general, profitable control of Canada thistle revolves around the use of a non-sterilant, highly effective material which will give a high degree of control in a short time. In my estimation, only one chemical fits this category--the amazing new herbicide, 3-amino-1,2,4-triazole. 2,4-D, which is used widely for thistle control and has been our only non-sterilant treatment in the past, is less than satisfactory. Under western Oregon conditions, we have been able to obtain only temporary control of Canada thistle with 2,4-D, even at rates up to 80 pounds per acre. This material, of course, can be used effectively to provide temporary control in grains and grasses; however, since the thistle is treated at an early stage of growth, it often regrows and is a problem in the crop at a later date. In addition, constant retreatment is necessary to effect control. Any lapse of control measures which might arise in crop rotation can well undo the good previously accomplished. 2,4-D has been rather discouraging to the farmers in our area since they become somewhat perturbed at treating what appears to be the same amount of thistle each year.

Extensive tests have been conducted in western Oregon the past three years with ATA and 2,4-D. In all tests ATA has been most outstanding. Stem counts have shown considerable reduction in stand from ATA treatments at the bud stage of growth. Early applications have also been effective. A summary of results from three separate experiments shows that ATA at 1, 2, and 4 pounds active ingredient per acre, applied at the late bud stage, gave an average of 60%, 78%, and 93% stand reduction respectively from one application as evaluated the following year. In comparison, 2,4-D at 1, 2, and 4 pounds gave average stand reductions of 18%, 33%, and 46% respectively.

The thistle plants which regrew in the ATA treatments were extremely stunted, chlorotic, and of very low vigor. In contrast, the regrowth in the 2,4-D treated plots appeared normal in all respects. With the low percent control from 2,4-D treatments and normal regrowth, complete stand recovery could result in a short time.

Another factor which the percent reductions in stand do not show is the variation in control between the various experiments and replications. For instance, with 2,4-D at 1, 2, and 4 pounds per acre, there was a range in control of from 7% to 38%, 14% to 49%, and 24% to 60% for the respective rates. This can be compared to a range of 44% to 70%, 73% to 84% and 87% to 97% control with ATA at 1, 2, and 4 pounds per acre respectively. These results further substantiate the effectiveness of ATA for Canada thistle control.

One limitation of ATA has been its non-selective nature with most of the usage for spot treatment. Research directed toward finding more effective ways of using this herbicide in crop production has uncovered promising leads which should make for even more profitable control of Canada thistle in the future. The most outstanding method and one which I would like to discuss at length is the selective use of ATA on oats.

In our evaluation trials conducted at the Central Station, the extreme tolerance of oats to post-emergence applications of ATA was observed. Since oats are grown rather widely in many areas of the country, a method of using this chemical to selectively control perennial weeds such as Canada thistle in an oat crop would have wide application.

Since the use of ATA for thistle control has been fairly well established, an experiment was set up to test the effect of ATA on growth and yield of Victory spring oats where weeds were not a factor. ATA at 1, 2, and 4 pounds active ingredient per acre was applied to oats at the six to eight inch stage, boot stage, and headed stage of growth. These stages were periods of growth during which treatments might be applied for control of perennial weeds. Although the oat plants displayed a chlorotic striping following applications of ATA, the effect was quite transitory and was rapidly outgrown. There appeared to be no stunting in growth or reduction in stand from any of the treatments.

The following table summarizes the yield results for Victory oats.

Yield--Victory Oats			
Treatment	Rates/Acre	Growth Stage Treated	Average yield in lbs/plot
ATA	1, 2, & 4#	8-10"	2.83
ATA	1, 2, & 4#	Boot	2.78
ATA	1, 2, & 4#	Headed	2.99
Untreated Check			3.20

These results show slight yield reductions from ATA treatments. However, statistical analyses showed no significant differences between any of the treatments.

To further evaluate possible effects of ATA, seeds from each treatment were planted in the greenhouse in soil and allowed to grow to a height of approximately eight inches so that the germination and growth could be evaluated. The average germination percentages for Victory oats are given in the following table.

Germination--Victory Oats			
Treatment	Rates/Acre	Growth Stage Treated	Average % Germination
ATA	1, 2, & 4#	8-10"	87.3
ATA	1, 2, & 4#	Boot	89.6
ATA	1, 2, & 4#	Headed	90.2
Untreated Check			86.2

There was no injurious effect of ATA on the growth or germination of the oat seed, although seed from treated plots gave a somewhat higher percent germination.

The same results were not true for spring barley which happened to be a contaminant of the oat seed and was sparsely but evenly distributed throughout the experimental area. Applications of ATA at all rates completely killed the barley at the eight to ten inch stage. Boot stage and headed stage treatments injured but did not kill the barley plants. The following table summarizes the barley yield information.

Yield--Hannchen Barley			
Treatment	Rates/Acre	Growth Stage Treated	Average Yield in Grams/Plot
ATA	1, 2, & 4#	8-10"	0
ATA	1, 2, & 4#	Boot	44.04
ATA	1, 2, & 4#	Headed	75.36
Untreated Check			97.61

Although ATA caused a reduction in barley yield, the later stage treatments appeared promising for possible selective control of perennial weeds with at least a partial crop yield. As a result, germination tests were conducted in the greenhouse to check for possible effects on the seed. The following table presents these germination percentages.

Germination--Hannchen Barley			
Treatment	Rates/Acre	Growth Stage Treated	Average % Germination
ATA	1#	Boot	23.0
ATA	2#	Boot	25.1
ATA	4#	Boot	16.1*
ATA	1#	Headed	16.6
ATA	2#	Headed	1.4*
ATA	4#	Headed	2.4*
Untreated Check			95.8

The barley seed from ATA treated plots was greatly reduced in germination. In addition, the few plants produced were quite chlorotic and stunted, with headed stage treatments the most severe. These results would discourage use of ATA in barley, particularly if grown for seed.

The results with oats are quite promising and, I believe, point the way for more effective and profitable control of Canada thistle in the future.

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SINGLE AND COMBINED EFFECTS OF HERBICIDES AND FERTILIZERS ON THE
CONTROL OF SPURRY AND THE YIELD OF
OATS

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In our earlier years as a nation, spurry, Spergula arvensis L., was spoken of as a field weed of the "Old World," common to England, France, Germany and Scandinavia, in fact all of northern Europe. Growing in the grain fields of England it was named corn spurry.

Since nearly all weed migrations to this continent are hidden in ambiguity, one can only surmise that spurry arrived prior to 1700, possibly with the Dutch, English, French, or Swedish settlements or possibly with the Pilgrims. Who knows.

We do know that it has plagued the north Atlantic states for several generations. In 1914 Ada Georgia wrote in Manual of Weeds, "So rapid is the growth of this weed that a field of young turnips or carrots may be swiftly smothered by it." And, peculiarly, it does the same thing today!

Further, Ada Georgia said, "Among crops in which hand hoeing is impracticable, a 5-percent solution of copper sulfate, applied when the plants are about half grown or even in first bloom will prevent seed production."

So almost exactly 40 years later we find spurry also generally distributed throughout the upper north central states and in localized concentrations in the western states. In Idaho alone there is an infestation covering about 50,000 acres. Each year there are several new small infestations quite remote from the generally infested areas. This could be a caution sign of the potential future problem.

Our studies on the germination and growth show that spurry is best adapted to an acid soil.

Present observations show that our infestations are limited to acid soils ranging from pH 5.0 to 6.5. Our greenhouse studies indicated that spurry growth decreased progressively as the soil pH increased. This indicates that it may never be a weed of any consequence in soils approaching a pH of 7 or greater. Precisely we had 12, 22, 31, and 45 centimeters of growth after 12 weeks in soils ranging in pH 8., 7.4, 6.4, and 5.8 respectively.

Germination of the preceding years crop will range from 7 to 15 percent by midwinter. The small black seeds seldom germinate from soil depths exceeding $\frac{1}{4}$ inch. Field counts show that dense stands produce 100 to 1,000 seedlings per square foot. Accordingly, such stands are the result of a soil seed infestation of 2,400 to 24,000 seeds per square foot of furrow slice 6 inches deep, assuming 100 percent germination in the upper $\frac{1}{4}$ inch of soil. Actually, we have found seed concentrations

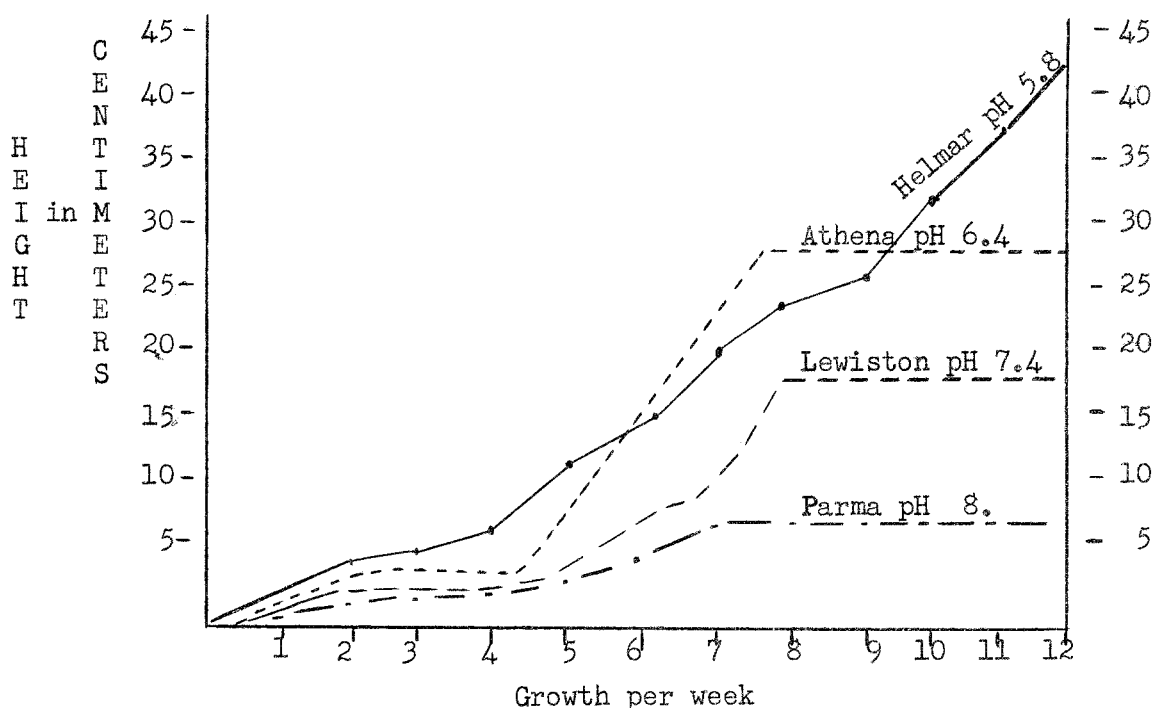
approaching 70,000 per 1/2 cubic foot of soil. Under field conditions germination continues throughout the first half of the growing season. At this point the early plants are in blossom and all of them continue to grow, mature, and shatter seeds until killing frosts arrive. Consequently seeds are produced in such abundance that the soil surface may be completely covered, giving a blackish coating to an otherwise light colored soil.

Between the era of Ada Georgia and the present little has been learned about better methods to control this weed. Farmers learned a few years ago that the conventional 2,4-D post-emergence applications were ineffective. The germinating seed is sensitive to 2,4-D, but the seedling becomes suddenly resistant. The nature of this sudden resistance has not been determined. The thick cuticle may be a dominating factor. Korsmo in his Anatomy of Weeds notes, "several layers of thick walled strengthening cells exterior to the vascular tissues." The latter may also be a factor. Whatever the nature of this resistance, it is sudden and spectacular.

Ada Georgia noted the "sudden smothering effect," which spurry has on associated crop plants. We have noted that this factor is pronounced on tall growing oats while scarcely evident on low growing dutch or alsike clover. We suspicion a selective toxic root exudate but this remains to be investigated.

After observing the spotted nature of spurry infestations we filled greenhouse benches with four soil types ranging in pH from approximately 5 to 7.5. The growth response of spurry to these soil types is illustrated in the following diagram.

Figure 1. The growth of spurry in 4 soil types.



The growth performance shows a distinct preference for the more acid soils. Its persistence in an alkali soil with or without crop competition is questionable.

The following field study was conducted at Donnelly, Idaho, on an irrigated granitic alluvium soil having a pH of approximately 5.5. The experiment was designed to test the effects of two variables; herbicides and nitrogen fertilizer.

The land was spring plowed, followed by disced in applications of ammonium nitrate at 0, 20, 35, and 70 pounds per acre. A smooth seed-bed was prepared and sown to Overland oats.

On the following day the herbicides were superimposed on all the different nitrogen rates. This equaled:

$$\begin{aligned} 4 \text{ nitrogen rates} \times 3 \text{ replications} &= 12 \\ 4 \text{ herbicides} \times 4 \text{ rates} \times 3 \text{ replications} &= 48 \\ &\text{or } 576 \text{ plots.} \end{aligned}$$

To avoid a mass of figures, the data hereafter have been reduced to show the average performance of each herbicide as influenced by each nitrogen rate. Further, the data have been categorized to show the influence of time on the results obtained. I believe that most of you will agree that readings and observations made a few days after treating are valuable, but data obtained as we approach harvest is of much greater value. It is the evaluation the user ultimately places on the product.

Table 1. The average effectiveness of 4 herbicides on the stand (% soil surface covered) of spurry in oats 4 and 8 weeks after treating. (Pre-emergence applications)

W	Herbicide	Av. rate per acre	Rate of Nitrogen in lbs/A.				
			0	20	35	70	Av.
4	E Check	0	23.0	46.0	33.0	32.0	33
	E 2,4-D	1½ lbs.	1.7	1.8	1.9	2.3	1.9
	K PE	5 qts.	1.0	2.0	1.0	1.0	1.3
	S MCPA	1½ lbs.	0.2	0.6	0.5	0.5	0.4
	Av.		6.5	12.6	9.6	8.9	
8	W Check	0	56	90	88	91	76
	E 2,4-D	1½ lbs.	14	18	31	9	18
	K PE	5 qts.	6	11	34	9	15
	S MCPA	1½ lbs.	8	5	7	2	5
	Av.		21	31	40	28	

In brief the data show the following:

1. That spurry is extremely efficient in utilizing available nitrogen.
2. The spurry cover had increased 2 to 34 fold between the 4 and 8 week interval.
3. That MCPA maintained its position as the most effective herbicide, and that the alkanol amine salts DNOSBP and 2,4-D were of equal effectiveness.

It was conspicuous that the nitrogen applications consistently increased the growth of spurry. This was especially distinctive between the check and the 20 pound rate. The plots were later harvested to determine the interrelated effects of spurry control and nitrogen levels upon the yields of oats.

Table 2. The effects of 4 pre-emergence herbicides and 4 nitrogen rates on the yields of oats (bushels per acre).

Herbicide	Av. rate per acre	Rate of Nitrogen in Pounds Per Acre			
		0	20	35	70
Check	0	33	29	36	34
PE	5 qts.	31	42	68	41
2,4-D	1½	51	49	66	61
MCPA	1½	48	54	75	77
Av.		41	43	59	53

These data show that the highest yields were obtained with 35 pounds of nitrogen per acre, and that the MCPA treatments were most consistent in increasing oat yield. Actually the most satisfactory treatment applied was 2 pounds of MCPA and 35 pounds of nitrogen per acre. This combination yielded 91 bushels of oats per acre and resulted in approximately 98 percent spurry control.

Finally, what are the possible profits that can be gained from spurry control. In addition to the benefits of just plain weed control for the sake of cleaner fields, easier and more economical harvesting, and reduced dockage, what is there to gain?

Figuring the oats at \$40 per ton, this gives a gross income of \$20 per acre for the non-treated check which yielded 33 bushels per acre. From the remaining treatments there must be subtracted the cost of the nitrogen, or the herbicides, or both; what ever the additional production costs might be. The following table shows the approximate returns from each treatment.

Table 3. The average gross returns per acre, after subtracting the additional costs of nitrogen and herbicides.

Herbicide	Av. rate per acre	Rate of Nitrogen in Pounds Per Acre			
		0	20	35	70
Check	0	\$20	\$15	\$18	\$12
PE	5 qts.	9	13	26	6
2,4-D	1½ lbs.	28	24	31	23
MCPA	1½ lbs.	24	25	35	32

The results show that the pre-emerge dinitro compound with 35 pounds of nitrogen gave a net increase of \$6 per acre. All the 2,4-D and MCPA treatments were profitable giving gains of \$4 to \$15 per acre. The

greatest profit obtained from any treatment, was obtained using 2 pounds of MCPA combined with 35 pounds of nitrogen per acre. This yielded a net gain over the non-treated check of approximately \$23 per acre. In other words this treatment more than doubled the income of the non-treated check. Does weed control pay?

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GERMINATION STUDIES WITH WILD OAT SEEDS

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Wild oat seeds were collected from several locations in the fall of 1954. These seeds differed considerably in color and in the amount of dormancy they possessed. In fact considerable variation occurred in individual samples. Pubescence differences were difficult to observe because most had been threshed clean. In most cases seed was limited which in turn limited germination tests made. It was determined that considerable differences existed between various seed lots in the dormancy they possessed.

Table 1. Source of wild oat seeds used in this study.

Sample Number	Location of Seed Source
1	Bozeman, Montana
2	Bozeman, Montana
4	Fairfield, Montana
5	Choteau, Montana
6	Valier, Montana
7	Bozeman, Montana
8	Williston, North Dakota
9	Moscow, Idaho
10	Logan, Utah
11	Stavelly, Alberta
12	La Combe, Alberta
14	Fargo, North Dakota
17	Pullman, Washington
19	Regina, Sask.
22	Fort Collins, Colorado
23	Corvallis, Oregon
24	Logan, Utah

Seeds from each source was planted in 1955 so that uniform climatic conditions were secured. It was found that considerable differences also occurred between vegetative characteristics. Plants differed in leaf size, growth habit, heading date, height and ripening date. Several pounds of seed were harvested for future testing.

There are numerous accounts of instances where sod fields have been plowed up after many years, and wild oats appeared, presumably from seed in the soil. We have usually blamed the seed used for the first crop after breaking, or manure or some other source for the contamination. It does

not seem possible that a wild oat seed with the poor seed cover it possesses could exist for any length of time against soil micro-organisms attempting to decompose it. However, it seems that there are too many accounts of wild oats living in the soil for long periods of time to discredit them. Consequently one of the first tests undertaken was to initiate a study to determine just how long wild oats can remain in the soil. Accordingly 100 seed samples of the most dormant strain available (No.9) were enclosed in Lumite plastic (32 x 32 open weave) screen and buried at 2,6, 12 and 18 inches under a blue grass sod and in a cultivated area. Three replications were used and enough samples were provided so that they could be removed during each of the 5 succeeding years.

Samples were removed during each of the last three years and the results shown in the following table were secured.

Table 2. Wild oat seeds recovered from samples buried in Bozeman silt loam soil at various depths for 1, 2 and 3 years, Bozeman, Montana.

Depth in inches	No. of seeds recovered of 300 buried at each depth under each condition					
	1 year		2 years		3 years	
	Sod	Cultivated	Sod	Cultivated	Sod	Cultivated
2	171	137	88	19	40	4
6	182	149	116	28	43	14
12	184	126	112	45	58	14
18	170	120	90	39	39	8

These results show that after one year 59 percent of the 300 seeds under sod, and 45 percent of those under the cultivated area were recovered. The others had either decomposed and/or germinated. Differences between depths were not large. Twenty one percent of those under sod and 25 percent of those under cultivated area germinated when dug up. The seeds that did not germinate were not tested for viability, but it is assumed they were viable, but dormant.

After two years 34 percent and 11 percent of the buried seeds were recovered of which 37 percent and 63 percent respectively germinated. The ungerminated seeds were hulled and the endosperms pricked after which almost all of them germinated indicating they were still dormant prior to the pricking and hulling.

Three years of burial left only 15 percent of the seeds buried under sod alive. Only 3 percent of those under cultivation were alive. Of those recovered 52 percent of those under sod and 58 percent of those under cultivation germinated. Almost all the remaining seeds were induced to germination by hulling and pricking thus indicating viability.

It is not uncommon to find 15 to 20 bushels of wild oat seed mixed in the soil. Seventy bushels have been reported. While only 15 percent of the seeds were alive after 3 years under sod it still leaves 3 bushels if 20 were there to start with. Three bushels are ample to provide rather

effective competition to crops if they followed a sod crop. This test will continue for two more years.

Our aim in studying wild oats has been to discover the factors that affect dormancy and if possible to make practical application of the information in controlling this weed. While no one has been able, as yet, to determine what the inhibiting substance is, several investigators have studied the problem. It was pointed out by Johnson in 1935 (5) that primary seeds are much less dormant than secondary wild oat seeds and that tertiary seeds are most dormant of all. While all dormancy is overcome with time it is possible to destroy dormancy in certain ways.

The easiest and also a fairly effective way to cause germination of dormant wild oat seed is to moisten them with a .2 percent solution of potassium nitrate and then chill them for 10 to 14 days at a temperature of 40-45°F.

Atwood in 1914 discovered that if he (1) ruptured wild oat seed coats by pricking with a needle he was able to increase germination from 35 to 65 percent up to 95 to 100 percent. In our tests we have also been able to increase the germination percentage by pricking the wild oat seeds through either the endosperm or the embryo. We have found that removing the hull was an even more effective means of causing the wild oat seed to germinate. Results of one test is presented in table 3.

Table 3. Effect of mechanical treatments on seeds from three wild oat strains (4)

	Strain and av. % germ.		
	9	11	12
Seeds punctured with a needle through embryo	27	86	52
Hulls removed	51	97	89
Hulls removed, caryopsis punctured	41	99	93
Check (no hulling or puncturing)	1	35	14

It is evident from these results that the hull plays an important role in preventing germination. However, it is also evident that something else is involved, because in no case have we been able to get strain 9 to germinate more than 50 or 60 percent irregardless of what we do with it. There are other strains that do not respond even as well to hulling.

We can theorize that the hull acts as a barrier against the entrance of water or oxygen and in that connection holds the products of respiration in contact with the seed and thereby impairs the germination process. It is also quite possible that there is a germination inhibitor in the hull. We have demonstrated that the hull does not serve as a barrier in keeping water away from the caryopsis. For the first several hours after applying water dormant and non-dormant seeds absorb water at the same rate, and it is not until the germination process actually gets underway

that this rate of water absorption changes.

To test the theory that hulls serve as an oxygen barrier we have germinated wild oats in various concentrations of oxygen from that in the air to 80 percent. Increases have resulted with each increase in oxygen concentration. An average increase of 17, 18, 21, and 23 percent resulted from 50, 60, 70, and 80 percent oxygen concentrations respectively.

This agrees with results obtained by Bibbey (2) several years ago. The discrepancy in our results is that all strains are not affected in the same way. In fact strain 9, the same one that responded only partially to hulling and pricking, did not respond by increased germination to increased concentration of oxygen.

Elliott and Leopold (3) have shown that there is a substance that can be moved from a dormant Avena seed to a non-dormant one that can prevent germination of the latter. Our first attempt to accomplish this was made by removing the hulls from three strains and then putting the hulls around and over the naked caryopsis. Treatments and results are recorded in the following table:

	9	11	12
Hulls loosened	5	64	20
Hulls removed caryopsis covered with hulls	43	88	65
Hulls removed	46	87	71
Check (Intact seed)	3	34	7

These results indicate a definite advantage to germination by removing the hulls. With the caryopsis simply loosened inside the hulls a considerable inhibiting effect remained. It is possible that the inhibiting substance diffuse so slowly through the hull that when the caryopsis is removed from the hull it germinates before the germination inhibitor can make its effect apparent. To test this theory non-dormant caryopsis were placed inside the hulls from dormant seeds. Results did not substantiate the theory since they germinated as well as the non-dormant check samples.

If this germination inhibitor is water soluble it seems logical that it can be removed by washing. Several samples of a dormant wild oat strain were washed in running tap water for varying lengths of time. Results indicated a secondary dormancy was induced by washing and it was not possible with the techniques employed to determine whether washing had removed a substance that interfered with germination. In other tests we have not been able to reduce the percent germination of non-dormant wild oat seeds by water extracts from dormant strains. Testing continues along this line.

Helgeson (6) recently reported stimulation of dormant wild oat seeds by the use of gibberellic acid. In preliminary tests conducted in Montana using gibberellic acid we have found considerable stimulation resulted when dormant seeds were soaked in various concentrations of gibberellic

acid for 30 minutes. Results are given in table 4.

Table 4. Effect of various concentrations of gibberellic acid on germination of wild oats, Bozeman, Montana

Concentration in ppm	Average percent germination after 10 days	Average percent germination after 13 days
0	24	26
1	26	31
10	50	52
100	64	76

The most interesting result was the increase in germination that occurred between the 10 and the 13 day. Another trial was initiated in which concentrations were varied and soaking the seeds was compared to placing dry seeds on blotter paper moistened with the gibberellic acid solution.

Table 5. Effect of various concentrations of Gibberellic acid on germination of wild oat seeds.

Wild oat strain	Concentration in ppm	Av. percent germination after--		
		10 days	14 days	23 days
L2A	0	14	18	18
L2A	5	43	52	55
L2A	10	41	49	53
L2A	100	50	77	88
L2A	1000 not soaked	44	73	91
L2A	10 not soaked	25	34	36
9A	10 soaked	0	0	1

Of particular interest was the increased germination with increased time and the effect of gibberellic acid concentration on germination. Soaking the seed was more effective than moistening the blotter paper. The most dormant strain did not respond to gibberellic acid.

Our germination studies have shown that:

1. Genetic differences cause strains to react differently to various treatments. Several factors may be involved. They may act individually or collectively. Their effect may be expressed in the embryo, the endosperm or the hull.
2. Dormancy in wild oats is overcome with time.
3. Wild oat seeds live longer under sod than in a cultivated soil.

4. Potassium nitrate plus chilling, removing the hulls and/or rupturing the seed coat, increasing the concentration of oxygen and the use of gibberellic acid have all been helpful in breaking the dormancy in wild oats.

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A NEW APPROACH IN CEREAL WEED CONTROL

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Cereal crops have played the leading role in the development of selective herbicides. Both in dollar volume and acreage, cereal crops represent today's biggest weed control industry. The early work with such selective compounds as sulphuric acid, iron sulphate, and dinitro compounds was largely devoted to selective post-emergence weed control in cereals. The first large use of selective herbicides was the spraying of dinitro compounds for selective removal of mustard and other annual broad-leaf weeds in small grains.

Since the introduction of the phenoxyacetic acid compounds 2,4-D and MCPA, there have been no new developments in the selective control of weeds in cereals. There are several reasons for the lack of change in the basic weed control practices in cereal crops. The cost per acre of 2,4-D is so minor that it is unlikely that new herbicides with the same high efficiency could replace 2,4-D on the basis of price. Since 2,4-D can be applied in low volume, at low dosages, under a wide range of conditions post-emergence when the weed population can be assessed, it is difficult to find a superior material.

In spite of the merits of 2,4-D for selective weed control in cereal crops, this compound does have several disadvantages. There is danger of drift injury to susceptible crops. This has caused lawsuits, legislation, and hard feelings. The annual use of 2,4-D for the past ten years has caused changes in the weed complex found in cereal fields. In some areas grasses have become a major consideration as weeds in cereals. It is also known that yield reduction is caused by competition of young weeds in cereals prior to the time they are killed with the normal 2,4-D treatment. Although these are all good reasons why further work might be done to replace 2,4-D, the major reason for such work has come about as a result of new developments in cereal production.

The production of cereals, primarily wheat, in the Pacific Northwest has been undergoing a number of changes. Trashy fallow has been adopted in many areas subject to severe erosion. The trashy fallow system offers excellent protection against soil erosion by wind and water, but it has been ideal for the build-up of cheatgrass, Bromus tectorum. The seriousness of cheatgrass as a weed in wheat has been magnified by another major change in production. This has been the introduction of inorganic nitrogen fertilizers for cereal production in both the summer fallow and the annual cropping areas of the Northwest. The use of high nitrogen fertility has also greatly increased the problem from many 2,4-D resistant weeds west of the Cascade Mountain range in Washington and Oregon. This area has a substantial acreage of winter cereals. The winter weed complex of the west slope consists heavily of annual ryegrass, several annual bromes, annual fescue, annual bluegrass, chickweed, dog fennel, and a variety of other winter annuals. These weeds form a dense carpet in many of the wheat fields and use much of the nitrogen during the nitrogen-short winter period.

The introduction of commercial nitrogen fertilizer has brought about the need for another major change in cereal production. This is the need for short-strawed, high-yielding wheats. The addition of high nitrogen fertility on the west slopes of the Cascade Mountain range has caused excessive straw height which has led to serious lodging. East of the Cascade Mountain range, in the drier areas of the Pacific Northwest, the use of nitrogen has frequently caused so much straw growth that moisture was depleted prior to the maturity of kernels. This frequently results in shriveled grain. The plant breeders have been working on this problem and have introduced short-strawed genetic material from Japan which has been bred onto the high-yielding wheats of the Pacific Northwest. Medium-strawed crosses are already in commercial production channels. Extremely short-strawed varieties are approaching release. Test work with the short-strawed varieties has indicated where weed and disease problems do not interfere with their production, they are capable of producing in excess of one hundred bushels of wheat per acre. Under high fertility, grasses such as ryegrass and cheatgrass overtop the short-strawed wheats and seriously interfere with yield.

These changes in production practices necessitate a new approach to cereal weed control. This was undertaken in early work by Mr. David E. Bayer at the Pendleton, Oregon, Experiment Station. His work centered largely around pre-emergence compounds that might selectively remove cheatgrass. Although his work was largely unsuccessful, it did lead into extensive research by D. O. Chilcote and D. G. Swan of Oregon State College which produced new practices that promise to solve the knotty problems of grass and broadleaf weed control in short-strawed cereals.

The major portion of this work has been pre-emergence weed control; however, recent work indicates the same practices can also be used effectively post-emergence under many conditions. Although a variety of compounds have been tested that were more or less effective for removal of weedy grasses from wheat, oats, and barley, the work has been narrowed down to two basic chemicals. The one that has been given the greatest amount of work is diuron, known under the trade name Karmex DW. This material when applied immediately after planting of winter wheat, oats, and barley, has been selective on all varieties in four years of test work. The weed control in western Oregon has been consistent and highly effective without any reduction in yield on a variety of soil types. Recent work has indicated that post-emergence applications can be made effectively. The pre-emergence use of this material eliminates practically all weed problems in the three major cereal crops and oat-vetch mixtures for the production season without any detrimental residues in succeeding crops. The only major weed control problems not solved are the control of wild oats and ripgut brome. Since this practice has been thoroughly explored for four years including state-wide off-station trials at a large number of locations throughout western Oregon this year, the chances are good this will soon become an accepted practice.

The problem in eastern Oregon has been complicated by the lower efficiency of diuron herbicide on cheatgrass, particularly where the cheatgrass may establish a fairly extensive root system before rain occurs in sufficient quantity to carry diuron into the root zone. Work by Dean Swan at the Pendleton Experiment Station has shown, however, that cheatgrass as well as the other major weeds such as tarweed are quite

sensitive to both pre- and post-emergence applications of Simazin and related triazine herbicides. Simazin appears to be the most selective on wheat. This material gave highly effective results last year and appears equally promising in trials so far this year for selective removal of cheatgrass in wheat. Trials in western Oregon also indicate wild oats are quite sensitive to this material and there may be enough selectivity under some conditions to remove wild oats from barley and wheat. This work is still in the experimental stages and has not been recommended for field use. Residue data are now being collected so that application may be made for clearance under the Miller Amendment to the Food, Drug, and Cosmetic Act for these practices. The new approach in cereal weed control would appear to offer excellent promise of solving problems brought about by the new approaches to cereal production.

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PANEL ON WEED CONTROL IN FIELD CROPS

Panel Leader - L. O. Baker
Montana State College, Bozeman, Montana

CONTROL OF WEEDY GRASSES IN SMALL GRAINS

R. N. Raynor
The Dow Chemical Company

The successful and widespread control of broad-leaved weeds in small grains with 2,4-D has led to an awakening of interest in the control of weedy grasses in those same crops, if indeed it has not actually increased the acuity of the grass problem through reduction of competition in 2,4-D sprayed fields. This may not be true of wild oat, the grass weed that is probably more wide-spread and detrimental than any other occurring in grain fields on the North American continent, but it is doubtless true of cheatgrass or downy brome in the major wheat areas of the western United States.

On the assumption that wild oats and cheat grass are the two species of most interest to those attending this conference, discussing the proven and promising methods, both cultural and chemical, for each of them separately will perhaps be the most immediately valuable method of presenting the general subject. At the same time, the application of these methods to other grass weeds will be apparent.

Cultural methods of alleviating the wild oat problem may be listed as:

1. Use of clean seed - This is more of a prophylactic than a therapeutic measure, since fields when once infested have a lot more seed in the soil than would conceivably be planted. Soil screening measurements show as high as 70 bushels of wild oat seeds per acre in old infestations.
2. Preplanting tillage with delayed seeding - Wild oat stand reductions of 85 to 100 percent are attainable with this procedure. Till lightly in early spring to aerate the soil and promote wild oat germination. Tillage in this and later operations should be no deeper than 4 inches. Till again to destroy seedlings when they are in the two or three leaf stage.

Pick a hot day to insure a good kill. Seed as shallowly as is practical, to promote early crop emergence. Heavier than normal seeding rates plus fertilizer are helpful. An early-maturing variety of barley, seeded heavily and fertilized, has been most successful.

3. Pre-emergence tillage - Shallow cultivation with a rod weeder, flexible harrow, or drag harrow may be done before the crop sprouts are one-half inch long.

4. Fall cultivation - The object here is to shallowly cover wild oat seeds after they are fully dried out, so germination will be stimulated.

5. Crop rotation - Either row crops or forage crops will reduce seed populations in the soil. At the same time, wild oats may be quite troublesome in early planted crops such as peas and sugar beets.

6. Fallowing - This is just an extension of the practice of early tillage and delayed planting. Since wild oats are not ordinarily as serious in low-rainfall areas where alternate fallow and cropping is practiced for moisture storage as they are in areas where precipitation is sufficient for yearly cropping, fallowing obviously is effective. However, the economics may be questionable where the practice is not necessary for moisture storage.

Chemical control methods applicable to wild oat control in small grains, and that have given some degree of success experimentally, are preplanting soil applications, pre-emergence soil applications, and postemergence spraying with systemic grass herbicides when wild oat seeds are in a stage of maturity susceptible to having their viability impaired.

1. Preplanting - A wide variety of soil-active germinative toxicants has been tested, generally as fall application on land to be spring planted. Compounds tested include IPC, CIPC, EPTC, dalapon, endothal, monuron, naphthylphthalamic acid, CDAA, CDEA, 2,4-D, 2,4-D acetamide, 3,4-D, and chlorobenzoic acids. The general conclusions seem to be that all of these compounds are most efficient when worked into the soil; that certain of them are more efficient when applied in the spring and seeding delayed than when applied in the fall; and finally the reduction in wild oat stands is not consistently great enough to offset the hazard of crop reduction from residues that may still be present at planting time. Applications in the spring of CDAA or EPTC with delayed seeding have been the most promising of chemical treatments.

Since the compounds listed above are what may be described as germinative toxicants, rather than seedicides, there is no reduction in the seed population of the soil over that resulting from normal germination, and so the benefits and economics of using any of them must be balanced against the efficiency and economy of delayed seeding. The efficiency of preplanting chemical treatments would be greatly improved if a germinative stimulant were available that would overcome dormancy and cause all buried seed to germinate simultaneously. So far, none have been discovered; although I understand gibberellins are being studied for this purpose.

A pre-planting application of a seedicidal compound would appear to have a better chance of success, and 1,2,4,5-tetrachlorobenzene offers promise in this area of investigation. Properties, procedures, and results

will be presented in another panel at this meeting, so it suffices to say now that 10 to 15 pounds per acre, worked into the surface 4 to 6 inches of soil, will kill a high percentage of the dormant as well as germinating wild oat seeds. However, there is some trouble with this compound from residual toxicity to grain crops.

2. Pre-emergence - Most of the compounds tested as preplanting treatments have been included in pre-emergence trials also. None show sufficient selectivity to be worthwhile.

3. Postemergence - Maleic hydrazide, sprayed on an infested grain crop when wild oats are in the early milk or full milk stage, at dosages of 1/2 to 1 pound per acre, will reduce the viability of those seeds by 95 percent or more.

Unfortunately for the commercial acceptability of the maleic hydrazide treatment, the viability of wheat, oats, barley, and flax is likewise impaired if they also are in the milk stage when sprayed. In Canadian tests, the Olli variety of barley was found to differ from wild oats sufficiently in phasic development to permit a high degree of selectivity.

Dalapon, too, affects the viability of wild oat and small grain seeds when sprayed on plants in the reproductive stage. The effect is different than from maleic hydrazide, which inhibits germination. Dalapon does not necessarily reduce percentage germination, although rate may be retarded, but it does cause the seedlings to be abnormal and of low vigor, with many not surviving past the coleoptile stage. Some affected seedlings may later recover, but their development is such that it is much behind that of the crop.

Evidence so far accumulated shows that the timing in relation to reproductive development is not as critical as with maleic hydrazide. At dosages between 2 and 6 pounds dalapon per acre, the reduction in numbers of normal seedlings is not greatly different for sprays applied at late tiller, early boot, boot, early head, milk, or dough stages. Small grains, including flax, are similarly affected at comparable stages, but yields are not greatly reduced when spraying is done after they are in the dough stage. Further experimentation on timing of spraying in relation to development of wild oat and crop plants is suggested, using rates in the range of 2 to 4 pounds per acre.

The increased abundance of cheat grass in wheat fields in the Pacific Northwest and the Northern Great Plains has been attributed in part to the decreased competition of broad-leaved weeds where 2,4-D is consistently used. Stubble-mulch farming may also be responsible in part, since tillage shallow enough to destroy cheat also tears out much stubble. (In a recent summary of research experiences with stubble-mulch farming in the western states, Zingg and Whitfield (U.S.D.A. Technical Bulletin 1166, October, 1957) state that "Cheatgrass or downy brome (Bromus tectorum) caused more trouble than other weeds at locations where these studies were conducted.") A poor job of subsurface tillage, especially if done when the soil is moist, certainly permits survival of cheat grass. Least trouble was experienced in the studies reported by Zingg and Whitfield in semi-arid regions and under an alternate fallow-cropping system. Most trouble from cheat occurred in sub-humid to humid areas, and under continuous cropping. Under continuous wheat, the most trouble occurred in years when insufficient rainfall

occurred before seeding time to germinate the cheat seeds. When they had germinated by seeding time, a rod weeder successfully controlled the seedlings.

In addition to the obvious application of thorough tillage on summer fallow and in preparation for planting, chemical methods show promise. One such is chemical fallowing.

Although perhaps no more effective than tillage in controlling cheat grass and other weeds, chemical fallow does offer advantages in the way of fewer operations and increased moisture storage. Herbicides being evaluated include both residual and foliage-applied systemic types. Soil residual compounds may have an advantage in that theoretically a single application should suffice for the season, but there is the serious limitation that such compounds must be toxic to the crop in order to control volunteer growth, and yet must be detoxified by the time the next seeding is made a few months later.

Foliage systemics having transient soil residues offer less hazard to the succeeding crop, and considerable experimental work has been done with combinations of dalapon and 2,4-D, and with amino triazole. One properly timed spraying in the spring will generally take care of cheat grass and volunteer grain, but summer annual broad-leaf weeds may require one or two additional sprays of 2,4-D.

The second chemical method showing promise for control of cheat grass and other shallow-germinating weeds is the pre-emergence application of monuron or simazin. Work along this line at the Oregon Agricultural Experiment Station has already been reported to this Conference by W. R. Furtick.

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WEED CONTROL IN FURROW IRRIGATED COTTON

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Two points should be stressed when considering the use of chemicals or special methods of weed control in furrow irrigated cotton. (1) Mechanical sweep cultivation is still the best single method of providing overall weed control, (2) Chemicals and other special methods generally will not do a thorough economical weed control job by themselves and should be considered only as supplements to normal sweep cultivation.

Good farming practices are a pre-requisite to good weed control regardless of the mode of control used. Elimination of plant residues, formation of uniform beds, using properly adjusted equipment - all are essential if good weed control is to be accomplished.

Since mechanical equipment still provides the greatest control of weeds in the irrigated southwest, perhaps it should receive the most attention here. However, since there is so much variation in how any one of the many weed control implements can be used, it would be futile to suggest any one best way for using these implements. I might include, however, some of the implements and methods that are used to supplement sweep cultivation. Reversed disk hillers and bed knives are used to some

extent. The Bye hoe and rotary hoe find some favor, and in the West Texas area and southwest New Mexico, capping is quite popular.

Special methods of weed control which are finding more favor of late and perhaps which should be pushed even more, involve the use of oils as directed sprays on early cotton followed by flaming until layby. Non-selective oils are directed on the cotton beds using care to prevent them from contacting the apical meristem of the young cotton plants. Later, flaming is used on the beds in the same manner. Thus, excellent economical control of annual grasses can be provided from the cotyledonary stage until layby by combining these two methods. Cloddy soils, non-uniform emergence, large perennial weeds and/or poorly adjusted equipment may limit the effectiveness of these operations.

Herbicidal control of weeds in cotton has shown little economic promise to date except perhaps when used as a layby application, or when used in spot treatments on certain perennial weeds.

Monuron has been recommended at 1-2 #/A rates in cotton at layby by the University of Arizona for control of annual grasses, morning glory and some other weeds. Research at the Shafter Cotton Station indicates that diuron at similar rates, granular CIPC at 9 #/A or NPA at 6-9 #/A provide good control of weeds. The value of the treatment is gained by (1) eliminating 1 or 2 cultivations and (2) by preventing seed production of subsequently maturing annual weeds. No increases in cotton quality or yield due to control of late weeds by August 1 treatments were found; however, improved cotton grades were found with July 1 treatments.

In areas of no summer rainfall, the value of layby applications is directly dependent on irrigation management. Unless the beds are completely moistened, the chemicals will not be activated.

It should be noted that the substituted urea herbicides will leave a residue which is toxic to winter-sown grains, an important consideration in some cases.

Treatment of spot infestations of Johnson grass has been successful in most research studies when dalapon, dalapon-TCA combinations and fortified oils are applied in repeated applications to the Johnson grass foliage. The fact that cotton plants sprayed with either dalapon or oil will be injured or killed, limits this practice only to spot treatment.

In short, one can consider herbicidal control as a supplement to normal mechanical weed control practices, but one must be aware of the limitations involved. Ordinary sweep cultivation or directed oil sprays must be relied on for the early part of the season. Flame cultivation can be started when the cotton becomes 6-8" tall, and will provide good control of annual weeds until layby.

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BROADLEAF WEED CONTROL IN SMALL GRAINS

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Effects of Crop Rotations and Cultivation

The role of land management, that is, crop rotation, use of commercial and barnyard fertilizers, and fallow have in the past occupied considerable space in the literature on weed control. This was especially true of Agronomy texts of 20 years ago. In brief these texts said, "crop rotation is weed control." Farm management texts said, "farm management is weed control." And, thus ended the concrete detailed information on weed control.

I happily have some data on 11 crop rotations which have been continuous for the past 42 years, at the University of Idaho. The weeds now present reveal a bit of information on the subject although I am certainly not prepared to say the results obtained would occur elsewhere. There are three replications for each treatment under a uniform management system. That is, the 3 plots in the wheat-oat-pea rotation are all in wheat in the same year.

Table 1. The effect of 11 crop rotation systems on weed population after 42 years (Data from 41st and 42nd year).

Rotation	Crop sequence	Total weeds per square ft.
No. 1	W. Wheat-oats-manure 5T + peas	26.0
" 2	W. Wheat-oats-peas	5.2
" 3	W. Wheat-oats-manure 5T + fallow	3.7
" 4	W. Wheat-oats-fallow	2.4
" 5	W. Wheat-oats-manure 5T + corn	5.5
" 6	W. N. Wheat-N20# + oats-corn	2.6
" 7	W. Wheat-oats-corn	2.1
" 11	W. Wheat-wheat-manure 5T + W. wheat	13.6
" 12	Continuous W. wheat	11.3

Fanweed was the dominant rotations No. 1, 2, 5, 6, 7 and 11. Tumbling mustard was dominant in rotations 3 and 4, and henbit was dominant in No. 11. Rotations with manure averaged 4 times more weeds than those without manure. It further appears that fallow or cultivation aids in weed control.

Table 2. The effect of 5 crop rotations on weed populations after 19 years (Data from 18th and 19th year).

Rotation	Crop sequence	Total weeds per square ft.
No. 10	Alfalfa grass 4 yrs.-S. wheat	9.7
" 13	W. wheat-peas-wheat	
" 14	Peas-wheat	11.4
" 14	Peas-Sw. Cl.-S. wheat	15.0
" 16	W. wheat-peas-W. wheat	
" 16	Peas-alfalfa 3 yrs.-	12.9
" 17	W. wheat-W. wheat	
" 17	Sw. cl. grass 2 yrs.-S. wheat-N30# W. wheat	8.7
" 17	peas-N20# W. wheat	

Fanweed was dominant in all of the 19 year rotations. As an average the weed population is higher in this study where fallow has been omitted from the cropping sequence. Data on the weed populations in these rotations must be gathered for several more years conclusive results.

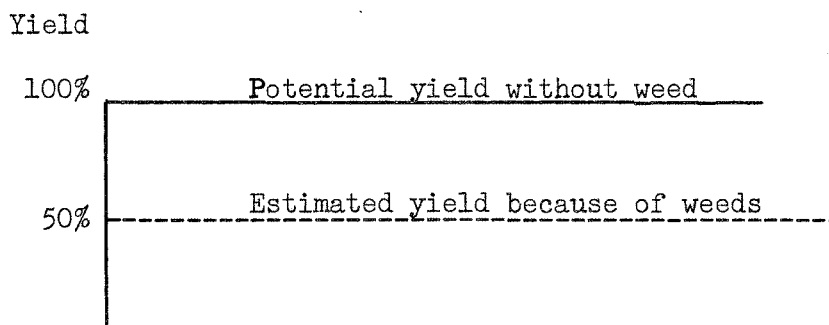
Factors in Chemical Weed Control

Any partial review of the now massive literature, on chemical weed control of broad leaved weeds in small grains, or any evaluation of one's own results over the years, brings one to this substantial conclusion. There is no one uniformly best; whether it be material, rate, method or whatever category one may choose to name. This is because of the multitude of ecological, anatomical, and physiological variables which we have no time to develop here. Most difficult of all is the constant mixture of weed species.

There are I believe a few principles which we can utilize in selective control so soon as we know something of the 3 following factors:

1. The herbicide which you are going to use. Most commonly you will consider these factors in reverse order.
2. The susceptibility of the dominant, the most detrimental, or the most undesirable weed species; which do we wish to control?
3. The tolerance of the crop.

Theorizing now, that without weed competition your potential crop yield is 100 percent. But, the estimated weed competition will reduce your yield 50 percent to give you the following diagram:



Now we will construct another diagram to illustrate the probabilities that may occur as a result of herbicide treatment. We know the following:

1. That herbicide toxicity is relative between weeds and crops.
2. That the amount of crop damage will depend upon how much we use.
3. And that the degree of weed control we obtain will depend on the quantity we use.

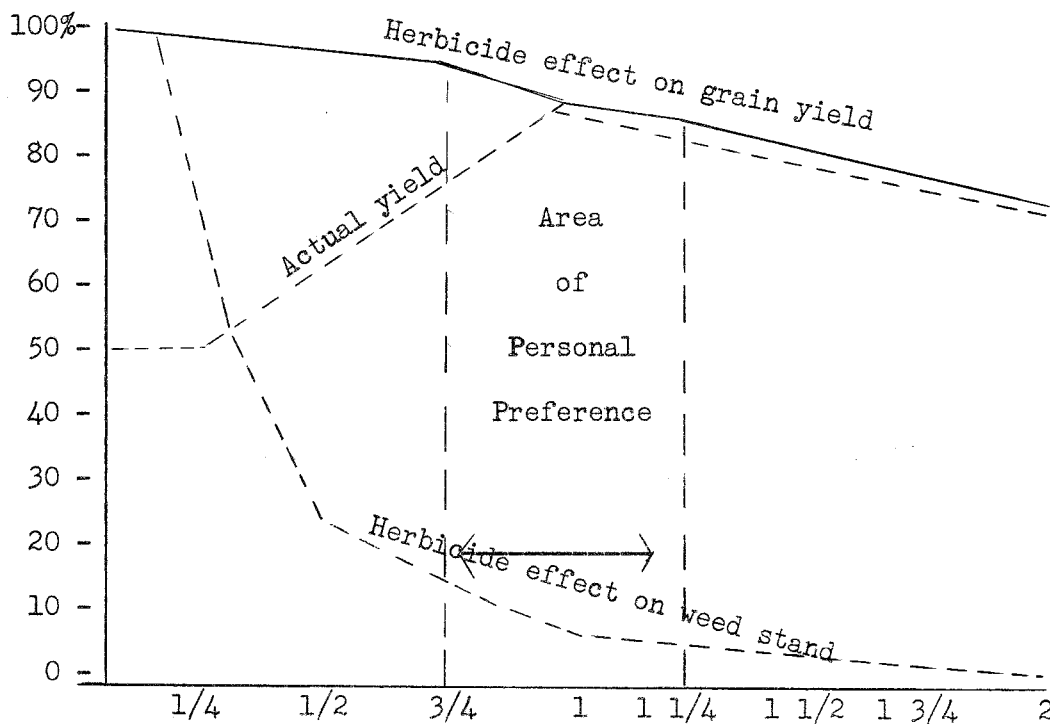
Let us assume in this third instance that we wish to treat with that quantity which gives us the highest crop yield. We will call this quantity, "one herbicide unit." We can't reach the 100 percent yield because of our known herbicide damage to the crop. Furthermore, the weeds have already lowered the potential yield. We also know that we can't kill all the weeds, but we can do a relatively satisfactory job.

Previous experience in this hypothetical instance shows us that our chosen "one unit" of herbicide will in itself reduce the grain yield 10 percent and 2 units will reduce the yield 25 percent. Previous experience shows us also that 1 herbicide unit will reduce the weed stand 93 percent, and 2 units will reduce the weed stand 98 percent.

From this background we can construct our final diagram.

Effects of units of herbicide on weed and crop stand

Crop and
Weed Stand



The diagram is self-explanatory. The indicated, "area of personal preference" may at times be much greater than that which I have indicated. However, I believe the unit area indicated is rather average. Personally, I tend to favor the high side because from experience it results in (1) a reduction in highly erratic results, (2) a higher percentage of satisfied users, and (3) a more stable weed control program.

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RECOMMENDED WEED CONTROL PROCEDURES IN GRASSES AND LEGUMES

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1. Seedling Grasses and Legumes

Management - In planting small seeded grasses or legumes special attention should be given to make conditions as favorable as possible

for a rapid development of the crop species. Proper land preparation, fertilization, etc. cannot be emphasized too greatly. Any practice that will speed up the establishment and growth of these small seeded crops will aid in solving weed problems.

Chemical Controls

- a. Seedling grasses - For control of susceptible broadleaved weeds in seedling grasses, the amine or sodium salts of 2-methyl-4-chlorophenoxy acetic (MCPA) or 2,4-dichlorophenoxy acetic (2,4-D) at rates of 1/2 to 3/4 pound per acre can be used with safety if applied 6 to 8 weeks after emergence of the grasses. Bentgrass is an exception and should not be sprayed with these herbicides. Treatments should be made while the weeds are small and growing rapidly.
- b. Seedling legumes - For control of seedling broadleaved weeds in legumes or in legume-grass mixtures, apply the amine salts of dinitro-secondary-butyl-phenol (DNBP) at rates of 1.0 to 2.0 pounds in 30 to 40 gallons of water per acre. This treatment can be applied without serious injury to grasses or legumes if made at the time the legumes have four or more leaves. When high temperatures and humidities prevail, use the lower rate of this material.

New materials which show considerable promise as pre-emergence applications for control of weedy grasses in seedling legumes are: 2-chloroallyl diethyldithiocarbamate (CDEC), 2-chloro-N, N-diallyl-acetamide (CDAA) and ethyl-N, N-di-n-propylthiocarbamate (EPTC). Rates of application range from 2 to 8 pounds per acre. Promising materials for post-emergence control of certain broadleaved weeds in seedling legumes are: 4-(2,4-dichlorophenoxy) butyric acid (4-(2,4-DB) and 4-(2-methyl-4-chlorophenoxybutyric) acid (4-(MCPB)). Rates of application range from 1.0 to 3.0 pounds per acre.

II. Established Grass - Legume Hay Mixtures.

Management - Making conditions favorable for growth of the crop plants can be very effective in controlling certain perennial weeds. Fertilization, timely cutting of the hay crop, irrigation, etc., can do much to prevent the spread of certain perennial weeds and may even result in their reduction or elimination. Most annual weeds can also be controlled or at least reduced by such practices.

Chemical Control - Several chemicals are being used successfully for control of annual weeds in legumes and grasses hay crops.

- a. Weed control in perennial grasses - Chemicals being used for weed control in perennial grasses are: 2,4-D at rates of 1/2 to 1 pound for control of broadleaved annual or perennial weeds, fall application of isopropyl-N-phenylcarbamate (IPC) or isopropyl-N-(3-chlorophenyl) carbamate (CIPC) at rates of 2 to 3 pounds per acre for control of weedy grasses or certain broadleaved annuals as chickweed and dormant season application of 3-(3,4-dichlorophenyl)-1, 1-dimethyl urea (diruon) at rates of 1.0 to 3.0 pounds per acre for control of all annual weeds.

- b. Weed control in established legumes - Chemicals being used for weed control in legumes are: dormant season applications of IPC and CIPC at rates of 3.0 to 6.0 pounds per acre for control of weedy grasses, dormant season applications of diuron to alfalfa at rates of 1.0 to 3.0 pounds for control of all annual weeds, spring applications of 2,2-dichloropropionic acid (dalapon) at rates of 6 to 8 pounds for control of weedy grasses, and DNBP at rates of 2.0 to 3.0 pounds applied in the winter, spring or summer (after removal of a hay crop) for control of annual broadleaved weeds. Chemicals which look promising for weed control in legumes are: 4-(~~2~~),4-DB and 4-(MCPB) at rates of 1.0 to 3.0 pounds for control of certain broadleaved annual and perennial weeds and disodium 3,6-endoxohexahydrophthalate (endothal) for control of annual grasses.

III. Established Grass-Legume Pastures.

Management - Good cultural practices will do much to control weeds in pastures. Fertilization, grazing management, clipping of weedy growth, etc., should be emphasized in any pasture program.

Chemical Controls - Where weeds persist even under good management, applications of 2,4-D at rates of 0.5 to 1.0 pound will control most broadleaved weeds without too much injury to Alsike, ladino, and white clover. Such treatments may cause severe injury or even eradication of most other legumes. Applications should be made in the late spring after the legumes have made their original rapid growth but while the weeds are still small. Where certain perennial broadleaved weeds are present, a spring and fall application each year may prove to be much more effective than a single treatment.

4-(2,4-DB) and 4-(MCPB) at rates of 1.0 to 4.0 pounds also shows considerable promise for control of certain broadleaved perennial weeds infesting pastures.

IV. Established Grass or Legume Crops for Seed Production.

Chemical Controls - For control of annual and perennial broadleaved weeds in grass seed crops, apply 2,4-D or MCPA at rates of 0.5 to 1.0 pounds per acre. Applications should not be made at the early seedling, boot or early heading stages of growth. Bentgrasses are sensitive to these chemicals and thus they should not be used unless a crop failure would result without treatment.

In the Pacific Northwest fall applications of IPC, CIPC and diuron at rates of 2.0 to 3.0 pounds per acre are being used for control of weedy grasses and some annual broadleaved weeds in perennial grass seed crops. Timing is of great importance since treatments made after the first of November have caused reductions in seed yields and may cause the loss of the entire seed crop if delayed much beyond this date. Grass species differ in their response to these chemicals and thus the tolerance of specific grasses to specific chemicals should be known before making applications. For weed control in legumes IPC, CIPC, DNBP, dalapon and diuron are being used. IPC and CIPC are applied during the dormant season at rates of 1.0 to 4.0 pounds for control of weedy grasses and certain broadleaved weeds. They are

especially useful where winter annual weeds are a problem. DNBP can be applied at rates of 1.0 to 3.0 pounds during the dormant season, early spring or following removal of a hay crop for control of annual broadleaved weeds. At the present time diuron is being used only on alfalfa and should be applied at rates of 2.0 to 3.0 pounds during the dormant season. Dalapon is applied at rates of 6.0 to 8.0 pounds in the early spring soon after the grasses emerge or while they are still in the seedling stage.

Many of the recommendations covered in this paper apply to control of weeds in particular areas of the western states and cannot be given wide spread application without the consideration of many factors. Thus treatments should not be made unless recommended by the state or extension agencies in your area.

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PANEL ON WEED CONTROL IN RANGE LAND

Panel Leader - H. Alley
University of Wyoming, Laramie, Wyoming

PERENNIAL WEED ERADICATION BY TILLAGE

C. I. Seely
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Cultivation is one of the oldest and yet one of the most useful methods of perennial weed eradication. Cultivation has a number of advantages as a method of eradicating creeping perennial weeds. Perhaps the three most important are: (1) the relatively small amount of cash money required, (2) it uses equipment generally available and familiar to the farmer, and (3) the procedure is simple and sure. Probably the greatest disadvantage of cultivation is that it predisposes the soil to erosion and much of this disadvantage can be eliminated by proper management.

Basically the principle involved in weed eradication by tillage is killing the weed by starvation. In order to most efficiently do this we attempt to (1) prevent food manufacture for plant use and (2) speed up the use of foods already stored in the roots by encouraging growth. Five questions are usually asked about cultivation as a method. These are: (1) when should cultivation start? (2) how frequently should cultivations be made? (3) what depth of cultivation should be used? (4) how late should cultivation be continued in the fall?; and (5) how long will eradication take? Each of these questions will be discussed briefly. It should be mentioned, however, that while cultivation tests have been run on all five of the weeds being discussed here, that is Canada thistle, Russian knapweed, bindweed, leafy spurge, and white top, the tests on leafy spurge are not comparable to the others and hence little will be said about this species.

Many tests have shown that the sooner cultivation is started the sooner the kill is obtained and the number of cultivations is not materially different irrespective of when it is started. As a consequence, cultivation

should be started as soon as the land is available which normally is as soon as the crop is harvested. A realization of this fact would improve most cultivation programs more than any other single thing since it would frequently reduce the period of cultivation by as much as a season.

The best frequency of cultivation is determined by many factors but theoretically the closer one can come to the point where the reserve food is at its lowest level the less cultivations will be required for eradication. The time required to reach this low point, however, is a variable since it is influenced by temperature, moisture, day length, species, depth of cultivation and reserve food supply. This makes it practically impossible to always cultivate at this time. In general, however, the point of lowest reserves on these weeds has been about 12 days after first emergence at the narrowest, and tests have shown that cultivations based on this frequency have generally resulted in the least cultivations being required for eradication. Usually this frequency has also required the least time for eradication although getting the frequency too wide has more effect on the time required for eradication than it does on the number of cultivations. It is primarily because of this latter factor that recommended frequencies are generally narrower than might be considered ideal. Different species have different growth rates and hence require varying periods of time for emergence. This makes the ideal frequency vary from species to species. Frequency of cultivation tests where the frequencies were spaced at 7-day intervals have been run under comparable conditions on bindweed, Canada thistle, Russian kanpweed and white top, and these tests have shown that the best frequency for bindweed was between 14 and 21 days, for Russian kanpweed 21 days, for Canada thistle between 21 and 28 days, and for white top 28 days. Since constant frequencies based on a multiple of 7 days are much easier to handle than variable frequencies, most recommendations call for either 14 days on all species, 21 days on all species, or 14 days on bindweed and 21 days for all others. Either the first or third alternatives are to be preferred since with intervals of every 21 days the margin of safety on bindweed is so small that this frequency normally does not give satisfactory results.

The problem of depth of cultivation is relatively simple since tests have shown that although less cultivations are required for eradication with deep tillage the time required for eradication rises materially as the depth is increased and this combined with the high cost of deep tillage makes deep cultivation impractical for general use. Generally for the cheapest and quickest eradication, cultivations should be made only as deep as is necessary to do a thorough job with the implement being used. Where deeper than normal cultivations are used the frequency of cultivation may be widened to allow for the slower rate of emergence. Theoretically the frequency may be widened 2 days for each inch of depth greater than 4 inches.

The problem of how late in the fall cultivation should be continued has not been adequately studied. However, the studies which have been made and field observations indicate that cultivations should continue to within at least one month of the end of the growing season for that particular weed and that stopping too early is a frequent source of trouble.

The period of time required for eradication of these species is a variable depending largely on (1) the amount of stored food in the roots, (2) growing conditions, and (3) the thoroughness of the cultivation job,

and hence only general statements can be made. From tests which have been made, the period of time for a complete kill of all the plants is about as follows: Canada thistle 1 to 2 seasons, Russian knapweed and leafy spurge 2 seasons, and bindweed and white top 2 to 3 seasons. It should be mentioned that by spot treating the few remaining plants with a chemical such as sodium chlorate the period of eradication can frequently be materially shortened and sometimes by as much as a season.

Cultivation as a means of weed eradication well fits into the present farming situation and this no doubt contributes to a renewed interest in this method. With acreages of many surplus crops being reduced, the removal of the infested acreages from production and the placing of these areas under good weed control measures seems to be an excellent management practice both from the standpoint of the present and the future. The small amount of cash outlay required by this method is especially appealing when farm incomes have been reduced by both reduced acreages and reduced income per acre. As a consequence of these two factors it would appear that further increases in interest in cultivation as a weed eradication method may be anticipated.

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SELECTIVE CONTROL OF PERENNIAL WEEDS WITH HORMONE-TYPE HERBICIDES --
DALAPON AND AMINO TRIAZOLE

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A discussion on control of deep-rooted herbaceous perennial weeds would not be complete without mention of methods where herbicides may be used at the same time a crop is raised in the area infested. The control of perennial weeds without serious interruption of crop production has been made possible primarily through the introduction of the hormone-type herbicides 2,4-D, MCPA, and 2,4,5-T. This has been due to the selectivity these materials exhibit towards the grass family which permits their use in such crops as the small grains, corn, and grasses. Unfortunately, most of the deep-rooted perennial weeds are not readily killed by a single application of these selective herbicides. A carefully planned program for their use is needed to get the maximum reduction in the primary weeds under discussion. In many ways, the use of the hormone-type herbicides is closely related to cultivation or mowing since they aid in carbohydrate reduction in the root systems. In other words the chemicals act in one sense as a means of chemically mowing the weeds. That is why generally the use of these materials is suggested at the time the plants reach the bud stage. This is the stage at which depletion of carbohydrate reserves in the roots has progressed to the maximum. The use of chemicals in most cases, however, also gives a certain amount of root damage, which is an additional benefit over carbohydrate starvation alone. Similar to carbohydrate starvation, however, the use of selective herbicides must be carried out on a planned schedule to prevent the weeds from recovering and bringing their reserves back up to an improved level. There are several systems that may be used to accomplish this, but the method will be dependent on the growth habits of the individual weeds. Many of the weeds will recover enough to send up new growth during the summer or fall.

Maximum damage can be done to these species by using more than one spray per year. This can be accomplished by spraying the regrowth in the crop stubble after harvest. In all cases it is necessary to plan the program so annual treatment can be given the perennial weed patches either with chemicals or other control methods.

Some of the perennial weeds are more sensitive to newer materials, such as amino triazole and dalapon. This presents a real problem in selective weed control because these materials are not selective on most crops. Fortunately they can be used selectively in crop production because of their short residual life in the soil. This is particularly true of amino triazole. Research indicates that if it is applied a week or two before plowing and seed bed preparation, it is highly effective in killing or injuring many of the perennial weeds, both the broadleaf types like thistle and grasses such as quackgrass. There will not be soil residues to injure the crop planted.

Dalapon has been found highly effective as a pre-planting treatment in much of the Midwest on grasses. It is used in the spring as soon as quackgrass has six to eight inches of new growth. Two weeks after treatment, the land is plowed and prepared for seeding. In most cases an additional 2-3 weeks is allowed after plowing to permit the dissipation of dalapon residues. The more tolerant crops such as corn, beets, oats, and a number of vegetable crops may then be planted. These chemicals offer concrete means of reducing the population of serious perennial weeds on a farm.

With any chemicals, a planned approach must be carried out to keep the plants from ever getting a chance to recover and to prevent seedlings from buried seed to re-establish the infestations.

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CONTROL OF PERENNIAL WEEDS BY COMPETITIVE CROPPING AND CULTURAL MANAGEMENT

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Perennial weeds can be controlled and eradicated by competitive cropping and cultural management even without the use of chemicals. Several researchers (3)(4)(7)(8) have demonstrated the effectiveness of certain crops and the necessary cultural management in control and eradication of perennial weeds such as Canada thistle, field bindweed and others. This fact is often overlooked in this day of increasing emphasis on weed control with chemicals. This report will deal specifically with field bindweed (Convolvulus arvensis L.), leafy spurge (Euphorbia esula L.), Canada thistle (Cirsium arvense L. (Scop.)), and whitetop (Cardaria draba (L.) Desv.). Some of the principles of competitive cropping and cultural management will be discussed in relation to their control.

Competitive crops have growth habits that make effective use of their environment to the disadvantage of a particular weed. They are often called smother crops (6). These crops have important characteristics such as extensive root systems, vigorous dense topgrowth, rapid development, and

ability to become established.

Cultural management includes the timely performance of all practices necessary for the best growth of the crop and for the greatest interference with the growth of the weed. The cultural operations such as plowing, fertilizing, planting, cultivating, mowing, spraying, etc. are therefore planned to accomplish this.

An understanding of the growth habits of the roots and annual shoots of perennial weeds is of primary importance in developing the best cultural management and competitive cropping program. Apparently very few formal studies of growth habits of these perennial weeds have been made (1). However, some information has been gathered in connection with other studies.

Field Bindweed

This weed begins emergence much later in the spring than whitetop, leafy spurge and usually slightly later than Canada thistle. It makes its most vigorous growth in our western area during the warmest part of the growing season (7).

The most effective competitive crops found to combat this weed are fall sown cereals and vigorous summer crops. The fall sown cereals have the advantage of prior establishment of a heavy competitive growth before the emergence of bindweed shoots. The summer crops are managed so that they effectively compete with the bindweed.

Experiments conducted by Timmons in Kansas from 1936 to 1945 (8) showed the effectiveness of these two types of crops. Some of his data is shown in table I. In all of the treatments listed, cultivation was performed every 14 to 21 days for the remainder of the growing season following crop harvest or before planting as designated in the table. Eradication of bindweed was obtained in 2-4 years depending on the amount of cultivation the first year. Winter wheat, sorgo and sudan grass were effective competitive crops under conditions of this experiment. The advent of 2,4-D has provided another control measure which supplements competitive crops and tillage in bindweed control but does not replace them. 2,4-D should be applied at 3/4 to 1 pound per acre in cereal crops for control of bindweed. Cultivation or spraying again between harvest and planting the crop are necessary in eradication of this weed.

Leafy spurge

The annual shoots of this plant emerge very early in the spring and grow rapidly during cool weather (2). In a study of various control measures in Montana, Krall (5) reported that good competing crops were essential to obtain favorable results with 2,4-D spraying. Table 2 contains data showing the most effective treatments he found. Winter wheat was more effective than spring wheat or barley in this experiment. The cultivations were made 10-14 days after emergence of new shoots each time and are considered an important part of the cultural treatment in controlling leafy spurge on crop lands.

Whitetop

Whitetop was one of the first plants to begin growth in the spring in southwestern Idaho (3). This weed grows rapidly during the cool spring

weather and usually causes serious yield losses in early spring sown annual crops. The combination of competitive crops, 2,4-D spraying and tillage were tested in Southwestern Idaho for control of whitetop. Several of the combined treatments were effective, some giving eradication.

Table 3 lists results of some of the treatments. Spring wheat cropping alone did not control whitetop. However, the use of 2,4-D spray in the spring wheat crop caused eradication of whitetop in 4 years. 2,4-D spraying alone without cropping did not give as good kill of whitetop in the 4 year period.

Silage corn also proved to be an effective competitive crop when combined with 2,4-D spraying.

One of the big advantages to using silage corn in the control of whitetop is the difference in growth habits of the two species. Whitetop was found to begin growth very early and make its maximum growth during the cool spring weather before corn can be grown. Also the high temperatures of the summer under which corn makes its greatest growth result in a slow-down of whitetop growth. Cultural management in this situation allows 2,4-D spraying and/or cultivation of whitetop before corn is seeded. One of the better control methods of whitetop that has developed because of these growth characteristics consists of allowing whitetop to begin growth and proceed to the early bud stage. 2,4-D at 2 pounds per acre is applied at this time (usually early May). The ground is plowed 10-14 days later and the corn, or late barley, is sown. As shown in table 3 almost complete eradication of whitetop was obtained with this cropping and cultural management procedure.

Canada thistle

Canada thistle begins growth later in the spring than whitetop and leafy spurge, but earlier than field bindweed. It makes rapid growth after emergence and has the ability to grow tall and is a vigorous competitor to other plants.

The most effective competitive crops for control of Canada thistle are alfalfa, forage grasses, and winter wheat. Crops such as alfalfa and forage grasses are especially effective since they attain the proper stage for mowing at the same time Canada thistle is in the bud stage and somewhat depleted in root reserves. Canada thistle also does not recover after mowing as rapidly as alfalfa which gives this crop further advantage.

In a five year experiment that was just completed at two locations, Bozeman, Montana and Newdale, Idaho (4), several competitive crops and cultural management practices were combined for control of Canada thistle, table 4.

The results show that Canada thistle is not controlled by spring wheat cropping alone, in fact, the infestation increased in spring wheat in both experiments. When 2,4-D spray was used with spring wheat as a crop, control was quite effective. However, eradication was not obtained in the five-year study using 2,4-D and spring wheat. One year fallow and continuous wheat sprayed with 2,4-D also gave effective control but not eradication. Alfalfa and mowing gave very effective control of Canada

Table 1. Summary of the effect of competitive cropping and tillage on control of Field Bindweed, Hays, Kansas, 1936 to 1945.*

Crop and tillage practice	Years to Eradicate		Yields per year in 4-Yr. period
	Range	Ave.	
Alternate fallow and wheat, wheat seeded Oct. 5-10	2-4	2.9	14.1 Bu.
Fallow 1 year and wheat 3 years, wheat seeded Oct. 5-10	2-5	3.8	16.0 Bu.
Wheat every year, seeded Oct. 5-10 (Int. Cult. from harvest to seeding)	4-6**	---	15.3 Bu.
Cultivate 1st yr. and up to July 1 2nd yr. Sorgo seeded July 1	2-4	2.5	2.4 T.
Cultivate 1st yr. and up to July 1 2nd yr. Sudan seeded July 1	2-4	3.0	1.5 T.
Cultivated May 1 to July 1 Sorgo seeded July 1	3-6**	---	2.4 T.
Cultivated May 1 to July 1 Sudan grass seeded July 1	3-6**	---	1.5 T.

* These data represent a reorganization of data from Phillips and Timmons, 1954.

** Eradication not complete after 6 years.

Table 2. The effect of competitive crops, tillage and 2,4-D on control of Leafy spurge, Judith River, Montana, 1949 to 1952.*

Crop and tillage and spraying practice	Leafy spurge survival after		One yield per year in 4-yr. period
	2 yrs.	4 yrs.	
Percent			
Alternate cultivation and winter wheat with 2,4-D spray	15	T	12.0 Bu.
Alternate cultivation and spring wheat with 2,4-D spray	15	3	10.1 Bu.
Alternate cultivation and barley with 2,4-D	15	5	24.4 Bu.
Cultivation 1st year and fall sown intermediate wheat grass, sprayed with 2,4-D each year	50	10	

* These data represent a reorganization of data from Krall, 1955.

Table 3. The effect of competitive crops, tillage and 2,4-D on control of whitetop, Meridian, Idaho, 1948 to 1952.*

Cropping practice and other treatment	Survival of Whitetop each year after treatments begun			
	1	2	3	4
	Percent			
Spring wheat	81	97	57	109
Spring wheat, 2,4-D spray	34	8	1	0
2,4-D spray only	28	82	40	17
Whitetop sprayed at budstage seedbed prepared 7 days later and barley seeded	20	11	7	0
Whitetop sprayed at bud stage seedbed prepared and corn planted	74	10	1	T
Corn cropping	81	95	100	102
1st year spring wheat and 2,4-D pasture mixture and 2,4-D after first year	93	6	No data	No data

* These data taken from Hodgson, 1955.

Table 4. The effect of competitive cropping and 2,4-D spray on control of Canada thistle.**

Crop and/or Culture	Experi- ment A & B*	Survival of Canada thistle each year after treatments were begun			
		1	2	3	4
		Percent			
1. Spring wheat	A	119	146	156	218
	B	196	219	170	168
2. Spring wheat & 2,4-D spray each year	A	14	2	.9	6
	B	152	125	57	33
3. Spring wheat, nitrogen fertilizer and 2,4-D spray.	A	8	2	1	4
	B	99	25	8	3
4. Alternate fallow and wheat sprayed with 2,4-D	A	.2	.4	0	.6
	B	8	1	.3	.2
5. Alfalfa and mowing	A	14	5	.5	0
	B	121	11	11	.3
6. Seeded pasture and 2,4-D spray	A	13	3	.1	0
	B	19	8	3	3
7. Potatoes and 2,4-D 1st yr., Silage corn and 2,4-D each succeeding year	A	18	0	0	0
	B				
8. 2,4-D only	A	28	49	39	25

* Experiment A located at Bozeman, Montana, B located at Newdale, Idaho.

** These data taken from Hodgson, 1958 (4).

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THE USE OF SOIL STERILANTS IN CONTROLLING PERENNIAL WEEDS

- I. Extended Tests with Established Soil Sterilants.
- II. Exploratory Tests with the Benzoics.

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I. The soil sterilant tests on which the first part of this report is based were conducted over a period of five years and were subject to a wide range of conditions, being located in twenty-six counties representing five major regions in the state of Colorado. Altitude varied from 3,500 to 7,500 feet and the soils involved varied from light to heavy, but were characteristically alkaline. Precipitation during the period of the tests was generally below normal.

The overall results are summarized below, the herbicides and the weeds treated being listed independantly, with the comparative general effectiveness of the herbicides and the comparative general susceptibility of the weeds to these herbicides being indicated by index numbers by which total reduction would be respresented as 100 and no reduction as 0.

Herbicide	<u>1/Pounds</u> Sq.Rd.	<u>2/Index</u>	Weeds Treated	<u>3/Index</u>
1. Sodium chlorate	6	90	1. Woolly-leaved povertyweed	89
2. D.B.Granular	8	89	(Franseria tomentosa)	
3. 2,4-D (Amine)	1/2	88	2. Canada thistle (Cirsium arvense)	80
4. Polybor-chlorate	12	87	3. Quackgrass (Agropyron repens)	76
5. Chlorea	8	86	4. Tall whitetop (Lepidium latifolium)	71
6. Chlorax	8	84	5. Field bindweed	69
7. Polybor	15	64	(Convolvulus arvensis)	
8. Borascu, conc.	15	59	6. Russian knapweed (Centaurea picris)	62
9. Karmex W.	1/2	56	7. Whitetop (Cardaria draba)	62
10. Ureabor	5	52	8. Leafy spurge (Euphorbia esula)	67

1/ Rates used were those generally recommended for the respective herbicides.

2/ Comparative effectiveness as based on weeds treated.

3/ Comparative susceptibility as based on herbicides used.

It may be noted that the presence of either sodium chlorate or 2,4-D characterized the soil sterilants that were most effective against the deep-rooted perennials treated in these tests. The formulations lacking these materials were considerably less effective, this being contributed to in part, no doubt, by the generally sub-normal precipitations, as associated with their characteristically lower solubilities. Although woolly-leaved povertyweed proved to be the most susceptible to soil treatments it has been one of the most resistant to foliage treatments. A similar lack of direct correlation between susceptibility to soil and foliage treatments appears to characterize certain other deep-rooted perennials.

II. Although the benzoics are indicated to be largely effective through the soil, the first Colorado tests were applied as foliage sprays in the spring and early summer at rates of 5, 10, 15, and 20 pounds per acre. Soil treatments were applied in the fall at 20, 40, 80, and 160 pounds per acre. In all instances where comparisions were possible the foliage applications

of the 2,3,6-trichlorobenzoic at 20 pounds per acre were more effective than the soil applications at the same rate, and in several instances 10 pounds as a foliage application were superior to 20 pounds applied as a soil sterilant in the fall. Five pounds per acre as a foliage spray took field bindweed out of bearing tomatoes without injury to the tomatoes. The same rate was equally effective in onions, but had the same injurious effect on the onion bulbs as 2,4-D.

With foliage applications at the lighter rates the 2,3,6-trichlorobenzoic was far superior to the polychlorobenzoic, the 15 and 20 pounds per acre rates of the former each giving 100% reduction of field bindweed as compared to 10% and 60% reductions with the latter at these same rates. With soil applications this difference was not so marked, 20 and 40 pounds per acre giving 90% and 100% reduction for the 2,3,6-TBA and 60% and 90% reduction for the PBA.

In these exploratory tests a single foliage application of 2,3,6-TBA at 10 pounds per acre reduced Russian knapweed 98%, field bindweed 95%, Canada thistle 90%, mouse-ear povertyweed 90%, and leafy spurge 85%. At 20 pounds per acre the reduction varied from 95% to 100% for these same weeds. Whitetop was more resistant, 5, 10, and 20 pounds per acre giving 0, 20, and 70% reduction respectively. As already indicated soil treatments at the 20 pounds per acre rate were inferior to the foliage treatments. Soil treatments at the 40 pound rate reduced bindweed and knapweed 100%, whitetop 90%, Canada thistle and leafy spurge 80%. At the 80 and 160 pound rates all species were reduced 100% except Canada thistle which was reduced 80% and 85% respectively. It appears that some advantage may result from foliage applications although the time of application may also exert an influence.

Results of treatments were determined one year after application in all instances. The 2,3,6-TBA was DuPont's HC-1281-S, the PBA was American Chemical Paint Company's Benzac 103-A.

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METHODS OF CONTROL OF JOHNSON AND BERMUDA GRASS

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Johnson grass (Sorghum halepense (L.) Pers.) and Bermuda grass (Cynodon dactylon (L.) Pers.) have long been weeds of major importance in the warmer areas of the U. S. There appears to be a steady extension of their range northward. This is especially true of Bermuda grass which is appearing in some of the Northern States.

These two weeds are unusual, in that they were introduced as useful plants. Johnson grass was introduced as a forage plant into the U. S. about 1830 and into California as Evergreen Millet about 1884. It had become a pest by 1890. Bermuda grass was offered for sale as a lawn grass in San Francisco in 1858 at \$5.00 per flat. It had become abundant in Southern California by 1900. Both species continue to have important economic uses for forage and for ground cover but our concern today is with control in areas where they are not desired.

Bermuda grass is drought resistant, tolerant of alkali and perhaps the more persistent under unfavorable conditions. Johnson grass flourishes on most of the warmer irrigated soils but will persist, once established, on roadsides, ditchbanks and waste areas.

Cropping Methods. Both of these perennial grasses are vigorous plants and are difficult to eliminate through cropping methods alone. Bermuda grass is not tolerant of dense shade and spring plowing or cultivation followed by a crop such as sudan grass, millet or cow peas that grows rapidly and produces heavy shade will result in production of a crop plus some weakening of the grass. Johnson grass is better controlled in a crop such as alfalfa where frequent timely cuttings prevent seed formation and reduce root reserves. In orchards or vineyards frequent cultivation between the rows plus the effect of shading later in the season and some hand labor or chemicals in the row serve to keep the weeds in check in these crops.

Cultivation. Hand digging of individual clumps of Johnson grass is often the practice used on scattered infestations. This method has been successful in many orchards and vineyards in California. Bermuda grass is often controlled the same way in lawns and flower beds. On large field infestations Bermuda grass is controlled by shallow plowing in the spring, raking and burning as many rhizomes as possible and repeated cross cultivations throughout the summer with a spring-tooth harrow. The rhizomes of Bermuda are killed by exposure to the hot sun. One season of such persistent cultivation in a hot dry climate will virtually eliminate this grass and is the method commonly used throughout the Central Valleys of California. It is not as successful on heavy moist soils and does not prevent reinfestation from seeds already in the soil.

Johnson grass may be controlled in the same way by dry cultivation during hot weather or by repeated discing and irrigation. This latter method is used on heavy, moist soils and depends on decomposition of the chopped rhizomes by fungi and bacteria. The soil must be kept moist and the discings thorough and frequent. In general, discing is not sufficient for control of these grasses and the dry cultivation method is preferred.

Chemical Methods. Repeated oil sprays have been used for many years to control these perennial grasses in orchards, vineyards, roadsides, ditchbanks and other non-crop areas as well as for spot treatment in cotton and other row crops. The oils used have included orchard heater oil, diesel oil, diesel plus crude oil and more recently the weed oils of high aromaticity. Six or more thorough sprayings a season are required at intervals of two to three weeks or whenever there is sufficient regrowth to justify retreatment. It is sometimes possible to get eradication in one season, but usually some retreatment is necessary the following season.

Soil treatment with sodium TCA has been effective where rainfall or irrigation has been sufficient to carry the chemical into the area of absorbing roots when the roots were active. Because of the rapid breakdown of this chemical in soils and the high solubility that favors leaching, results have been satisfactory only under a limited range of moisture conditions. Nevertheless, sodium TCA is an excellent grass killer when it can be properly used.

More recently, control of Johnson and Bermuda grass with dalapon has become an accepted practice not only as a general spray on non-crop land but also for spot treatment in row crops such as cotton, in-the-row treatment in vineyards and around-the-tree treatment in orchards. This translocated grass-killer has quickly become a major weapon in the battle against these perennial grasses. Repeated sprays are necessary for eradication of the grass. Optimum dosage and interval between treatments vary with conditions but something in the order of 10 to 20 pounds per acre applied 2 to 3 times during the season usually gives a high degree of control. Eradication may require additional spray the following season, with of course, some provision for control of seedlings from seed in the soil.

Amino triazole is another of the newer translocated herbicides that shows promise on these grasses. Again, repeated treatments are necessary for a high degree of control or for eradication. Optimum dosages and re-treatment intervals are not as completely worked out as for dalapon. A possible advantage for the amino triazole on crop land is the limited soil effect. For non-crop land, the broad range of species susceptible to this chemical may be an additional advantage.

Soil sterilants are widely used for control of these grasses on non-crop areas and for spot treatment of limited infestations on crop land. If rainfall is low, irrigation or flooding may be required to carry the sterilants into the soil. In general the chlorate herbicides have been highly effective. Combinations of chlorate with other sterilants to lengthen the period of effectiveness in the surface soil have proven valuable.

Soil fumigants, properly handled, provide yet another answer to Johnson and Bermuda grass. Methyl bromide under a plastic covering is highly effective. Vapam in two treatments with a plowing or spading between has been used. Some of the newer fumigants have not yet been thoroughly tested. In general these grasses present a problem in control by fumigants in that the surface rhizomes as well as the deeper rhizomes and roots must all be killed. Covering of some sort to retain the fumigant at the surface, double treatment with plowing to turn the surface growth under and surface treatment with a translocated material such as dalapon followed by fumigation have all been used.

While not attempting to cover all possible control methods in this brief time, I believe I have shown you something of the array of methods available for control of these grasses. Johnson and Bermuda grass are serious perennial weed pests in many regions. They can be controlled and even eradicated by proper choice and application of control methods now available.

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PANEL ON PERENNIAL WEED CONTROL

Panel Leader - W. R. Furtick
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THE PLACE OF HERBICIDES IN RANGE RENOVATION

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The Dow Chemical Company

At the risk of seeming to over-emphasize the obvious, I think it bears repetition that chemicals are just one of the tools for suppression or removal of weeds and brush from range lands; and that brush and weed removal is just one of the practices that must be considered by range managers in the restoration of deteriorated range.

In many cases, brush removal, followed by suitable grazing management, may be all that is needed to restore a particular range to maximum productivity. In other cases additional, more basic steps, such as re-seeding and fertilization, must be taken in order to restore full productivity. Where this is true, the choice of brush removal method may be dictated in part by the primary decision on whether or not re-seeding is to be done. That decision generally rests on the kind and abundance of the resident herbaceous forage. On a sagebrush range for example, if the ground cover of desirable grasses is less than 2 to 4 percent, re-seeding is generally considered desirable. In some sagebrush soils, re-seeding may require the preparation of a seed bed, and where this is so, disking or plowing is the method of choice, as a single operation performs the double function of destroying brush and preparing the seed bed.

In other situations, re-seeding by drilling into unprepared soil may be accomplished after burning off sagebrush. Moreover, where re-seeding is to be done, there may even be merit in chemically killing the brush. The California Forest and Range Experiment Station has used a specially constructed, heavy duty drill for re-seeding in standing dead sagebrush after spraying, and reports that the brush debris aids in establishing grass stands by protecting the seedlings.

Where the residual grass stand still provides a good ground cover, and all that is needed is release by removal of brush and weed cover, plowing or disking are inadvisable because they destroy the grass. The choice of tool then lies between spraying, burning, beating and railing. The cost for spraying or beating lies in the range of \$3 to \$6 per acre; while burning or railing costs \$1 to \$2. Railing is cheap but the percent kill of sagebrush is lower than from the others, even when dragging is done in opposite directions. Neither burning, railing nor beating have any permanent effect on sprouting species associated with sagebrush, such as rabbitbrush and horsebrush, and burning delays the recovery of many of the desirable perennial grasses. Spraying, on the other hand, kills not only sagebrush and many forbs that also compete with grasses, but also retards recovery of sprouting brush species; and does this without hurting the grasses. A second application at a more appropriate season will largely control sprouters too. Thus, spraying alone of range not deteriorated beyond the point of recovery, frequently results in a three-fold increase in forage production from sagebrush range; and at a very nominal cost.

As another example of proper versus improper use of chemical tools, and their relation to other tools for brush control, I cite the experience on chamise and chaparral control in California. Beginning about ten years

ago, after it was discovered that full volume spraying with suitable concentrations of 2,4-D or 2,4,5-T would kill practically every species involved in the chaparral complex, sprouters as well as non-sprouters, many attempts were made to kill mature standing chaparral by aerial spraying. Unfortunately, these attempts were not all experimental. Quite a number of them were commercial, and disappointing results led to a partial rejection of the concept.

It was later discovered, largely through the researches of Dr. Oliver Leonard of the University of California, that chamise and the various other sprouting chaparral species could be controlled by aerial spraying if (1) the mature stems were first destroyed by prescribed burning, (2) the crown sprouts were sprayed within a year after burning, and (3) spraying was done in the spring while soil moisture was still adequate for growth.

Here, then, we have an example of the necessary and proper integration of fire and of chemicals as brush removal tools. One without the other is futile. It should be mentioned also that burning provides an ash seed-bed in which grasses and legumes are broadcast without further preparation or follow-up. Reseeding is a must, since in most chamise and chaparral brushfields there is practically no understory of grasses, even annual ones.

A final example, again from California, will bring out further considerations on choice of methods. In the Sierra Nevada foothills, just above the valley floor, is a vegetation type called the grass-woodland, with scattered oaks, mostly liveoaks, and in the upper elevation of the type, blue oak and digger pine. These are all medium to large trees, so foliage spraying with ground equipment is impractical, and aerial spraying is ineffective.

The individual trees may be felled, using chain saws, at a nominal cost per acre in the usual density of stand, and where there is a market for firewood, this method may even be profitable. Falling alone, however, is not the end of it with liveoak and blue oak, which crown sprout. Stump spraying concurrently with falling is therefore necessary.

Where there is no incentive for salvaging the wood, falling alone, without trimming, piling, and burning, results in a concentration of debris that suppresses grasses in that spot; and, of course, the stumps must be sprayed. With no more labor cost than for falling, the standing trees can be frill-girdled and the frill filled with undiluted 2,4-D amine. The grass is adequately released, and as the tree decomposes, the dropping limbs scatter and fragment, with but minor smothering of grass.

In summary, chemicals alone may be the best tools for control of weeds and brush on range land in some situations. In others, either fire, mechanical removal, grazing management, or, as in the case of St. Johnswort, biological methods, may be more advantageous. In still a third category are situations where a combination of chemical with other methods is the best solution.

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THE CONTROL OF SOME CALIFORNIA RANGE WEEDS

Lester J. Berry
Extension Range Improvement Specialist
University of California

For purposes of this discussion California's range weeds will be grouped into the following four broad classifications: (1) broad leaved plants (2) weedy annual grasses (3) summer growing annuals and (4) poisonous plants. These are of necessity broad classifications and it is conceivable that any particular plant might be included in one or more of these groups.

Italian thistle is a good example of the broad leaved weeds and can be controlled by two pounds of 2,4-D acid equivalent per acre in enough water to afford satisfactory coverage. While 2,4-D applications either by ground rig or by aircraft has afforded good control the scattered nature of the plant's infestation and the terrain on which it occurs has made it a relatively expensive operation, and most range operators have not considered the control of Italian thistle to be economically feasible.

Two outstanding examples of weedy annual grasses are Medusa Head (Elymus caput-medusae) and Goat grass (Aegilops species). These grasses, particularly Medusa Head have become wide spread throughout most of the range areas in northern California and constitute one of the major range problems. Burning in order to prevent seed production, or damage the already produced seed so as to prevent germination, appears to be the most feasible control so far developed for these plants. Some recent work done by staff members of the Department of Agronomy of the University of California and by county farm advisors show that very striking reductions in seed germination occur as a result of a slow hot fire after the plants have matured and seed has dropped. The slow firing can be best accomplished by backfiring against a slight wind. The fire should be hot enough to consume nearly all of the vegetation but should not be so cold that it merely burns the stems off and and lays the plants on the ground. Treatment by this method has reduced the germination of Goat grass by about 97 percent and that of Medusa Head by about 80 percent over unburned seed. A hot fire which merely singes the awns has little effect in reducing germination. Apparently the awns have to be more than half consumed by the fire to have any appreciable effect in reducing germination. In many areas striking control of both Medusa Head and Goat Grass has occurred by first reducing the population of these plants either by burning or by use of contact spray and then establishing an annual legume, particularly subterranean clover, and encouraging its development and growth by a phosphorus fertilization program. In this case the subterranean clover, and to a lesser extent Rose and Crimson clover, act as a competitive crop and afford excellent control.

Tarweed species are good examples of our summer growing annuals. These plants can be generally controlled by properly timed application of from one and a half to two pounds of 2,4-D acid equivalent per acre in sufficient water to afford satisfactory coverage. It has been noted, however, that striking control of plants of this type has occurred where a range fertilization program has enabled the earlier growing grasses to increase their growth and thus extract nearly all of the soil moisture

thereby making it almost impossible for the later growing plants to survive.

Larkspurs, Lupines and loco weeds are common California poisonous plants. Partial control of Larkspur can be secured from 2-3 pounds of 2,4-D acid in the ester form per acre applied in five or more gallons of water. Lupines respond to the same treatment. The only effective control which we have found for the loco weeds comes from the application of two pounds of 2,4,5-T low volatile ester per acre in ten or more gallons of water. Some mention should be made here of Halogeton. This plant occurs only in a small isolated section of north-eastern California with the majority of the infestation being confined within the boundaries of the Sierra Ordinance Depot of Herlong in Lassen county. While it is not yet considered to be a serious pest in California the large Nevada infestations adjacent to California pose the threat of possible future infestation on similar type lands. Satisfactory kills of this plant have occurred from the use of both 2,4-D and the dinitros. The principal problem of control in California, so far, has been one of a matter of adequate survey and positive identification of the areas of infestation.

It can be seen from the foregoing discussion that adequate control of most range weeds by herbicides are far too expensive for our present economy. The nature of our range operations and the extent of the infestation of the common range weeds limits present methods of control to those which can be accomplished by range management practices rather than from the extensive use of chemical treatments. Such practices as range fertilization that permit mid-season grasses to more completely use the available soil moisture thereby preventing the growth of summer weeds have considerable promise. Early concentrated grazing followed by a reduction of grazing pressure discourages the early maturing grasses which include many of our weedy species and encourages the development of the mid-season grasses which contain few weedy species. The introduction and establishment of a legumenous species which will respond to phosphorus or sulfur fertilization and thereby crowd out some of the weedy grasses offer good possibilities. Burning of weedy grasses before seed production or at a time when seed viability will be impaired has much the same results as contact sprays and at much lower costs. All of these methods can be incorporated into range management systems with little added cost and will greatly reduce the range weed problems.

So far it appears that under our present economy chemicals can play only an auxiliary role in most of our range weed control problems. We need refinements in techniques both as to manufacture and use so that herbicides may more readily fit into the extensive type of management that will always exist on range lands.

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SELLING RANGE WEED CONTROL

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Results of research on weed control have little or no real value to the people who are paying the bill unless the results are put into practice

on the land. We can say that generally, a fine job has been done, but there is still a long way to go. We, who are working to get practices for the control of range weeds and brush into action by land operators, often feel frustrated. The apparent lack of interest, slowness in adopting practices, or failure to recognize individual responsibility for weed control on public and private ranges, makes us wonder if we are doing the job.

Much of the range land in the West is publicly owned. As a result, we expect the public administrator of the land to control weeds and brush, and provide, at a very minimum cost, good range for our livestock. Weeds and brush are a problem on these lands, as well as on our own private ranges. Selling weed and brush control to the farmers and ranchers who use these lands is often more difficult than getting it across to those who administer the public lands.

Selling weed control methods may not be as life and death critical as the message to Garcia, but it is important to the long time value of our range lands. We want the people responsible for, and using, the range lands to go out, use the good methods available, and actually control weeds and brush. Just knowing about the problem and its solution is not enough. Ken Warner, formerly of the Federal Extension Service, often pointed out that: "If there is no action, there has been no learning or no teaching."

A land operator who knows he has a problem and can recite a good control program, but who actually never does anything about it, perhaps doesn't have the idea of weed and brush control. He isn't sold on the need for, or the method of control. On the other hand, the man who sprays sagebrush or wyethia to improve the range, or the man who uses the 3-point control program for halogeton on his own land, and encourages the range association or the public land agency into doing weed control and prevention work, is the man who has received the message and has learned.

Teaching methods used, have to be adapted to the area and the people in order for them to be effective. Let me tell of some of the successful ways and means of getting range weed control practices across to the farmer and rancher.

Demonstrations have always been the backbone of the Extension Service. Both method demonstrations and result demonstrations are effective. Many times, we think people can understand and visualize what we are telling them to do. Just as often, the people can't quite see what we mean so we have to actually show them.

George Hoffman, range specialist in Texas, gives us the following experiences: quote, "It appears to me that any new method of weed control or practice takes lots of effort and hard work on the part of the specialist to get it over to the rancher and the various land owners. The method I have used in Texas, to get range weed control across, is by working with the county agents. I have the county agent make arrangements for a place to spray weeds. We have a method demonstration to show how to mix the chemicals, the kind of chemical to apply, the time of year the weeds should be sprayed, and some of the prospective results to be expected. After the results show up, we have a result demonstration field day at the same ranch. We go over the plot, describe the results, and show the results we have

obtained from chemical weed control."

To make the demonstration more effective and to clinch the case for weed control, Mr. Hoffman says, quote, "If at all possible, we make grass clippings on the sprayed and unsprayed plots to show a comparison of the amount of forage that can be produced with weed control as compared to non-control. Then we convert the forage production into air-dry forage and then illustrate that it takes so many pounds of air-dry forage to maintain a 1000-pound cow. We put this into days of grazing or forage supply for the cow as compared to the unsprayed plots."

Mr. Hoffman is pointing out that it is important to cover the field completely - tell them, show them, show them the results, and then discuss it with them. But, don't stop here. Continue by showing them what the results mean in terms of dividends of more grass, better grass, better fed livestock, and finally, in more money in the pocket of the range operator. At the same time this is being done, range management is stressed. Hoffman points out that here is a chance to show the need for deferring grazing for a season or a year so that the grass has a chance to grow in order to develop top and root growth and make a seed source before grazing starts. He says, quote, "Although these methods may seem slow, they have been very successful in getting weed control across in Texas. These demonstration discussions are usually eye-openers to the farmers and ranchers attending the field day."

It seems to me, and many others have expressed the same opinion, that any method or approach that shows and emphasizes the profitable economics of weed and brush control is the key to success in stimulating farmers to adopt the practices necessary.

As I have mentioned, showing results is one of the best ways to get action on range weed control. In Clark county, Idaho, spraying of wyethia, and sagebrush, has been well accepted. Ranchers in that area have seen the results of a spraying program and realized the profitable return from increased forage following spraying. An enterprising forest ranger, along with the county agent, demonstrated this principle effectively. A tour of result demonstrations soon convinced the Clark county stock growers of the merit of the program. Their association sponsored the spraying program that has followed.

Good crowds turned out for halogeton tours in Idaho. As a result, many counties and individuals conducted control programs on spot infestations. Advisory groups assisted the public land agencies in grass plantings and other control and prevention measures on the range.

An important item in demonstrations, tours, and meetings, is the cooperation necessary from other public and private agencies involved.

Demonstrations, tours, and meetings, need supporting work to make them most effective. We have to get the people to the demonstrations and meetings with some smattering of knowledge on the subject. It's like the story of the farmer trying to break his first mule. He was having a difficult time. Made no progress at all. Finally, an old sharecropper, with years of successful experience with mules, offered to help. The farmer turned the mule over to his new-found friend and sat back to see

how to do it. The first thing the sharecropper did was to take a 6 foot length of 2 X 4 and knocked the mule down with a blow between the ears. This, of course, brought the owner of the mule around with concern. "Hey", he shouted, "I just wanted you to break my mule, not kill him." The old fellow responded with, "Son, the fust thing you does when breaking a mule is to get his attention." This is also the first job we have to do before we can teach weed control methods.

Newspaper, radio and television offer the best way to reach a lot of people. Through one of these media, we may get the attention of the farmer or rancher who has been a little slow to accept. Some states are using open end tape recordings prepared by the state office and completed by the county workers. Short, precise information programs and interviews have good listener response. Interview the farmer or rancher who is proving that range weed control does pay. Interview the research workers who have developed the control program for the problem.

Newspapers are always eager for pictures and stories on how to do it. Halogeton made the headlines regularly. The fact that halogeton killed 4000 sheep made it very easy to get lots of publicity and rancher interest.

Magazine articles on how to control range weeds are important cogs in the chain of information reaching the people who are putting these methods into practice.

Bulletins and leaflets giving explicit control programs provide another way to get the message across. Sent out through the mail, used as hand-outs at meetings, demonstrations and tours, and handed out at the office, they offer another effective means of teaching.

Posters, maps, displays, plant mounts, and pictures, are great aids in reaching people. To get the halogeton story across in Idaho, a display was developed showing pictures and plant mounts of halogeton. This was coupled with publications and information on how to control it. It was displayed in county extension offices, at county fairs, and at livestock meetings.

An exhibit showing plant mounts of medusa head, pictures showing the results of control practices, maps showing the infestations of medusa head, halogeton, and goatweed, were displayed at the state wool growers' meeting, the state farm bureau meeting, and the cattlemens' association meeting.

Weed control exhibits at local fairs offer opportunity to sell methods of range weed and brush control. Many county weed control departments have developed good exhibits promoting weed control.

The use of color slides is particularly valuable. Slides showing before and after situations, control results, prevention results and methods, all carry impact. Since it is difficult for the rancher to visualize what it was like before treatment, we need to show all of the story in order to bring people into the situation, and help them see how they can do something about it. By using a good set of color slides, the summer demonstrations can be brought into the winter meetings. Farmers and ranchers unable to attend the summer demonstrations and tours can be reached by this method. This is another place where research workers can

contribute. When they are doing a piece of research on methods of weed and brush control, perhaps they can prepare before and after illustrations that could be made up for use by county agents and others doing weed control educational work.

To get range weed control methods across is challenging to all workers. Everyone here can tell of success in getting farmers and ranchers to adopt recommended practices. Many methods are necessary and all have their place.

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WEED CONTROL ON RANGELANDS OF THE INTERMOUNTAIN REGION

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Idaho Agricultural Experiment Station

The range weed problems of the Intermountain West compare with those of other western areas in one important respect; The major problems generally exist on low-value lands. Thus, the major limiting factor of weed control on rangelands in this region is the economics of control. Yet, there are situations in which we must attempt to control the unwanted and harmful plants on our ranges, regardless of cost. This is especially true of poisonous plants and noxious weeds new to an area.

Time does not permit the discussion of specific control measures for each of the 15 or 20 range weed problems encountered in this area. Furthermore, successful control methods have not been worked out for many of these problems. Therefore, I will discuss several of the means available for range weed control in this region.

In this era of mechanization and "chemicalization", it is hard to sell the idea of grubbing or hand hoeing as a successful means of weed control. However, in the case of some poisonous weeds, where the plants are found in scattered or small remote patches, this method is effective and should be used. Yet, the amount that can be accomplished by hand methods is definitely limited.

Biological control by insects is characteristic of the type of control that we would like to have for all of our range weed problems. It is economical, and where it is successful, it is self-perpetuating. The control of goatweed or St. John's Wort (Hypericum perforatum L.), by beetles which feed specifically on this plant, has been spectacular in Idaho as well as California and other states. However, this method is limited by the number of situations for which specific predators can be found that will do the job successfully and safely.

The successful revegetation of our ranges, whether it be alone or in conjunction with other control methods, has a great potential in bringing serious weed problems in check. The successful revegetation of our ranges with perennial forage plants not only provides competition to the invading weeds, but also increases forage production.

Many acres of low-producing sagebrush lands have been reseeded with crested wheatgrass (Agropyron cristatum (L.) Gaertn.) in southern Idaho in connection with the halogeton (Halogeton glomeratus C.A.Mey.) control programs. Although it is not apparent that this method has delayed the spread

of halogeton, the seriousness of the problem has been diminished in some infested areas. In the first place, the halogeton is not readily eaten when the more desirable forage is available. Secondly, the increased forage production has allowed the deferment of grazing on the salt-desert shrub vegetation types. Subsequently, the condition of the perennial shrub vegetation has been improved and these areas are less vulnerable to the invasion of halogeton.

It is also known that the Mediterranean sage (Salvia aethiopsis L.) and some of the other perennial weeds move tardily into vigorous stands of perennial grass. Thus, where it is possible to improve the condition of desirable range forage plants, serious weed problems are less likely to develop. Yet, the usefulness of revegetation in range weed control is limited from two respects: (1) The revegetation of many of the very poor vegetation types is not feasible, and (2) once a weed problem has developed, it often is not controlled by mere improvement of range conditions.

Many of the possibilities for herbicidal control of range weeds have not as yet been explored. However, sufficient examples are available to show that herbicidal materials can be put to practical use in combating range weed problems, especially when used in conjunction with other practices. When used properly, 2,4-D will successfully kill such problem plants as halogeton, rabbitbrush, larkspur, lupine, loco, water hemlock, and others. The recommended rate of application varies. In most cases, the esters of 2,4-D are superior to the amine 2,4-D formulations.

Regardless of the rate of application, the formulation, or the volume or type of carrier, one very important factor in obtaining good results from herbicides on our ranges is the time of application. For example, one week's delay in applying 2,4-D for halogeton control can mean the difference of obtaining a good kill or no appreciable kill. The timing of spray applications on rabbitbrush (Chrysothamnus spp.) is equally important for obtaining satisfactory results. Likewise, a herbicidal trial in Idaho has shown that dalapon applied in April at 2.0 pounds per acre gave 90 percent control of medusa head ryegrass (Elymus caput-medusae L.). However, when applied in May, one month later, the 4.0 pound rate gave a 50 percent control. This was no better than the 1.0 pound rate applied in April.

In summary, I want to point out two fundamental factors which I believe have created situations favorable to the development of serious range weed problems in the Intermountain Region. The most prominent is the introduction of plants from other parts of the world which are aggressive and which have few natural enemies. However, the primary reason for the extensiveness of the problem is due to the generally depleted condition of the rangelands of this area. This has not only allowed new weeds to spread more rapidly, but it has also caused existing problems to become more serious. I believe that the general improvement of our range weed problems in this area will come only after we have taken two major steps: (1) Through well organized survey and control programs we seek out and then eradicate, at any cost, new weeds prior to their becoming widespread; and (2) through management, we team-up the control methods with other cultural practices to give lasting and economic control of existing problems.

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PANEL ON BRUSH CONTROL

Panel Leader - R. H. Ruth
U. S. Forest Service
Oregon State College
Corvallis, Oregon

BRUSH CONTROL PROBLEMS IN ARIZONA

Thomas N. Johnsen, Jr., Range Conservationist
Crops Research Division
ARS, USDA

There are approximately 30 million acres of grazing land in Arizona which are infested to some extent with undesirable woody plants. In order of importance the major woody plant problems of Arizona are: junipers, mesquite, chaparral, cactus, and the tarbush-whitethorn-creosote bush complex.

Chopping, dozing, and chaining or cabling have all proven effective for controlling junipers. To date almost 600,000 acres have been cleared using these methods in Arizona. However, these methods are limited in use so other methods are being sought. The uses of fire and chemicals are being studied. The results of these studies are still preliminary.

Basal applications of diesel oil around each stem 8 to 10 inches above the ground line is very effective on mesquite. Foliage applications of herbicides with airplane or ground equipment may be used. Spring treatments in two successive years with an ester of 2,4,5-T have given adequate control, but the cost is moderately high.

Effective methods of controlling chaparral, cholla cactus, and the tarbush-whitethorn-creosote bush complex have not been developed yet for use in Arizona.

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THE CONTROL OF BRUSH ON CALIFORNIA RANGE LAND

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University of California

The control of brush has been a long time problem to California range operators. Until recently only the range operators, fire suppression organizations, technicians and the research people of both public and private institutions were really concerned with the range brush problem. Lately there has been a general realization that these low elevation ranges are also watersheds and that the control of brush and its replacement with a grass cover increases the water yielding capacity of these areas as watersheds. Brush control and range improvement in general is now recognized as having public benefits as well as results accruing to the land owner or operator.

Controlled fire is probably the oldest and certainly the most widely used method of brush control in California and many thousand acres of brush land are so treated each year.

The degree of brush control by fire is influenced by several factors which include (1) the type of brush involved, (2) the intensity and completeness of the burn and (3) the type of management practice applied after the burn. Of the many factors which influence the completeness of a burn, the type, age and distribution of the brush itself, the terrains and the changing climatic conditions which exist at the time of the burn are most important.

Most stands of brush are actually difficult to ignite unless almost explosive fire conditions exist at the time the fire started. Much research work has been done to find out how to successfully burn brush without high temperatures, low humidities or high wind conditions. Mashing the brush down with a bulldozer or other suitable equipment six months or more prior to the burn produces a dry fuel that is rapidly ignited and burns cleanly under conditions of much lower temperatures and higher humidities than is required on non-mashed brush. It also leaves a good ash bed free from brush stubble for subsequent seeding to range grass mixtures.

New techniques have been developed to provide rapid ignition of areas prepared for control burning. "Fire grenades", which can be thrown by hand, projected by sling, dropped from air craft or ignited electrically after previous placement in areas of fuel concentration, make it possible to fire the interior of a burn very rapidly and thus create indrafts which are beneficial in keeping the fire within the control lines. This adds greatly to the safety as well as to the success of the burn.

Once the brush is removed it is imperative, both from the standpoint of range and watershed use, that it be replaced with a good stand of grass in order to hold the soil in place and to prevent the regrowth of brush seedlings. Unless the original stand of brush contained more than a 25 percent grass stand it is necessary to seed with a grass mixture. Seed is usually applied by air or other broadcast methods. Mechanical coverage of seed either by dragging or drilling will greatly improve the success of any seeding and is a necessity in southern California. Heavy duty range drills are being developed to seed rough range areas.

A great array of chemicals have been tested in California for their efficiency in controlling our common brush species. It is now apparent that the primary place of chemicals in most California range brush control is that of a follow-up treatment after the brush has first been removed either by controlled fire or by mechanical means. It is also apparent that unless chemicals are used as a follow-up treatment, particularly where sprouting species are involved, the brush control job will not be nearly as successful as the operator desires. The notable exceptions are in the case of big sage brush, coastal sage and coyote brush where 2,4-D does an excellent job of initial control. The most significant advances in our recent knowledge of how to use chemicals in a range brush control program has been in the matter of timing of the application. This timing differs both with the type of brush and chemical involved. Without going into detail it is sufficient to say that most brush can be controlled if the right chemical is applied in the right way and at the right time.

To give a specific recommendation on mixed chapparel, use 3 quarts (3 pounds acid equivalent) of brush killer preparation (equal parts 2,4-D, 2,4,5-T) in 8 1/2 gallons of water and one half gallon of diesel oil per acre applied as an aerial spray in the first spring following a fall burn. This application must be made while the soil moisture is still high. Usually a retreatment on an individual plant basis must be made in the second or third year following the burn using three quarts of brush killer, one gallon of diesel oil and forty gallons of water.

Incomplete planning of the operation from start to finish has been the cause of most of the failures in range brush control. Careful thought should be given to all phases of the program. The treatment of the brush prior to burning, the burning operation itself, the seeding following the burn and the amount and timing of the chemical follow-up necessary to control the regrowth. The size of the area to be treated can then be limited to that on which all of the necessary operations can be performed properly. Too often, and sometimes too late, the operator finds that the area burn was composed largely of sprouting species and that its size, or the cost involved, prevented the proper chemical follow-up treatment. Because of the lack of chemical treatment or treatment at the wrong time the brush comes back rapidly and little if any control is secured. Only by careful thought and the planning of all details can any job of brush control be successful.

We have many range areas where trees, in contrast to brush, are a problem. Often heavy riparian growth creates a problem around stream courses and around springs and ponds. Fire does not provide satisfactory control in these areas. Often, too, terrain factors prevent satisfactory treatment by mechanical means. The use of undiluted 2,4-D amine applied in fills around the base of individual trees affords complete economical and selective control. This treatment results in a spectacular increase in range feed with a high palatability as compared with the feed growing in the inter spaces between trees. Aerial application of 2,4-D, 2,4,5-T and mixtures of these two compounds in both the acetic and propionic formulations have not proven successful for the control of oak trees in California.

The Irrigation Department of the University of California is carrying out extensive hydrological tests to determine the effect on water yield when a brush cover is converted to a good grass cover. The conversion methods which they have used are those which I have just outlined. These investigations have used paired watersheds, one of which has been treated after a suitable calibration period to determine the general trends on both watersheds. These watersheds are now located in nearly all the major areas of California although the ones of the longest period of record are located in northern California. The data from these treated watersheds indicate that if sufficient rainfall occurs to prime the watershed system, replacement of brush with grass will yield approximately 2 acre inches more water per year than from the similar watersheds left in brush cover. These watershed treatment studies also indicate that during the initial period of conversion the erosion rate may be accelerated as a result of treatment but that as soon as a grass cover is established the erosion rate rapidly decreases to less than that which occurs under brush cover.

If we have learned anything from our years of experience in brush control in California it has been that the success of any control practice depends upon careful planning and thoughtful analyses of the complete program before it is undertaken. If the proper attention is paid to the details that will allow the right things to be done at the right time and in the proper sequence our brush control practices will be reasonably successful.

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BRUSH CONTROL PROBLEMS

Auburn L. Norris, Vice President, Chem-Air, Inc.
Seattle, Washington

When Bob Ruth asked me to participate in the program as a member of this panel I thought it would be quite easy, as we have taken a number of pictures of our brush control operations, and I expected to make a very informal presentation with a few remarks while I showed the slides. About two weeks before the meeting I got a letter asking for a copy of my paper. This request disturbed me as formal papers pin one down so as to make it very difficult to get out of any traps unintentionally set during the preparation. To dodge this I am going to show my slides while making a few comments, and then if any of you wish to get at those trapping statements you will need to do so during the question and answer period. Even if I err giving extemporaneous answers, and they are printed, I than have a pat excuse of not being correctly quoted or not being fully quoted, or - well you know, I worked for a Division of Government for nine years, and if I learned nothing else, I learned to maneuver like a State Weed Specialist to cover my tracks.

The pictures I have are of operations and do not show much of results of foliar applications. For this reason you will have to take my word that on Alder and Willow, our results are excellent with little or no injury apparent on the conifers found in the understory, and which we are releasing.

Slide #1

This is a picture showing a contrast in nozzles and resulting spray pattern, both being operated from the same pump. There are uses for each of these spray patterns, but here I prefer the fan type. Incidentally, this large sized Bean Sprayer is excellent to use in control of brush on roadsides and doubles as a good piece of fire fighting equipment.

Slide #2

This picture is of an application at ten gallons total per acre at bud break in April on Vine Maple.

Slide #3

This slide shows results of an application such as shown in the previous slide using 2,4,5-T in diesel oil. In this particular case four pounds of 2,4,5-T in nine gallons of diesel oil, and in this picture you

can see the sprouting of Alder especially from the central stem, but the Vine Maple still looks sick. This picture was taken in July following the application in April, so don't be misled. This is, however, one of the most encouraging of the applications we have made to date on this hard to kill species.

Slide #4

This slide shows what may happen to the Vine Maple sprayed in dormant. This is however of resprouting after a foliar application of 2,4,5-T at the same rate made in June, 1957 and the picture taken in 1958. The little conifer has probably been given considerable help, but the Vine Maple may still win out. At least we don't think this application quite good enough for commercial development.

Slide #5

This picture was put in to show what we believe to be a very important consideration in commercial applications of chemicals, that is the right type of equipment. This demonstrates what we believe to be the best equipment yet developed, as far as brush spraying in our area is concerned. This truck makes it possible for us to keep chemicals ready to load and turn the helicopter around in 30 seconds from the time it hits the ground.

Slide #6

This picture shows excellent distribution of chemicals over about a 35 foot swath, and also shows a typical release area with some conifers sticking up through the brush canopy. Also note the close quarters for flying and you will see what the helicopter is much safer than our fixed wing ships for such work.

Slide #7

This final slide was put in to again show a typical type area and also to show that we who work in this type endeavor have something to enjoy along with our menial tasks.

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Arthur F. Wetsch
Bonneville Power Administration
Portland, Oregon

Brush control on Bonneville Power Administration's rights-of-way is one of the biggest problems and expense in transmission line maintenance. Uncontrolled brush grows into transmission lines causing outages and it seriously impedes crews in restoring service and in performing routine maintenance work.

Until 1953 brush control work consisted of hand cutting and burning. Costs were excessive and regrowth followed quickly.

Herbicidal treatment properly employed offers the most promising solution to long range low cost brush control measures. B. P. A. employs three basic methods of control. These are:

1. Cutting, Disposal and Stump Treatment
2. Basal Treatment
3. Foliage Spray Treatment

Cutting, disposal and stump treatment, because of its high cost, is employed only in restricted areas. Significant is the fact that stump treatment must follow cutting very closely to be effective. It is also not effective when applied during a heavy rain.

A basal treatment is effective on nearly all species of brush if properly applied. It is, therefore, used in mixed stands of brush containing species resistant to foliage sprays, when near susceptible crops, and in inaccessible locations.

B. P. A. has found that: A dormant basal is not as effective as a summer basal; girdling of the larger trees prior to spraying ensures control; and application with power spray equipment is preferable to back pumps. Back pumps are used only in areas not accessible to power spray equipment.

Foliage sprays offer the widest variety in the method of application, selectivity of control, and the unit cost. However, many species of brush are resistant to foliage sprays. But because of its low unit cost and the predominance of susceptible species on many rights-of-way it is employed quite extensively. Applications by ground rigs is the accepted practice.

Control can be secured on alder, willow, hazel and in some instances cottonwood. However, by applying a more concentrated solution a top kill can be secured on many other species.

Helicopter spraying is ideal from a management standpoint for it does not tie up large crews for long periods of time, the cost is low, and the spray is uniformly applied.

To illustrate, in May of 1957, B. P. A. sprayed by contract 770 acres in 10 1/2 hours flying time in a little over three days. This was done on two different rights-of-way and over rough terrain. A preliminary examination indicates that over 90% control was achieved on these predominantly alder infested rights-of-way. However, because of drift hazards, helicopter spraying is very limited.

The Administration's experience with helicopter spraying indicates that it can be successfully performed by adhering to the following:

1. Select areas for spraying in which alder predominates and not near susceptible crops.
2. Spray only during mild weather and when the wind velocity is less than three miles per hour.
3. Watch local air currents in deep draws and make corrections in flying.
4. Maintain helicopter speed less than 40 miles per hour.

5. Apply spray in coarse droplets.
6. Use a spray solution that will not damage bordering tree crops.

Bonneville Power Administration specifies a 10 percent solution of brush killer (low volatile esters of 2,4-D and 2,4,5-T 2 pounds parent acid each) in water applied at the rate of 10 gallons total solution per acre. This has secured control of alder without any material damage to bordering timber.

The most recent experience is with the use of wind machines for brush spraying. From the limited time that we have used these machines it appears that they will play a prominent part in future brush control work.

The advantages are the low unit volume of spray material required, the ease of application and the thorough wetting action. At present the average time for spraying an acre of dense brush on a 100 foot right-of-way is ten minutes. A total solution of 25 gallons per acre is all that is normally required for adequate coverage. We hope to reduce this amount as we gain more experience. It is too early to make positive statements in regard to control, but it appears that a much wider variety of species can be controlled by the selection of different chemicals and carrier.

The advantages of herbicidal treatment can be seen by examining the rights-of-way treated a number of years ago. In most cases the recurrence of brush is considerably reduced and low growing native vegetation predominates.

B. P. A. plans on a respray cycle of five years to retain control, but the costs will be substantially less than initially.

#####

BRUSH CONTROL

John H. Kirch, Woody Plant Specialist
American Chemical Paint Company

Mr. Chairman, members of the Western Weed Control Conference. I would like to talk with you for the next few minutes about invert emulsions. Because of their low drift, improved marking, and better penetrating qualities I think they may have a place in your area.

Basically, an invert emulsion is a water-in-oil mixture. Unlike our standard oil-water sprays, which have all the oil droplets surrounded by water, invert emulsions have all the water droplets surrounded by oil. The formation of this water-in-oil emulsion, keeping the proportions of oil and water the same as in an oil-in-water spray, produces a viscous emulsion with a consistency about like buttermilk.

Being thicker than a conventional spray, an invert tends to form a layer on whatever it strikes, like icing on a cake. Having oil on the outside of the emulsion means that oil strikes the plant first. This oil penetrates into plants faster than oil from sprays with water as the outside phase. Since the active chemical is carried in oil, it penetrates

right along with the oil. There is some indication that substituting a non-phytotoxic oil for the diesel oil and fuel oils we have been using, may not only improve this penetration but may also increase translocation of the chemical within the plant.

The basic herbicide ingredients in the invert are the same as those used in an oil-water or water-borne spray. Thus all the phenoxyacetic and propionic esters of D and T, as well as any other oil soluble acid, may be made into an invert emulsion.

To mix an invert emulsion in the field, use a slightly different procedure than for mixing an oil-water spray. Add your oil to the tank first, then your chemical concentrate. While agitating this mixture, add water slowly until the desired volume is reached.

Invert sprays may be mixed for either high volume ground or low volume aerial applications. For ground applications we are using a ratio of one gallon of chemical to 10 gallons of oil, brought up to 100 gallons total with water. On more resistant species such as your vine maple, big leaf maple, salal, and salmon berry, I think a ratio of 1 1/2 gallons of chemical in 15 gallons of oil brought up to 100 gallons with water will be more effective. These ratios are most effective and economical when applied as basal sprays.

For aerial applications we plan to use either 2 quarts of chemical in 2 quarts of oil brought up to 5 gallons total with water, or 4 quarts of chemical in 4 quarts of oil brought up to 10 gallons total with water. These are per acre rates and volumes.

We had anticipated using invert emulsions primarily on woody plants, applying them in volumes comparable to those used in ground applications of oil-water sprays (200 to 400 gallons per acre). However, the major advantages of the invert type of spray - low drift, marking characteristics, faster penetration, reduced evaporation - have interested weed workers in other fields.

Having oil on the outside phase may be an advantage in water weed control. Oil droplets containing the active ingredient may float on the surface and make better contact with plant tissue. We are presently comparing invert and oil-water aerial sprays on water hyacinth in Florida.

Having talked with some of you men here and having seen the phenomenal terrain over which you must make aerial applications, particularly in the forestry field, I think the heavier droplets of invert may enable you to fly higher swaths and still get your chemical down on the ground in a good pattern. This should increase your safety margin.

We are currently working on a special rig operating on the principals of gravity flow and centrifugal force for making these aerial applications. This is to be used in the event that we cannot get inverts through the conventional equipment now used on helicopter and fixed wing aircraft.

I would like to leave you with this work about invert emulsions. They are still very much in the research stage. They show great promise in many fields, but they must be tried experimentally until we find just where they will fit into the overall weed control picture.

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BRUSH CONTROL ON FOREST LANDS IN THE PACIFIC NORTHWEST

H. Gratkowski
Pacific Northwest Forest and Range Experiment Station
Roseburg, Oregon

Brushfields and brush encroachment on forest land are causing serious losses in timber production in the Pacific Northwest. The losses result from delayed stocking, understocking, and reduced growth of trees at all ages. In southwestern Oregon alone, brush is a problem on about 1 1/2 million acres of commercial forest land; and additional acreage is being lost as brush invades some of the new cuttings. However, the problem is not limited to southwestern Oregon. Brush is also reducing forest growth on large areas of forest land in the ponderosa pine region of eastern Oregon and in other parts of the Pacific Northwest as well. The need for brush control and brushfield reclamation will become increasingly more serious as the need for wood products increases with our growing population.

Two typical brush problems on ponderosa pine lands in eastern Oregon are extensive, non-stocked brushfields and understocked stands with a dense understory of brush. In the understocked stands growth is slowed and stocking is delayed, for young trees under the brush may remain suppressed for decades. The non-stocked brushfields are entirely unproductive.

Three of the most troublesome species in eastern Oregon are pine manzanita, snowbrush ceanothus, and a shrubby form of golden chinkapin. Results to date indicate that pine manzanita can be controlled during the period of active growth with low volatile esters of 2,4-D applied as a foliage spray at a rate of 1/2 pound a.e. per acre in an emulsion carrier. Aerial application has been successful with a 2 pound per acre dosage of 2,4-D and a spray volume of only 3 gallons per acre. Aerial parts of snowbrush have been killed with 3/4 to 1 pound of 2,4,5-T per acre in an emulsion carrier; but treated plants resprout. Aerial parts of chinkapin can also be killed with low dosages of 2,4,5-T. On one plot, chinkapin treated in the fall of 1955 with 1 1/2 pounds of 2,4,5-T per acre in an emulsion carrier has not resprouted after a lapse of 2 years.

Brush control is especially difficult in the extensive brushfields of southwestern Oregon, where a single brushfield may contain 20 or 30 different species with extreme variation in susceptibility to herbicides. Screening tests of herbicides on 13 of the more important brush species showed that they could be classified into three categories on the basis of degree of susceptibility to foliage sprays: (1) susceptible, (2) moderately susceptible, and (3) resistant.

Susceptible. -- Four species proved very susceptible to herbicides and were readily killed with low concentrations of 2,4-D in water and emulsion carriers. Species in this group were hairy manzanita, hoary manzanita, howell manzanita, and deerbrush ceanothus.

Moderately susceptible. -- Aerial portions of four brush species were readily killed with chemicals, but relatively few of the shrubs

were completely killed. Most of the treated plants resprouted the year after treatment. This group includes greenleaf manzanita, snowbrush ceanothus, varnishleaf ceanothus, and mountain whitehorn ceanothus. 2,4,5-T was most effective on the three species of ceanothus, while 2,4-D was most effective on greenleaf manzanita.

Resistant. -- Five species proved resistant to herbicides. Only portions of the stems and branches died back after being sprayed with herbicides; none of the treated plants were killed. Resistant species were golden chinkapin, golden evergreenchinkapin, scrub tanoak, saskatoon serviceberry, and canyon live oak. The chinkapins were most affected by 2,4,5-T. There was little difference, however, between the effects of 2,4-D and 2,4,5-T on tanoak and serviceberry. On canyon live oak, 2,4-D was more effective than 2,4,5-T.

An aerial application of herbicides followed by a prescribed burn in an evergreen brushfield in the Siskiyou Uplands did not control the brush to a degree which would allow reforestation. Species composition consisted of greenleaf manzanita, canyon live oak, mountain white-thorn ceanothus, scrub tanoak, and a shrubby form of chinkapin. Low volatile esters of 2,4-D at a dosage of 3 pounds acid equivalent per acre proved as effective as brush killer mixtures of 2,4-D and 2,4,5-T in this brush type. Extensive resprouting occurred following all treatments. A second application of 2,4-D is planned during 1958 to determine the effect of aerial sprays on the sprouts.

SUGGESTED SOLUTIONS OF HERBICIDES FOR FOLIAGE APPLICATION
ON BRUSH SPECIES IN SOUTHWESTERN OREGON

Common Name	Chemical	Pounds acid equivalent per 100 gallons	Carrier	Estimated degree of control 1/ control 1/	Comments
Manzanita, Hairy	2,4-D	2	Emulsion ^{2/}	100/100	Good control with one treatment.
Manzanita, Hoary	2,4-D	2	Water	100/100	Good control with one treatment.
Manzanita, Howell	2,4-D	2	Water	100/95	Good control with one treatment.
Manzanita, Greenleaf	2,4-D	2	Emulsion	90/20	Respray sprouts.
Ceanothus, Deerbrush	2,4-D	2	Water	100/90	Respray probably not needed.
Ceanothus, Snowbrush	2,4,5-T	2	Emulsion	100/30	Respray sprouts.
Ceanothus, Varnishleaf	2,4,5-T	4	Emulsion	100/85	Respray sprouts.
Ceanothus, Mountain Whitethorn	2,4,5-T	2	Emulsion	100/20	Respray sprouts.
Chinkapin, Golden	2,4,5-T	2	Emulsion	60/0	Several applications probably required to kill.
Evergreenchinkapin, Golden	2,4,5-T	2	Emulsion	60/0	Several applications probably required to kill.
Tanoak, Scrub	2,4-D	2	Emulsion	60/0	Several applications probably required to kill.
Serviceberry, Saskatoon	2,4-D	2	Water	50/0	Several applications probably required to kill.
Oak, Canyon Live	2,4-D	2-4	Emulsion	50/0	Several applications probably required to kill.

^{1/} Estimated degree of control possible with one application. Top kill in percent/root kill in percent.

^{2/} Oil-and-water emulsion containing 3 percent black diesel oil by volume.

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REPORT OF THE RESOLUTIONS COMMITTEE

F. L. Timmons, Chairman

The Resolutions Committee moves the adoption of the following resolutions and further moves that the Conference Secretary be instructed to send copies of each resolution to the appropriate agencies and/or individuals concerned.

Resolution No. 1

WHEREAS, the Western Weed Control Conference has greatly enjoyed and benefited from the excellent arrangements and facilities provided for holding this 16th meeting of the Conference,

NOW, therefore be it resolved that we express our appreciation and thanks to the following:

Mr. A. W. Lange, Chairman, and other members of the Local Arrangements Committee for much time and effort in ably working out the local arrangements

The Spokane Chamber of Commerce which furnished without charge the facilities and stenographic help necessary for registration

The Davenport Hotel which furnished without charge the meeting room and other space and facilities for Conference meetings and registration.

Resolution No. 2

WHEREAS, our officers during the past biennium, Vice President, R. A. Fossee, Secretary-Treasurer, W. R. Furtick, and Research Section Chairman, Jesse M. Hodgson, have spent much time and effort in handling Conference business and in arranging the well planned and interesting program for this 16th Conference meeting,

NOW, therefore be it resolved that we express to these persons our deepest appreciation and thanks for their services.

Resolution No. 3

WHEREAS, research is the basis of advancement in weed control and reports of research are important to the members of the Conference,

NOW, therefore be it resolved that this 16th Western Weed Control Conference commend the Research Section for the contributions to and assembling of the Research Progress Report for this meeting, and

BE it further resolved that this Conference commend Jesse M. Hodgson, Section Chairman, and the nine Project Committee Chairmen for their capable leadership in that effort.

Resolution No. 4

WHEREAS, every effort should be made to make published information on weeds and weed control available for reference purposes, and

WHEREAS, libraries of educational institutions with agricultural interests are frequently found without copies of proceedings and research reports of weed conferences,

NOW, therefore be it resolved that the Secretary of the Western Weed Control Conference send notices to the libraries of said institutions in the 11 Western States advising of the availability of Western Weed Control Conference Proceedings and Research Reports stating the source and cost of these reports, and

BE it further resolved that Conference members strongly recommend to the libraries of their respective institutions that a file of these publications be obtained and kept current.

Resolution No. 5

WHEREAS, the proceedings of regional weed conferences have limited availability, mostly within the particular conference concerned, the proceedings are mimeographed, bound in paper covers and not suitable for reference use more than 5 to 10 years, and

WHEREAS, WEEDS, the Journal of the Weed Society of America, is a permanent reference with wide circulation throughout the United States, Canada, and certain other countries,

NOW, therefore be it resolved that the Western Weed Control Conference request the Editorial Board of WEEDS to consider accepting for publication in WEEDS worthy papers that have been included previously in the proceedings of a regional weed conference.

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REPORT OF EDUCATION COMMITTEE

Eugene Heikes, Chairman

The Education Committee met with representatives from California, Washington, Idaho, Utah, Montana and Nevada present .

It was proposed that a newsletter be prepared and exchanged among Extension weed workers in the Western Conference. There being 11 western states, it was suggested it be a monthly newsletter-each state responsible for publishing the letter once during the year. The purpose of this letter would be to exchange ideas, learn more about each others problems, teaching methods used and for all to become better acquainted with each others work. The chairman was instructed to write each specialist and set up an order for publishing the letter, probably on an alphabetical basis.

The committee also discussed the 1960 conference which will be held in Denver. The Western Conference will be meeting with the National Conference at this time. As guest speakers it was suggested that Beal and Bowland from Iowa State be considered. It was thought these men would be very interesting to Extension people, as well as others attending the conference.

It was also proposed that the Extension people meet one day before the Conference began. This would give us time to become better organized and discuss our problems in more detail.

REPORT OF THE TERMINOLOGY COMMITTEE--WSA

Chemical Name	Designations accepted for use in all publications of WSA
2,4-dichlorophenoxyacetic acid	2,4-D
2-methyl-4-chlorophenoxyacetic acid	MCPA
2,4,5-trichlorophenoxyacetic acid	2,4,5-T
3,4-dichlorophenoxyacetic acid	3,4-DA
4-chlorophenoxyacetic acid ²	4-CPA
2-(2,4-dichlorophenoxy) propionic acid	2-(2,4-DP)
2-(2-methyl-4-chlorophenoxy) propionic acid	2-(MCP)
2-(2,4,5-trichlorophenoxy) propionic acid	silvex
2-(3,4-dichlorophenoxy) propionic acid	2-(3,4-DP)
2-(4-chlorophenoxy) propionic acid	2-(4-CP)
4-(2,4-dichlorophenoxy) butyric acid	4-(2,4-DB)
4-(2-methyl-4-chlorophenoxy) butyric acid	4-(MCPB)
4-(2,4,5-trichlorophenoxy) butyric acid	4-(2,4,5-TB)
4-(3,4-dichlorophenoxy) butyric acid	4-(3,4-DB)
4-(4-chlorophenoxy) butyric acid	4-(4-CPB)
sodium 2,4-dichlorophenoxyethyl sulfate	sesone ^a
2,4,5-trichlorophenoxyethyl sulfate	2,4,5-TES
2-methyl-4-chlorophenoxyethyl sulfate	MCPES
2,4-dichlorophenoxyethyl benzoate	2,4-DEB
trichloroacetic acid	TCA
2,2-dichloropropionic acid	dalapon
2,2,3-trichloropropionic acid	2,2,3-TPA
dichloral urea	DCU
2-chloro-N,N-diallylacetamide	CDA
2-chloro-N,N-diethylacetamide	CDEA

Chemical Name	Designations accepted for use in all publi- cations of WSA
isopropyl-N-phenylcarbamate	IPC
isopropyl N-(3-chlorophenyl) carbamate	CIPC
sec-butyl N-(3-chlorophenyl) carbamate	BCPC
2-chloroallyl diethyldithiocarbamate ²	CDEC
3-phenyl-1,1-dimethylurea	fenuron
3-(p-chlorophenyl)-1,1-dimethylurea	monuron
3-(3,4-dichlorophenyl)-1,1-dimethylurea	diuron
1-n-butyl-3-(3,4-dichlorophenyl)-1-methylurea	neburon
pentachlorophenol	PCP
4,6-dinitro-o-secondary butylphenol	DNBP
4,6-dinitro-o-secondary amylphenol	DNAP
3,5-dinitro -o-cresol	DNC
2,3,6-trichlorobenzoic acid	2,3,6-TBA ^b
2,3,5,6-tetrachlorobenzoic acid	2,3,5,6-TBA ^b
N-1-naphthylphthalamic acid	NPA
3,6-endoxohexahydrophthalic acid	endothal
sodium-N-methyldithiocarbamate	SMDC
phenylmercuric acetate	PMA
potassium cyanate	KOCN
hexachloroacetone	HCA
isopropyl xanthic acid	IPX
maleic hydrazide ²	MH
trichlorobenzenes	TCB ^b
orthodichlorobenzene	DCB
2-chloro-4,6-bis(diethylamino)-s-triazine	CDT
3-amino-1,2,4-triazole	Amitrol

Chemical Name	Designations accepted for use in all publications of WSA
octachlorocyclohexenone	OCH
ethyl xanthogen disulfide	EXD
monomethylarsonic acid ²	MAA
2-(2,4,5-trichlorophenoxy)ethyl 2,2-dichloropropionate	erbon
polychlorobenzoic acid	PBA ^b
2-chloroethyl N-(3-chlorophenyl) carbamate	GEPC
2-(1-chloropropyl)N-(3-chlorophenyl) carbamate	CPPC
ethyl N, N-di-n-propylthiolcarbamate	EPTC
ethyl bis(2-ethylhexyl)phosphinate	EBEP
P,P,-dibutyl-N,N-diisopropylphosphinic amide	DIPA
disodium monomethylarsonate	DMA
chlorate-borate-monuron mixtures	CBMM ^c
chlorate-borate-fenuron mixtures	CBFM ^c
chlorate-borate-diuron mixtures	CBDM
chlorate-borate mixtures	CBM ^c
borate-monuron mixtures	BMM ^c
borate-2,4-D mixtures	BDM ^c
ammonium sulfamate	AMS
2-chloro-4,6-bis(ethylamino)-s-triazine	simazin ^a
2,3-dichloro-4-naphthoquinone	dichlone
3,5-dimethyltetrahydro-1,3,5,2H thiadiazine-2-thione	IMTT

^a Common names "tentatively accepted" by the Terminology Committee of WSA.

^b These herbicides are usually available for use as mixed isomers. When possible the isomers should be identified, the amount of each isomer in the mixture specified, and the source of the experimental chemicals given.

^c These abbreviations are used to designate mixtures used as soil sterilants. The writer should indicate in a footnote the percentage composition of the product. For example: sodium chlorate - 40.0%, sodium metaborate - 57.0%, and monuron 1.0%.

REGISTRATION LIST

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March 18, 19, 20

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