

PROCEEDINGS



Is There a Better Way?

THIRTEENTH
WESTERN WEED CONTROL
CONFERENCE

RENO, NEVADA - FEBRUARY 5, 6, 7, 1952

PREFACE

A committee under the chairmanship of Archie R. Albright, Washoe County Extension Agent handled the display of chemicals, equipment and weeds. The value of the meeting was enhanced by these displays and the Conference thanks Mr. Albright and the following exhibitors for their cooperation and effort.

Food Machinery Company
Hurst Industries, Inc.
Nevada Tractor and Implement Co.
Nevada State Department of Agriculture
California Spray-Chemical Company
American Cyanamid Company
E.I. duPont de Nemours & Company
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WESTERN WEED CONTROL
CONFERENCE

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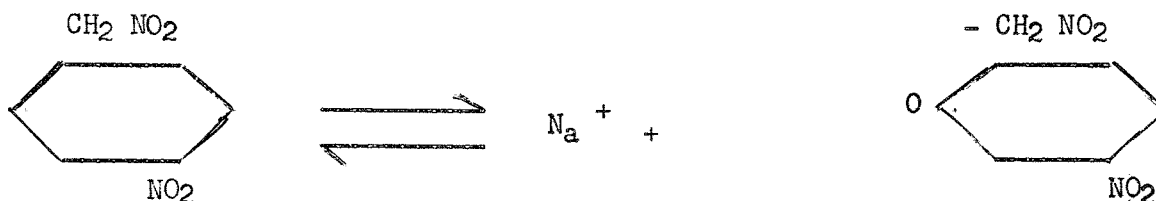
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RELATION OF pH TO THE PENETRATION AND TRANSLOCATION
OF 2,4-D IN PLANTS

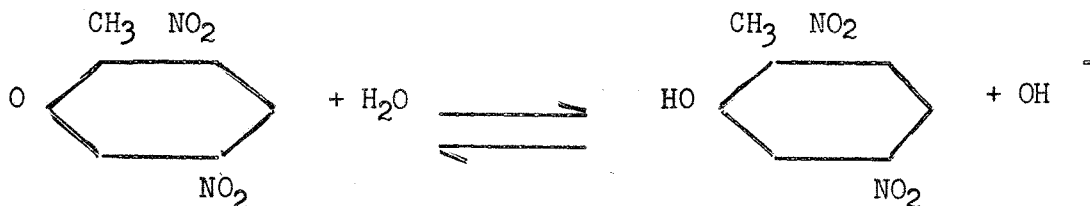
A.S. Crafts, California Agricultural Experiment Station, Davis, California

Soon after the introduction of Sinox (sodium dinitro ortho cresylate) into the United States it was found that addition of ammonium sulfate materially increased its effectiveness. Tests proved that other acid salts including sodium bisulfate and aluminum sulfate would bring about the same effect; likewise sulfuric acid. Addition of acid or acid salts was termed "activation" and it soon became standard practice in the use of this selective weed killer.

Because any of a number of sources of acid caused the same activation it seemed that some general chemical principle was involved and investigation proved this to be true. When Sinox is dissolved in water it dissociates according to the following reaction.



However, because dinitro cresol is not a strong acid the following equilibrium exists in aqueous solution.



If acid is added to the solution hydrogen ion tends to unite with the free OH⁻ on the right forming water and the reaction tends to shift toward the right resulting in an increase in undissociated cresol molecules.

Plants growing in the open are covered with a waxy coating the cuticle that prevents loss of water vapor from the leaves except through open stomata. Undissociated cresol molecules are more soluble in the waxy cuticle than are the cresylate ions; hence activation, increasing the concentration of cresol, causes greater absorption by the plant leaves and therefore greater activity.

Studies on indole acetic acid and other acidic growth regulators, insecticides having anionic active groups and a number of other weak acids having physiological activity have shown that they all follow the same rule, namely, activity increases through a pH range up to the pK value. This is illustrated by figure 1 from Simon.

The weed killer 2,4-D and its analogs all have an anionic group as their active principle and they follow the same rule.

This is illustrated by the fact that the activity increases through the following series: sodium salt, ammonium and amine salts, acid. The short chain aliphatic

esters are two to three times as active as the salts; they are fat soluble and do not dissociate. Evidently any factor tending to lower dissociation of a water soluble form of 2,4-D increases its activity. This is confirmed by the pH series reported in table 1. These data were obtained by use of the bean test.

The bean test as developed by Day is conducted by treating one unifoliate leaf of a young bean seedling with a measured quantity of 2,4-D and measuring the curvature of the epicotyl when bending has taken place. The test is illustrated by figure 2.

In the experiment reported in table 1 buffered 2,4-D solutions were applied and measurements were made 1, 2, 3, 4, 5, 6, 7 and 8 hours after treatment. The values are averages of five plants and they indicate the degree of bending started within two hours at pH 2 and 3 but slower at lower pH values. Study of the table shows that there was a regular prolonging of bending time and a decrease in amount of bending from pH₂ to pH₁₀. Evidently dissociation of the 2,4-D molecule reduces its rate of penetration and activity in the bean plant.

Table 2 is included to show two things. The pH values 0.5 and 1.0 are too acid to give normal response; the treated spots turned brown within a few minutes and translocation of the 2,4-D was inhibited as shown by the bending values.

A reading made after 28 hours shows that the plants may recover, at least to a degree after so long a time. Whether this is from the bulk of the 2,4-D moving beyond the sensitive epicotyl, from its metabolism within this region, or from diffusion across resulting in a symmetrical rather than a unilateral distribution remains to be studied.

It seems logical to conclude from these experimental results that the undissociated 2,4-D molecule enters the plant rapidly and is more active than the 2,4-D ions. What does this tell us about the formulations that are available on the market?

Figure 3 shows the 2,4-D acid molecule and it indicates the various salts and esters that have been studied. Most of these are available commercially. Starting at the top we see the sodium salt, then the ammonium salt, the triethyl amine salt, and the triethanolamine salt. The ammonium salt is about equal in activity to the amine salts but it is less soluble and hence inconvenient to formulate and use. The triethanolamine salt is probably the most popular of the salts. All of the salts are effective against susceptible annuals and against certain sensitive perennials. However, when one treats the deep-rooted perennials where translocation is necessary the salts are less effective than the acid and certain of the esters.

The first 2,4-D product placed on the market in this country was an acid formulation using carbowax as a cosolvent. It was very effective against perennials. Suspended acid formulations involving a small amount of non-toxic oil have proved extremely effective against certain difficult brushy species. And an emulsifiable acid formulation tested during the summer of 1951, on Russian knapweed, cattails, and brush proved very effective. Evidently the acid will move into the plant and down to the roots. Its greatest drawback is its low solubility in both water and aliphatic oils making formulation difficult.

Turning now to the center group in figure 3 we see the methyl, ethyl, propyl and butyl groups that form the corresponding esters with 2,4-D. At the

bottom of this list is the octadecyl group. Tests prove the first four about equally effective and all about three times as toxic as the salts against annual weeds. Against perennials they are not so good. Why should this be?

Being fat soluble the esters readily penetrate the cuticle and enter the leaf cells rapidly. However, being low in water solubility they have little tendency to part into the aqueous phase and move on into the phloem. They are more like toxic oils than they are like 2,4-D acid. The octadecyl ester was tried in the bean test and it caused scarcely any bending. Evidently it was so oil-like that it did not translocate to any appreciable extent.

On the bottom of figure 3 are shown schematically the butoxy ethanol ester and the propylene glycol butyl ether esters of 2,4-D. These heavy ester molecules do not dissociate to form the highly water-soluble ions. But they contain both CH₂ groups in chains, oil-like groups that make for fat solubility, and OH groups that hydrate by hydrogen bonds and hence bring about a degree of water solubility. These molecules represent a compromise between the short chain esters that enter the plant rapidly and the salts that enter slowly. The light esters fail to part into the assimilate stream and move into the roots; furthermore they cause rapid contact injury and destroy the mechanism responsible for translocation.

The salts on the other hand enter so slowly and have such low activity that they kill only the foliage and translocate only under ideal conditions. The heavy esters apparently represent a balance between water and oil solubility such that both penetration and translocation occur and perennial weeds and brushy species respond favorably.

From the above consideration one is prompted to ask "Has the ultimate been reached? Or will better formulations be found?"

Turning to figure 4 we see a number of aromatic acids that occur naturally in plants. Undoubtedly these are moved in the assimilate stream; that is they translocate in plants. On the right are diagrammed three amino acids that contain phenyl groups. These also translocate in plants.

Next we have illustrated in figure 5 some of the sugar molecules found in plants. On top are glucose and fructose, below them sucrose and at the bottom, for comparison, the tetrahydrofurfuryl ester of 2,4-D. Sucrose is the compound most readily translocated in plants. The ester molecule shown below it has many features in common with it. It would not be surprising to find that this ester is rather effectively moved in the plant.

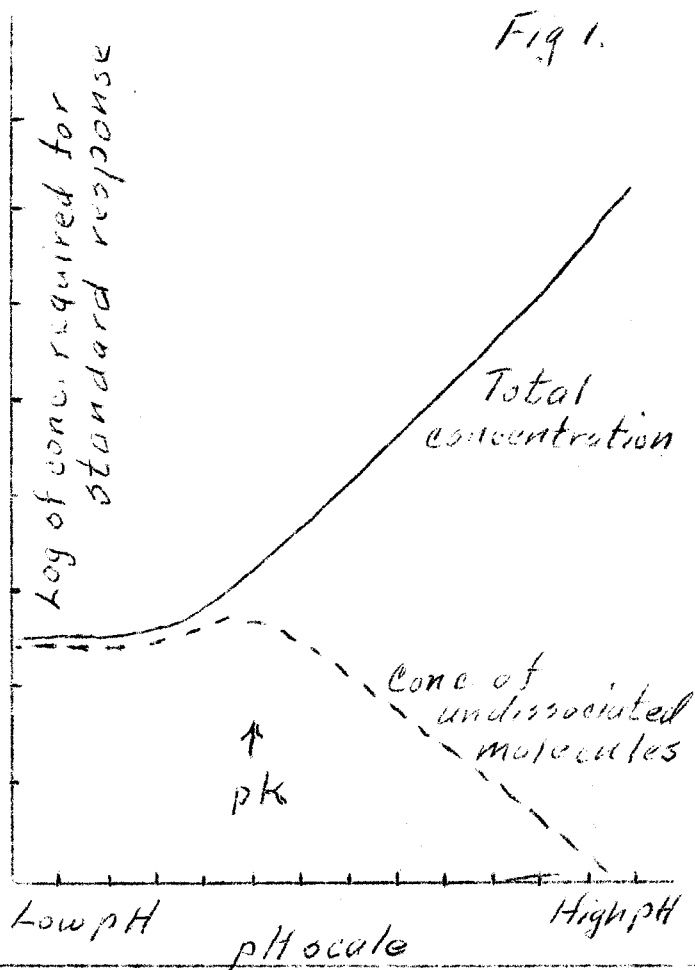
But butoxy ethanol, propylene glycol butyl ether alcohol and tetrahydrofurfuryl alcohol represent only three monohydric alcohols. Beyond these there are many other monohydric alcohols. And in addition almost innumerable dehydric alcohols or glycols, a number of trihydric alcohols such as glycerol and finally a number of sugars such as glucose and fructose. By proper means many of these can be esterified with 2,4-D acid. Figure 6 shows another possibility, namely the formation of diesters of the glycols. Both mono- and di-esters of glycols are under test and some of these are very promising. Furthermore higher alcohols including glycols, oils of low toxicity, and almost unlimited numbers of detergents, wetting agents, penetrants and fat solvents can be tried in an attempt to render the plant cuticle more permeable to 2,4-D. We have just begun to understand the major problem in formulating 2,4-D for perennial plant control.

TABLE 1. Absorption and Translocation of 2,4-D as indicated by bending of Bean Plants treated by application to one unifoliate leaf. Bending in degrees.

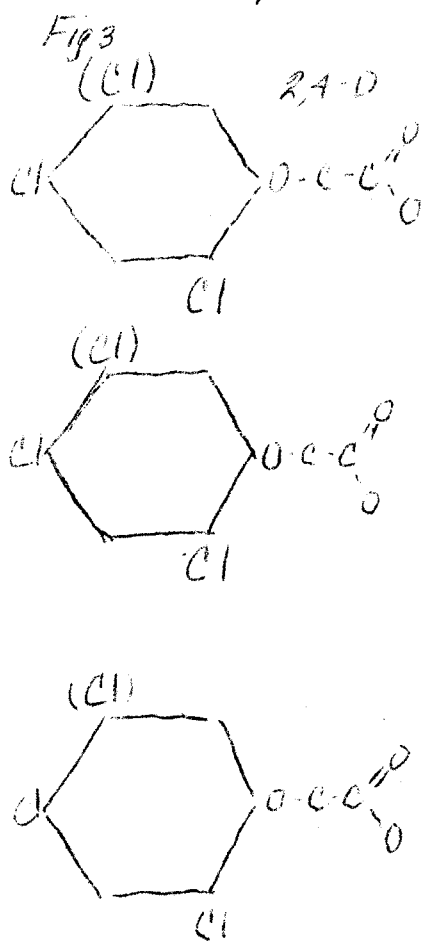
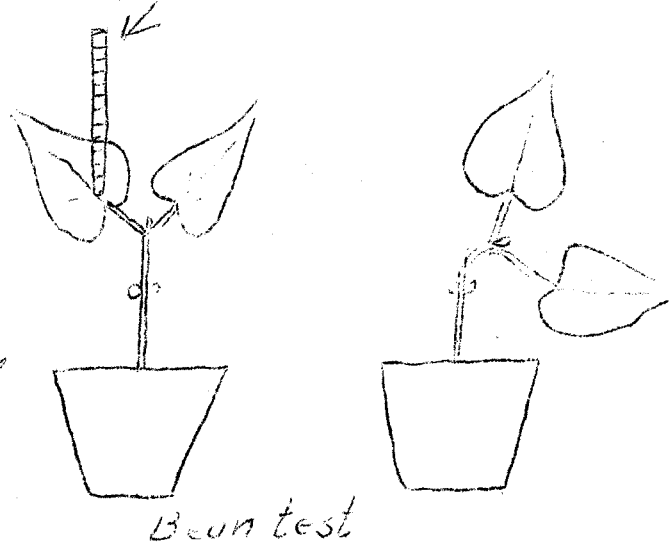
pH of Soln.	<u>Hours after Application</u>							
	1	2	3	4	5	6	7	8
2.0	0	13.0	78.7	90.0	97.5	96.2	88.7	86.2
3.0	0	5.0	50.0	71.0	77.0	80.0	74.0	83.0
3.3	0	0	18.0	52.0	72.0	89.0	84.0	75.0
4.0	0	0	21.0	50.0	71.0	86.0	87.0	85.0
5.0	0	0	20.0	54.0	78.0	86.0	86.0	84.0
6.0	0	0	9.0	40.0	62.0	82.0	85.0	92.0
7.0	0	0	4.0	13.0	21.0	28.0	35.0	37.0
8.0	0	0	0	2.0	10.0	16.0	29.0	38.0
9.0	0	0	0	8.2	15.0	18.0	28.0	37.0
10.0	0	0	0	0	0	6.0	18.0	30.0

TABLE 2. Absorption and Translocation of 2,4-D as indicated by bending of Bean Plants treated by application to one unifoliate leaf. Bending in degrees.

pH of Soln.	<u>Hours after Application</u>						
	3	4	5	6	7	8	28
0.5	1.0	3.0	1.5	2.5	7.0	10.0	11.0
1.0	2.0	2.5	1.5	1.5	4.5	5.5	7.0
2.0	5.5	21.5	65.5	100.5	102.5	94.0	91.5
3.0	4.5	27.0	58.0	88.5	94.0	87.5	92.5
4.0	0.0	15.0	54.5	94.5	96.0	81.0	84.0
5.0	0.0	11.0	46.0	87.5	100.0	88.0	86.0
6.0	1.5	12.0	44.5	90.5	100.0	91.0	79.5
7.0	0.0	1.0	9.0	32.0	70.5	56.5	82.5
8.0	0.0	1.0	1.0	10.0	24.5	72.5	76.5
9.0	0.0	0.0	1.5	10.5	39.0	70.0	91.5
10.0	0.0	0.0	1.0	12.5	40.0	68.0	86.5



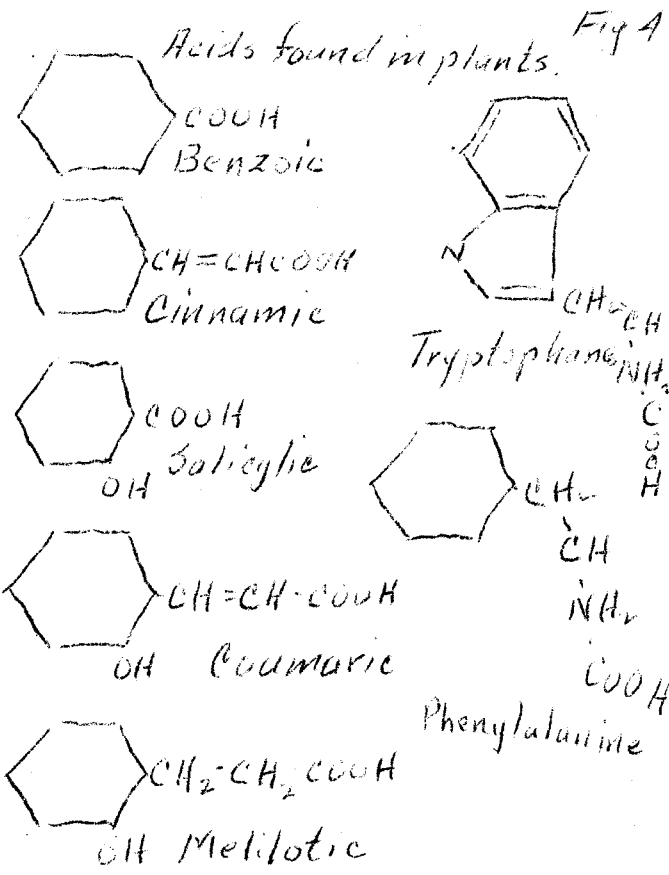
One drop of 2,4-D acid solution is applied to one leaf.

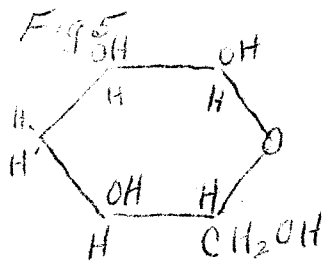


H^+ acid
 Na^+
 NH_4^+
 $NH(C_2H_5)_3^+$
 $NH(C_2H_4OH)_3^+$
 salts

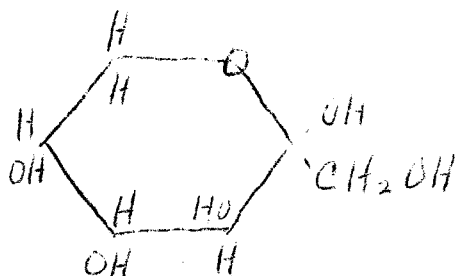
CH_3
 C_2H_5
 C_3H_7
 C_4H_9
 C_6H_{11}
 C_8H_{17}
 esters

$C-C-O-C_A$
 $C-C-O-C_A$
 C
 heavy esters

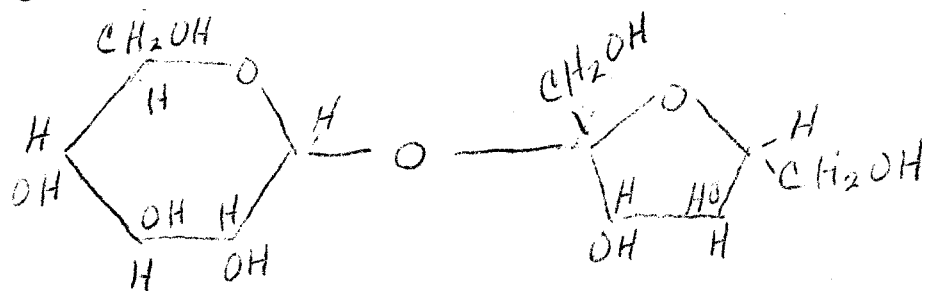




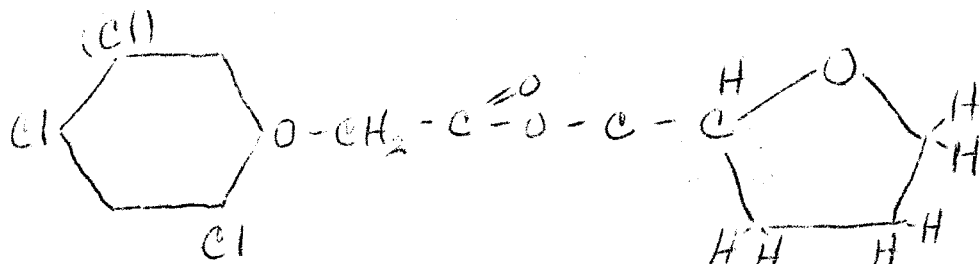
Glucose



Fructose

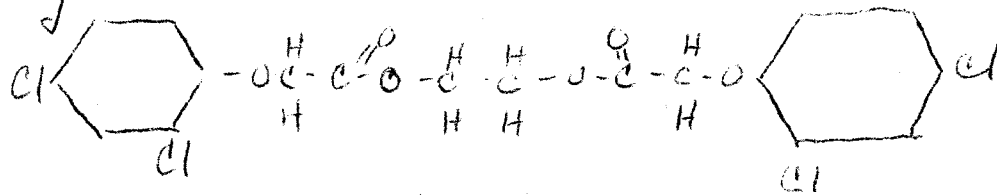


Sucrose

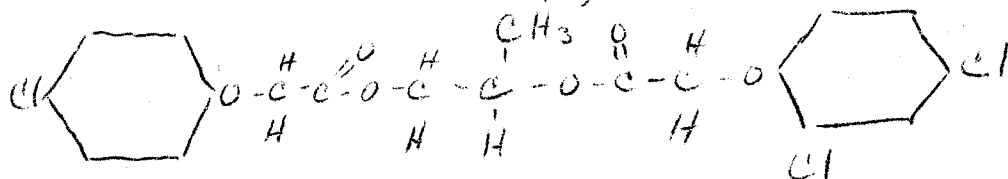


Tetrahydrofurfural ester

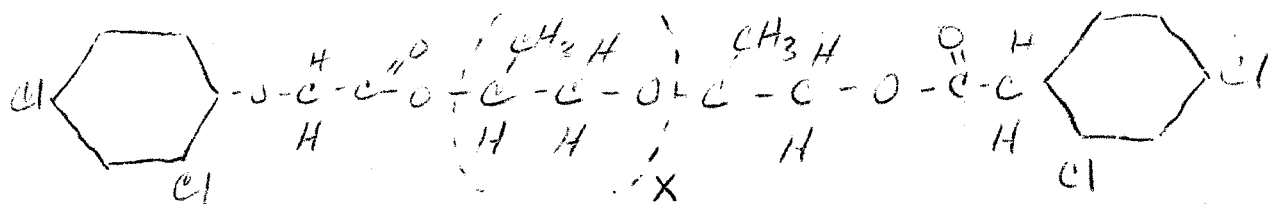
Fig 6



Ethylene glycol diester



Propylene glycol diester



Polypropylene glycol diester.

FACTORS WHICH DETERMINE THE EFFECTIVENESS OF GROWTH REGULATOR
HERBICIDES ON CANADA THISTLE

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Canada thistle is one of the most widespread perennial weeds of the northern United States. This weed was introduced into Canada and the United States about the time of the Revolutionary War. Detmers^{1/} reported that Vermont enacted legislation regarding this weed in 1795. New York outlawed the plant in 1813, and Ohio took similar action in 1844.

Efforts to control and eradicate Canada thistle, other than by passage of laws, date back to its first recognition as a weed to agriculture. Yet we still find the plant's infestation ever increasing. Early-day control methods involved either frequent removal of top growth or the application of a soil sterilizing chemical in sufficient quantity to kill the plant root system. Both of these methods precluded the growth of crops on the weed infested area for one to several years afterwards. The development of growth regulator type herbicides for Canada thistle control is of special interest, since these compounds are selective in action, permitting simultaneous weed control and crop production.

Preliminary tests showed that Canada thistle was somewhat resistant to 2,4-D herbicides. It was not known, however, whether certain related herbicides such as 2,4,5-T might be effective, nor whether the effectiveness of growth regulator herbicides was dependent upon the time of application and quantity of material. Tests were initiated at Pullman, Washington, in 1948, to determine the relationships among the specific growth regulator materials, quantities used, and the stage of development of the plant at the time of application. The test treatments included two growth regulator herbicides -- 2,4-D and 2,4,5-T as the ester formulations. They were applied at three rates -- 1.2, 2.4, and 3.6 pounds--acid equivalent per acre, when the plants were at bud, bloom, and mature stages of development. The treatments were arranged to include each material at each rate and at each time, thus permitting the observance of any possible interaction of the factors. All treatments were randomized and replicated eight times. The plots were 15 x 20 feet in size, and a narrow strip of sodium chlorate was applied along each border to prevent cross feeding of lateral roots. No plots were left as untreated checks because the objective was a comparison of the relative treatment effectiveness rather than a comparison of treated with untreated plots.

The original stand of thistle shoots was reasonably uniform throughout the plot area. Preliminary checks, made one year after the first treatments, showed no evidence of treatment differences. The original treatments were repeated and stand determinations were made a year later by a length-line-transect method in which the number of inches of line covering thistle shoots was recorded. Two diagonal twenty-foot transects were taken on each plot when the thistles were 6 to 8 inches high.

The analyses of the data showed considerable variation in stand among plots treated alike. Some plots within a treatment showed very few thistle shoots, while others had a nearly complete cover. It is believed that plant and environmental differences interacting with the treatments give rise to these irregularities. This variability in treatment effect suggests the need for studies of the relationships of plant age, plant composition, and differentiation, soil conditions, and root depth to herbicidal response.

^{1/} Ohio Agr. Expr. Sta. Bul. 414. 1927.

Despite the rather great variations, certain treatment differences were found to be statistically significant. Thistle stands were reduced more by treatment with 2,4-D ester than by treatment with 2,4,5-T ester. The stage of plant development at the time of treatment had a significant effect on later plant density. Plots treated at the bud stage had the lowest plant shoot density, while plots treated at the mature stage had the highest density. The quantity of material applied (rates) in this test did not show significant differences in the resulting plant density.

The treatments were all repeated in 1950 after stand densities had been taken. In early June, 1951, stand densities were taken by the same method used in 1950. The analyses showed an over-all stand reduction resulting from the third-year treatments. The variability among plots was accentuated, lending further support to the suggested effects of plant factors on the response of thistle plants to herbicidal application.

The 2,4-D treated plots showed a lower stand density than the 2,4,5-T treated plots. This difference was found to be highly significant. The differences in stands on plots which received the different rates of material were small and were not statistically significant. The stage of plant development at treatment time was significant factor affecting the response to both materials. The lowest stand densities occurred on plots treated at bud and bloom stages. Applications made on mature plants had little effect on stand reduction.

In 1950 tests were initiated combining cultivation, cropping and chemical control methods for Canada thistle. Since application of 2,4-D on young shoot growth appeared to be the most effective, and since tests on perennial morning glory indicated better results with fall application, 1/ the following plan was worked out against Canada thistle. An area was clean cultivated from May through July, 1950; then the plants were allowed to grow. By September 15, the shoots were 4 to 6 inches high and succulent. An application of 2,4-D at the rate of 2 pounds per acre was made on one-half of the area. Three weeks after the spray application, both the treated and untreated area were cultivated clean with a duckfoot weeder and a seed bed was prepared. On October 15, winter wheat was seeded. A good stand of wheat developed on both areas.

In the spring of 1951, the wheat stand was good on both areas despite rather severe winter killing on many wheat fields in the area. The emergence of thistle shoots was noticeably delayed in the area which had been fall sprayed.

In each area, thirty-six plots 12 x 15 feet in size were laid out for treatment in 1951. The 1951 treatments included 2,4-D and MCPA, both as esters, at 1 and 2 pounds per acre, applied when the thistles were at the early bud stage and also at the late bud or early bloom stage. These treatments, plus an untreated check, made nine treatments which were applied in a randomized, balanced, incomplete block design with four replicates.

The wheat yield from plots in the fall treated area was approximately double that from plots in the area not fall treated. The 1951 summer treatments did not affect wheat yield within the area which had been fall sprayed. However, in the area not fall sprayed, the summer treated plots yielded significantly more than the check plots.

The regrowth of thistles was approximately 50 percent less on the summer treated plots than on the check plots within the area not fall sprayed. Within the fall sprayed area, the summer treated plots and the check plots showed approximately equal numbers of shoots returning. The thistle shoot regrowth in this fall treated area

1/ Proceedings, Horticultural Society of America (in press).

was only one-fifth to one-half the amount in the plots not fall sprayed.

The fall spraying of 2,4-D on succulent thistle shoots caused the greatest reduction in thistle shoot regrowth, both during the time wheat was growing on the plots and during the fall months following harvest. The fall spraying also resulted in a substantial wheat yield increase.

Fall spraying of 2,4-D on Canada thistle is done at a time when vegetative growth is limited while the leaves are young and succulent and carbohydrate translocation is at a relatively high level. Therefore, it is speculated that the 2,4-D enters the leaves more readily and is translocated to the roots in larger quantities. Because regrowth which would provide recovery from the treatment cannot develop for about seven months, the 2,4-D fall application causes a greater reduction in root population than similar spring applications.

Summarizing the results, it is evident that 2,4-D is a more effective growth regulator type herbicide than 2,4,5-T for controlling Canada thistle. The stage of development of the thistle plants at the time of treatment was a highly significant factor influencing the degree of control. The greatest stand reductions resulted from applications to young top growth -- bud stage or succulent regrowth in the fall.

CONTROL OF WHITE TOP (*CARDARIA DRABA*) BY COMBINED
CHEMICAL, CROPPING, AND TILLAGE METHODS 1/

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White top or hoary cress (*Cardaria draba*) is a noxious perennial weed that requires consistent, properly managed efforts for control or eradication. Many studies of methods of cultivation, cropping and chemical treatments to control white top have been made. Some have proven effective. Cultivation and cropping have been somewhat neglected in recent years because of the emphasis of chemical treatments with 2,4-D for weed control.

This study of the effect of combined treatments of 2,4-D, cultivation and cropping for control of white top has shown that combinations of these methods into cropping programs are more effective in controlling white top than when they are used alone. These combined chemical, cropping and tillage programs were begun in 1948 and have been continued each season since that time.

Crops tolerant to 2,4-D such as corn, barley, and spring and fall wheat were grown and various combinations, 2,4-D selective, preplanting, and late fall treatments and cultivation of the white top were made. Programs involving only 2,4-D spraying, cultivation and untreated check plots were also included.

A tract of ground with a well established infestation of white top was leased for the study. All treatments were replicated three times and randomized on 1/10 acre plots.

1/ Cooperative investigations of the Division of Weed Investigations, Bureau of Plant Industry Soils and Agricultural Engineering, Agricultural Research Administration, U.S. Dept. of Agriculture, The Idaho Experiment Station, and Ada County Division of Weed Control, Meridian, Idaho.

The white top stand was determined before beginning the test and each spring since that time. Ten counts using a square yard quadrat were taken on each plot. Yield samples of the various crops have also been taken each year.

White top infestations after three seasons have been reduced by all combined cropping, spraying, and cultivation programs to less than 7 per cent of the original stands. Plots not sprayed with 2,4-D but cropped only each year to corn or spring wheat had approximately the same amount of white top as when the test was begun 3 years earlier. The white top infestation on check plots that were not cropped or sprayed doubled during the three seasons. Plots not cropped but treated each year with 2 pounds per acre of either an amine or ester of 2,4-D were reduced 60 per cent in stand of white top.

After three seasons of combined spraying and competitive cropping programs, white top control was about the same on all of the combined treatments. Earlier results, however, showed certain programs to be more effective.

The most effective white top control program after two seasons involved 2,4-D, cultivation, and fall wheat. The 2,4-D was applied late in April when the white top was in the bud stage of growth. The ground was plowed two weeks later. Late in June some white top regrowth appeared and cultivations were made at two week intervals until October when fall wheat was planted. This involved six cultivations. Another 2,4-D treatment was made the following spring in the wheat for control of the surviving white top. These combined practices reduced the white top infestation 95 per cent.

Field corn, another crop employed in various combinations for control of white top, also showed some good results. The most practical combination of 2,4-D spraying with this crop involved an early application of 2,4-D at 2 pounds per acre when the white top was in the bud stage of growth. Plowing and seed bed preparation for corn followed 7 to 10 days later. Two intertillage operations were made in the early growing period of the corn. The corn was harvested as grain. After two seasons of this program the white top was reduced to less than 20 per cent of the original stand. This program was varied slightly on another series of plots by giving a second 2,4-D treatment in the late fall after the corn was harvested as silage in September. In other words, 2 - 2,4-D applications per season on the white top. After two seasons of this treatment the white top had been reduced to less than 10 per cent and after 3 seasons less than 1 per cent of the white top remained where either of these two corn, cropping, and 2,4-D programs were followed.

2,4-D was also applied as a selective treatment with corn in a third combination and resulted in about 30 per cent survival of the white top after two seasons but was about equal to the other corn, 2,4-D and cultivation treatments after 3 seasons. Plowing and seed bed preparation and other practices were the same for all corn plots.

Corn cropping without the use of 2,4-D which served as yield check plots for the other corn and 2,4-D treatments did not cause any reduction in stand of the white top. In fact white top counts on these plots averaged slightly higher after 3 seasons than before treatments were begun. Another interesting point is that the corn on these check plots yielded within 2 per cent of the other corn and 2,4-D programs. Apparently there was little effect of white top competition upon the yield of corn when managed as these treatments were set-up. White top has a natural tendency to become dormant when allowed to produce flowers and flowering stalks before plowing or cultivation in the spring as was permitted on these plots. There was generally very little white top regrowth in the corn plots until after the corn was 8 to 12 inches high.

The yield figures in these programs were also used for a comparison of income of

the other various programs after production and weed control costs were subtracted. Those programs involving corn as a group average more than 50 per cent more return than any of the other programs of fall wheat, spring wheat or barley.

Spring wheat was included in the test in three combinations with 2,4-D spraying and check plots. These included spring wheat with a selective 2,4-D treatment when the wheat was about 6 inches high, spring wheat with selective and late fall 2,4-D treatments the same season, and spring wheat with late fall 2,4-D treatments only. After two seasons of these combined treatments, white top survival was 12 per cent for the late fall treatments, 7 per cent for the spring and fall treatments each season, and 15 per cent for the spring selective 2,4-D program. There was little difference between any of the treatments after three seasons and white top regrowth varied from 1 to 5 per cent for these spring wheat and 2,4-D spraying programs. The white top stand on the wheat check plots showed a slight decrease in stand during the three seasons. There was little additional white top control when two 2,4-D applications per season were made. Although actual white reduction was slightly greater the first two seasons when two treatments were made, after three seasons results were nearly equal whether one or two applications of 2,4-D per season had been made.

There was considerable variation in yield of wheat under the various combinations. The two programs that involved selective 2,4-D treatments in wheat resulted in yields 50 per cent greater than the wheat check plots and plots sprayed only in the fall. The reduced yield on wheat check plots was not caused entirely by the untreated white top as there were several other annual weed species present on these plots. However, there was considerable effect of white top competition on the spring wheat crop and apparently very little in the corn crops.

As stated earlier in this report the programs involving wheat brought much less return than corn crops. Several things may have caused this difference but undoubtedly the wild oat infestation which immediately began to take over after the first season was a major factor in the reduced wheat yields. This wild oat problem is typical of the type of weed problems encountered where continuous cropping is practiced.

Late barley was used in a combined control program involving 2,4-D treatment of the white top in the spring before planting the barley. 2,4-D was applied at the bud stage of white top 7-10 days before plowing and seed bed preparation. Late barley was then planted. This control program was equally as effective in controlling white top as the same program involving corn and resulted in less than 5 per cent survival of the white top after two seasons and only 1 per cent after 3 seasons. However, in this test there was less than 50 per cent as much income from the barley crop as from the similar program involving corn. The barley was somewhat handicapped because of necessity of irrigation immediately after planting to start growth in this test.

The program of delayed cultivation included in the test caused 95 per cent reduction in the white top in two seasons. This program consisted of cultivation at 14 day intervals through the first season of the test. Cultivations were at intervals of about 10 days after emergence the second season. Two cultivations were made the third season before planting corn making a total of 23 cultivations. White top infestation was less than 1 per cent of the original after the third season. Although two crops had been lost under this treatment, the corn crop the third season was much larger than normal and almost equalled two normal corn crops.

The record of the undisturbed check plots during the test period showed that

white top increased 245 per cent in the 3 seasons when the initial stand was considered 100 per cent.

Plots treated only with 2,4-D at 2 pounds per acre each year showed a 60 per cent reduction of white top as compared to 99 per cent for corn cropping and 2,4-D as a preplanting treatment, and 99 per cent for wheat cropping with 2,4-D as a selective treatment. The results definitely indicate that the combined cropping and spraying were more effective in controlling white top than 2,4-D alone.

Amine and ester types of 2,4-D at 2 pounds per acre were compared in all programs involving non selective 2,4-D treatments. Results show only slight differences of control of white top with these two types of 2,4-D. Percentage kills averaged about 5 per cent greater in favor of the amine where cropping or cultivation programs were involved. However, where no cropping or cultivation was involved percentage kills of white top averaged 7 per cent greater for the ester type, therefore the overall average was very nearly equal.

Programs of corn and wheat that involved selective 2,4-D treatments were used to compare the 1 and 2 pound rate of 2,4-D amine. The average regrowth of white top after one season was 15 and 32 per cent respectively for the 1 and 2 pound rates. Regrowth was 27 and 20 per cent after 2 seasons and was about 1 per cent for both rates after 3 seasons. Although the 2 pound rate caused more kill in the first two seasons the one pound rate gave almost equal reduction white top after 3 seasons of the continuous cropping and spraying.

Summary

Comparison of the combined chemical, cropping and tillage methods in controlling white top in this study has shown that combinations of these three proven methods of weed control into cropping programs are more effective and practical than when used alone. White top was more effectively controlled by 2,4-D sprays and cropping than either 2,4-D spray or cropping only.

RESPONSE OF THATCHER SPRING WHEAT TO 2,4-D RATES APPLIED IN LOW VOLUMES OF OIL AND WATER

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The response of spring wheat to 2,4-D applied in low volumes of oil and water as carriers is of interest in Montana for several reasons. The first is the large acreage of spring wheat in the state which is adapted to aerial application, i.e., large fields and the absence of nearly susceptible crops. The second is the relatively large amount of work being done by aerial applicators who have treated an estimated 750 to 800 thousand acres of cereals in each of the past two years. The third reason is the occurrence of severe damage as an apparent result of some factor associated with low volume application. The total acreage affected by this damage is small in relation to the acreage treated but the loss to individual farmers is large.

Basically, this damage is sterility or the failure of the wheat flower to produce a seed. This sterility is mostly apical in light or intermediate cases. As it becomes more severe, all florets except those in the center are sterile while the most

severe cases have caused almost complete sterility.

Within fields, the damage occurs in strips of fertile and sterile spring wheat which are easily recognized by the more erect heads and the darker color of the affected wheat. These strips are the result of improper distribution of the spray material. However, the actual rate of 2,4-D on the damaged strips did not exceed 0.5 lbs. 2,4-D acid equivalent per acre.

In 1950, ten growers of damaged fields were interviewed and their fields inspected. The most important consideration was to establish the stage of growth at the time of application. This was done in nine of the ten cases and it was determined that application had been made at least twenty days before heading in eight of the fields. This is considerably earlier than the boot and early heading stages when this type of damage can be induced by 2,4-D applications in some cases. This information also tends to support the custom applicators who claimed that applications were made at the safe tiller-boot interim in other cases.

A number of other factors were considered as to their possible influence on the damage. Whether they occurred in all cases or not is reported in Table 1.

Table 1. The constancy of possible responsible factors considered in the investigations of ten damaged fields of spring wheat in 1950.

Constant	Non-Constant
1. Crop - hard red spring wheat	1. Variety
2. Some degree of poor distribution of the spray material	2. The custom applicator
3. Growing conditions average or above	3. Weather at treatment time
4. Low volume application	4. Relative seeding date
5. Ester of 2,4-D	5. Kind or brand of 2,4-D
	6. Stage of growth at treatment
	7. Stages of growth within damaged strips
	8. Kind of carrier (water or oil)
	9. Environmental area (presence or absence of Russian thistle)

Because some of the factors remained constant, it would be expected that they alone or in combination would be primarily responsible for the damage. However, some of the non-constant factors may also contribute.

EXPERIMENTAL METHODS

For the experimental work, four row plots 4' x 10' in size were used. These were planted with a 6' grain drill modified to seed the desired plots. Each drill of 120 feet was divided into 12 plots by wheel hoeing out the emergent wheat on the dividing line between plots. Each harvest sample consisted of 8' of the two center rows. Weeds were controlled mechanically by one or two wheel hoeings as necessary and hand hoeing or pulling so that the effect of the treatments would not be confounded with the control of weeds.

The tests included four rates of a 2,4-D ester and four volumes of a No. 2

diesel fuel carrier applied at two dates in all possible combinations in each of the three years. Three replications were used in all comparisons.

In addition in 1949, 20 gallons of water as a carrier was used as a check against the oil. During 1950 and 1951, water was compared with the oil at the same volumes per acre.

Total volumes per acre (carrier plus 2,4-D) used were 1, 2, 4, and 8 gallons per acre. In 1949, oil only, and in 1950 and 1951, oil and water were applied at these volumes. In 1949, water was included at a volume of 20 gallons per acre. Rates of 2,4-D used were 0, .2, .4, and .8 lbs. acid equivalent per acre.

Applications were made with a hand held two nozzle boom on a 36 inch extension in which the nozzles were spaced 24 inches apart so that they released the spray directly over the center line between the first and second and the third and fourth rows of each plot.

The experiments were designed for a split plot analysis of variance. In 1949, replications and dates were the main plots with volume and rates randomized within date blocks. In 1950 and 1951, reps and dates were again used as main plots with rates being sub-blocks within which volumes were randomized. The location of blocks and sub-blocks were chosen at random.

Water was compared to oil at the early date by enlarging the size of the early-date blocks. Rates comprised the main plots and volumes the sub-blocks with carriers randomized within.

This design resulted in the use of two distinct analyses in which carriers were compared in one and dates in the other.

Tee-jet nozzles (number 730039) were used for the application. A protective frame (48" high 4' wide and 10' long) covered with cotton cloth was used to keep the spray material on the plots. The front end of the frame was open except for a trough 18" high which was appended to the outside to catch the excess spray material. The nozzles discharged 1.75 cc each per second at 13 lbs. pressure. On this basis, the 3.48 cc per plot which is equivalent to 1 gallon per acre was discharged in one second. The higher rates required times of 2, 4, and 8 seconds for the desired volumes.

To minimize the error associated with the short exposure periods necessary, the nozzles were turned on into a tray at the back end of the protective frame and then moved straight to the open end at the desired speed. In the case of the one second exposure, one fast step and a jump over the trough at the front end was necessary. The exposure period was ended by placing the nozzles into the trough.

In order to get a good pattern at the 13 lb. pressure used, it was necessary to have the nozzles pointing at a 15 to 20 degree angle above the horizontal plane. This apparently gave the droplets time to spread out sufficiently to form a uniform pattern.

RESULTS

Experimental results are presented according to the variables used in the test work. Highly significant interactions were obtained for the rate x date and rate x carrier interactions in 1951. However, the fact that the interactions when combined

with error still produced highly significantly "F" values for the main effects of carriers and rates indicates that the comparisons are valid even with the significant interactions.

Increasing rates of 2,4-D (Table 2) on a weed-free basis, reduced yields highly significantly in each of the three years. An analysis of the mean effect of the three years was not made because of design differences.

Table 2. The mean effect of rates of 2,4-D on yields of weed-free spring wheat when applied at volumes of 1, 2, 4, and 8 gallons per acre in oil and water carriers.

Rate 2,4-D lbs. acid equiv./A.	Yields in Bu./A.				Difference	
	1949	1950	1951	Ave.	Bushels	Percent
0	41.0	49.3	36.7	42.3		
.2	42.3	43.4	34.0	39.9	-2.4	-5.7
.4	38.5	41.0	31.3	36.9	-5.4	-12.8
.8	36.8	39.3	26.2	34.1	-8.2	-19.4

These data indicate that 2,4-D under the conditions of the tests did produce considerable injury to spring wheat.

Volumes of carrier as considered in Table 3, did not affect yields to any significant degree with the exception of 1949 when highly significant reductions at low volumes were obtained.

Table 3. The mean effect of volumes of oil and water carriers on yields of weed-free spring wheat when used with 2,4-D rates of .2, .4, and .8 lbs. per acre.

Volumes Gals./Acre	Yields in Bu./A.				Difference	
	1949	1950	1951	Ave.	Bushels	Percent
1	34.8	40.6	28.4	34.6	- - -	- - -
2	38.2	40.0	31.8	36.7	+2.1	+6.1
4	39.4	42.6	31.1	37.7	+3.1	+9.0
8	40.5	41.8	30.8	37.7	+3.1	+9.0
20	43.0	- - -	- - -	- - -	+8.2	+23.6

When the weed-free yield reductions are compared (Table 4) to data obtained from Thatcher spring wheat in adjoining varietal response tests for the same years and which received almost identical treatment except for volumes, it appears that the lower volumes reduced yields more than the higher volumes.

Table 4. Comparison of mean yields and yield reductions of Thatcher spring wheat as determined in separate tests (1949-1951) where volumes are the primary difference.

3.75 gallons *		VOLUME		15 gallons	
Rate 2,4-D	Bu./A.		Rate 2,4-D	Bu./A.	
	Yield	Difference		Yield	Difference
0	42.3	- - -	0	43.8	
.2	39.9	-2.4	.25	42.6	-1.2
.4	36.9	-5.4			
.8	34.1	-8.2	1.0	39.8	-4.0

*Average of 1, 2, 4, and 8 gallons

These data indicate the .4 lb. rate of 2,4-D in the low volumes is about as toxic as the 1.0 lb. rate at the 15 gallon volume per acre.

Diesel fuel #2 was compared with water in 1950 and 1951. Results are inconclusive (Table 5) since no differences were evident in 1950 and the fuel oil reduced yields highly significantly in 1951.

Table 5. Comparison of No. 2 diesel oil and water as carriers at various rates of 2,4-D. Each 2,4-D rate includes the carrier at 1, 2, 4, and 8 gallons per acre.

Rate 2,4-D lbs. acid equiv./A.	1950			1951		
	Oil	Water	Difference in favor of water	Oil	Water	Difference in favor of Water
0	50.1	47.7	-3.4	36.3	37.6	1.3
.2	41.6	45.3	3.7	31.1	35.8	4.7
.4	44.7	42.2	-2.5	25.1	32.7	7.6
.8	41.6	44.0	2.4	17.0	30.9	13.9
Mean Diff. with						
(1) all rates	44.5	44.8	.3	27.4	34.3	6.9
(2) zero rate excluded	42.6	43.8	1.2	24.4	33.1	8.7

More information will be necessary to establish the presence or absence of differences due to the carrier used.

As noted in Table 5, the 1951 comparison of oil and water resulted in severe yield reductions in which .4 of a lb. of 2,4-D in oil may be more toxic than .8 lb. in the water carrier. The primary reason for the yield reduction in 1951 was the occurrence of sterility which appeared to be the same as the previously described field damage. This response occurred from the application made on the early date (tillered, 7") and substantiates field observations that the damage is independent of the stage of growth near anthesis when damage of this type may be induced.

This reduction resulted in a significant difference due to dates of oil application and in a highly significant difference due to carrier in the oil-water comparison. In addition, the rate x date and carrier x rate interactions were highly

significant.

The main environmental differences existing between the 1951 sterility occurrence and its non-occurrence in 1949 and 1950 were colder conditions in 1951. This observation has also been made under some of the field conditions where damage occurred.

Because of the inconsistent occurrence of sterility under field conditions in relation to known damage causing factors, such as, rate of 2,4-D used and the stage of crop growth at treatment time, it would appear that environmental conditions before and/or during and/or after the low volume treatment could be responsible for the noted sterility.

SUMMARY & CONCLUSIONS

1. Yields of weed-free Thatcher spring wheat were decreased by 2,4-D ester applications. Increasing rates of 2,4-D reduced yields progressively.

2. Different volumes of carrier affected yields significantly in one out of three years.

3. Mean yield reductions due to rates of 2,4-D at all volumes when compared to an adjacent test for the same years indicated that greater reductions were obtained when low volumes of carrier were used.

4. No differences between No. 2 diesel fuel and water as carriers were found in 1950 while a highly significant decrease due to the oil was found in 1951.

5. Sterility similar to that reported under field conditions was reproduced by the application of 2,4-D in an oil carrier in 1951 27 days before heading when the wheat was about 7" tall and had tillered. This sterility is apparently independent of the stage of growth near anthesis.

6. From the consideration of data from field observations and experimental work, it would appear that the combination of relatively low temperatures and low volume application of 2,4-D might cause the described damage.

WEED CONTROL IN PEAS WITH HERBICIDES

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Peas are poor plant competitors and as a consequence weeds are a major factor in the production of this crop. The type of weed which predominates is usually associated with the major use of the crop in the particular area. In the freezing and canning pea areas the most serious weeds are usually nightshade, lambsquarters, pigweeds, and other broadleaved species. In the dry pea areas the most serious weed is usually wild oats although many broadleaved weeds also grow in large numbers in the pea fields. Since peas are the second most important crop produced in the Palouse and adjoining areas in Idaho and Washington an intensive research program on the control of weeds in peas has been conducted since 1947. The methods used in the control of wild oats and broadleaved annuals are entirely different and

hence the results from these experiments will be discussed separately.

Control of Wild Oats

Wild oats are such a serious competitor to peas that where they occur they are usually the major weed factor limiting production. Not only are they the most important single factor but they also materially influence the control of other weed pests. Tests conducted in 1949 indicated that not only was the elimination of broadleaved annual weeds in peas of no benefit from the standpoint of yield when wild oats were present in large numbers but that such elimination probably reduced pea production by increasing the growth of the wild oats. In this test the application of a dinitro to eliminate the broadleaved annuals in a mixed stand of peas, broadleaved annuals, and wild oats reduced the yield of peas by 40 pounds per acre and increased the yield of wild oats by 230 pounds per acre. In the absence of the wild oats in this test the dinitro application increased the yield of peas by 435 pounds per acre. From these data it would appear that the control of wild oats must take precedence over the control of broadleaved species where both weed types occur in pea producing areas.

Since wild oats are such an important factor in dry pea production, tests of the possible use of various chemicals have been conducted in Idaho for the selective control of wild oats in peas since 1947. Of the chemicals which have been tested only one, IPC (iso propyl-n-phenylcarbamate), has shown promise of solving the problem. Preliminary tests with this chemical were started in 1947 and detailed tests have been conducted since 1949. During this period of time the following factors have been studied: (1) rates of IPC application, (2) pre-emergence versus pre-planting treatments, (3) dust versus spray treatments, (4) disking versus rototilling the material into the soil, (5) three inch versus six inch depths of working the material into the soil, (6) emulsifiable versus wettable IPC, and (7) 3-chloro versus regular IPC. In all cases both effect on the yield of peas and the control of wild oats has been studied. Tests are also in progress to determine the residual effect of IPC applications to peas on the following grain crops. In practically all tests split plot Latin squares with four replications have been used.

The results obtained during this period of time may be summarized as follows. Four pounds per acre of IPC are required to obtain satisfactory results in the control of wild oats in peas. As an average of three years the checks produced 554 pounds of peas per acre, the one-pound rate 775 pounds, the two-pound rate 950 pounds, and the four-pound rate 1368 pounds. Wild oat kills were 40, 59, and 85 percent for the 1, 2, and 4-pound rates, respectively. These tests were all conducted with 50 percent wettable IPC as pre-planting treatments worked into the ground to a depth of about three inches. All the other tests were conducted at either two or three rates of application but since the four-pound rate appears to be the most practical the comparisons given for the other tests are on the basis of this one rate. It should also be noted that since all tests were not conducted at the same time comparisons of yields or kills between different experiments should not be made.

Pre-planting treatments were far more effective than pre-emergence treatments. Yields of peas for the two methods were 1745 pounds per acre for pre-planting and 1099 pounds for pre-emergence treatments. The wild oat kills were 90 and 27 percent, respectively.

Spray treatments were more effective than dust treatments with yields of 1266 pounds per acre for the spray and 893 pounds for the dust treatments. The wild oat kills in this case were 81 and 62 percent, respectively.

Disking the IPC into the soil was at least as good and perhaps slightly better than rototilling. The yields in this case were 1167 for disking and 1040 for rototilling. Wild oat kills were 75 and 69 percent.

Next to date and rate of application the depth of working the material into the soil was the most important factor studied. The six inch depth of working was better than the three inch. The yields in this case were 960 pounds per acre for the three inch depth and 1166 for the six inch. Wild oat kills were 85 and 99 percent, respectively.

The wettable form of IPC gave slightly better results than the emulsifiable with the yields of the emulsifiable being 974 pounds and the wettable 1152. Wild oat kills for both were 92 percent. There was no advantage in the 3-chloro IPC over the regular form. Yields of peas were 953 pounds for the 3-chloro and 974 for the regular IPC. Wild oat kills were 88 and 92 percent respectively.

The results obtained so far from the residual studies of the effect of IPC treatments in peas on the following wheat crop have been unsatisfactory because of unfavorable weather and the necessity of moving the tests from Genesee to Moscow in 1950. The fragmentary results obtained to date indicate that the yield of the following wheat crop may be closely correlated with the degree of wild oat control obtained in the pea crop. These data indicate that the yield of the following wheat crop may be increased about as much as was the pea crop.

At the present time there are still two major problems associated with the use of IPC for wild oat control in peas. The cost of the treatment is sufficient that only heavily infested areas will give an economic return to the pea growers from the immediate crop and the necessity of making the treatment before the wild oats have emerged makes it difficult to select the areas to treat. Past history of the field must be used to determine whether the area should be treated. Lower costs would eliminate much of this difficulty since over-all spraying would then be practical. The second problem, which to date remains unsolved, is the relatively large volumes of water per acre required in the application of IPC. Research is in progress to determine whether lower gallonages of solution per acre are possible but until further information is available the use of less than 40 gallons per acre with the wettable materials or 20 gallons per acre with the emulsifiable materials would appear to be unwise. Most of the formulations available during 1951 caused difficulties in application even at these gallonages when applications were made with the usual 2,4-D sprayer which has very little agitation.

A number of tests of small to medium sized areas were made in the Palouse region of Idaho and Washington by farmers, commercial companies, and others during 1951 and where uniform application was obtained the results were generally satisfactory. Most of the tests gave wild oat kills of about 90 percent and, where the yields were checked, yield increased of from three to eleven hundred pounds of peas per acre. On the basis of these results it would appear that farmers will materially increase the acreage treated in 1952. With present prices and normal weather it is estimated that about thirty thousands acres of dry peas could be economically treated in the Palouse area at the present time.

Where farmers wish to treat this year we are recommending an application of four pounds of IPC per acre as a pre-planting treatment to be applied as a spray any time during the ten day period preceding the seeding of the peas. The IPC should be worked into the ground to at least three inches and preferably six inches. The wettable form of IPC is preferred and this should be applied in at least 40 gallons of water per acre. Where the emulsifiable form of IPC is used, it should be applied in at least 20 gallons of water per acre.

Control of Broadleaved Annual Weeds

The discovery in 1947 that IPC held promise of solving the wild oat problem in peas made it desirable to conduct trials designed to also control the broadleaved annuals in this crop. In 1948 two dinitro materials were tested in comparison with four cyanamid derivatives. In these tests monosodium cyanamid dust appeared to hold considerable promise for selective control work in peas. It was further tested in 1949 and continued to hold promise from the yield standpoint although the weed kills were generally not as good as with the dinitros. It was removed from the tests in 1950 when the manufacturer indicated it might not become commercially available. Starting in 1949 ammonium DNOSBP (ammonium dinitro-ortho-secondary-butyl phenate) was compared with sodium K-1131 (sodium dinitro-ortho-isopropyl phenate) and potassium cyanate. In 1950 the ammonium K-1131 (ammonium dinitro-ortho-isopropyl phenate) was added to the test and in 1951 sodium 2-methyl, 4-chlorophenoxyacetate) was also added. Preliminary tests of both the butyl ester and sodium salt of MCP had been made in 1950. In all except the preliminary trials, three rates of application have been used with all materials with four replications usually in the form of either a split plot or split plot Latin square. All tests have been conducted on land where wild oats were not a problem. During the period of these tests gallowage trials with both ammonium DNOSBP and sodium K-1131 have been conducted.

Results have varied from year to year and this has been especially true with potassium cyanate and ammonium DNOSBP. However, the relative effectiveness of the various materials has remained fairly constant throughout the period of test. All materials except MCP increased the yield of peas in 1951 but only the two K-1131s increased the yield in 1950. During the 1949 only the sodium K-1131 increased the yield.

The average results obtained from the materials test for the period 1949-51 are given in Table 1.

Table 1. The effect of four selective herbicides on the yield of peas and the kill of broadleaved annual weeds. Averages for 1949-51 except for ammonium K-1131 which is for 1950-51.

Material	Yield of peas in lbs. per acre as increase or decrease from un- treated at rates listed			Percent kill of weeds at rates listed		
	2-qt.	3-qt.	4-qt.	2-qt.	3-qt.	4-qt.
Ammonium DNOSBP	60	40	-180	57	78	77
Sodium K-1131	330	250	80	88	92	93
Potassium cyanate*	-30	-50	-210	40	60	71
Ammonium K-1131	150	60	-30	65	69	90

*Rates for potassium cyanate were 3 1/3, 6 2/3, and 10 pounds per acre.

It is apparent from these data that of the three materials under test for the three year period sodium K-1131 was definitely superior to the others. Potassium cyanate gave unsatisfactory results both from the standpoint of yield and weed kill. During the two years that ammonium K-1131 was under test, it has given better results than DNOSBP and poorer results than sodium K-1131 in both weed kill and crop yield. The data from sodium MCP was not included in the table since only one year's complete

data are available, but in that year results were entirely unsatisfactory both from the standpoint of yield and weed kill.

Tests made in 1949 with ammonium DNOSBP using various gallonages of water per acre showed a steady reduction in the yield of peas as the gallonage of water was reduced from 40 to 20 to 10 gallons per acre. Each reduction in water was accompanied by a reduction in yield of about 200 pounds of peas per acre. Weed kills were slightly better at the 20 gallon rate but the increased crop injury indicates that under these conditions 40 gallons of water per acre is about the minimum that can be used with this material.

In 1951 a gallonage and date of application trial was conducted with sodium K-1131 since it appeared to have greater selectivity than the other dinitros and hence could possibly be used with less water per acre. This trial was conducted when the peas were five inches tall and again when they were eight inches tall. Three rates of application were used at each date and three gallonages of water with each rate. The second date of application gave the best kill of weeds--an average of 93 percent while the comparable rates at the second date averaged 74 percent. This was at least partially due to weed seed germination between the two dates. The yield of peas was also higher at the second date-- and average difference of 150 pounds of peas per acre. The effect of gallonage was practically the same at both dates of application and on the average there was little difference in either yield or weed kill between the 20 and 40-gallon rates. The 10-gallon rate was inferior in both weed kill and yield. At both dates, both yield and weed kill generally increased with increasing amounts of active ingredient per acre so that the 3-quart rate at the second date of application gave an average kill of 98 percent and a yield of 1729 pounds of peas per acre. This yield was an increase of 650 pounds per acre over the comparable untreated checks. From these data it would appear that peas can be successfully sprayed with sodium K-1131 in 20 gallons of water per acre and when water is especially important even less might be used at some sacrifice in yield and weed control.

The data obtained indicates that sodium K-1131 is the most satisfactory material that has been tested for the control of broadleaved annual weeds in peas. This material when applied under reasonably favorable conditions will give satisfactory weed kills and yields of peas at rates of 2 quarts per acre when applied in 20 gallons of water per acre. When this material becomes commercially available it should find rather wide use in the pea area. Of the tested materials that are at present commercially available, ammonium DNOSBP is the most satisfactory for use in peas.

In conclusion it can be said that with the development of IPC and sodium K-1131 considerable progress has been made in developing a program for selective weed control in peas.

IPC AND CHLORO IPC AS REPRESENTATIVE
CARBAMATES AS HERBICIDES

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The announcement of the herbicidal activity of O isopropyl n-phenyl carbamate was announced by Templeman and Sexton in 1945. More thorough investigation of the toxicity of this compound was made by Allard, deRose and Weaver as well as

subsequent investigations by Templeman and Sexton. More recently the 3-chloro derivative of isopropyl n-phenyl carbamate was announced by Witman and Newton and deRose. 3-chloro IPC was first synthesized by Freed in the fall of 1946 and was tested that year. Subsequent work with these compounds have indicated their potential herbicidal value.

It has been known for a long time that such compounds as colchicine, ace-naphthene and chloral hydrate have a pronounced effect on the progress of mitosis. In studying the effects of these and related compounds upon root development of Avena, Friesen, in 1929, first demonstrated the effectiveness of ethyl n-phenyl carbamate. Lefevere, in 1939, pointed out the narcotic effect of this material on mitosis, resulting in the death of the cell. This was corroborated by Deysson in 1945, and subsequently Templeman and Sexton in studying this compound discovered the high potency of the isopropyl derivative.

A number of carbamates possessing varying degrees of activity have been studied by Templeman and Sexton, by Freed and others. It has been demonstrated to a large measure the isopropyl derivative of n-phenyl carbamic acid or any of its homologues is primarily active. Other derivatives have been shown to possess activity, but not of equal magnitude with the possible exception being the cyclo propyl derivative. This phytocidal activity of alkyl-phenyl carbamic acid derivatives was shown to correlate directly with certain fundamental physical measurements. For other mitotic poisons and narcotic agents the lipid-water distribution coefficient has been found to correlate with activity.

Studies of the influence of the aryl nucleus upon activity has shown nearly equal specificity. Poly cyclic nuclei, such as, naphthyl and anthranyl and bi-phenyl have shown markedly less activity than corresponding phenyl derivatives.

Substitution on the ring shows very marked influence on activity. Where in most cases ortho-para substituents tend to increase biological activity, carbamates are one of the few exceptions to this rule. In the case of the aryl carbamates the meta position, or three position, possesses by far more activity than ortho-para substitution. For example, in the case of chloro substituents on n-phenyl carbamic acid, ortho substitution shows only approximately 10 per cent of the activity of n-phenyl carbamic acid derivative, para substitution shows approximately 50 per cent the activity, whereas the 3-chloro substituent shows activity equal to that of the isopropyl n-phenyl carbamate. However, as pointed out by Freed, this activity shows remarkable specificity for different plants.

Cytological studies demonstrated that the action of carbamates consists of inhibition of mitosis and narcotizing of the cell. Ennis describes the morphological effects of carbamate as hyperplasia of the root and hypocotyl of seedling plants with resultant deepening of the green color of the seedling. On older plants growth inhibition becomes readily apparent ten days to three weeks after exposure to the chemical again with subsequent darkening. Where exposure has been to a lethal dose, emarginate necrosis appears with subsequent chlorosis and death of the plant. Observations have indicated that this probably arises through death of the roots.

Carbamates cannot be considered as growth regulators in the sense that one thinks of indol 3 acetic acid or 2,4-dichloro phenoxy acetic acid as being a growth regulator. Deysson, Ennis, and Allard have presented data purportedly demonstrating that this material is not translocated basipetally. However, recent work with labeled IPC would indicate upward movement of this material in vascular bundles of graminaceous plants. Little, if any, basipetal translocation was indicated by these studies.

While carbamates have been studied intensively from a standpoint of their cytological effect, little is known of their physiological effect. Work in the author's laboratory has indicated that one of the principal effects of these carbamates is a severe inhibition of the hydrogenases. From a study of related mitotic poisons which have also been found to inhibit the hydrogenases, it is proposed that these enzymes are especially important to the cell during the metaphase stage of division.

The use of carbamates as herbicides has been met with indifferent favor in many areas because of erratic results with these materials. It had been pointed out that certain climatic and edaphic factors are of paramount importance in determining the success of a treatment. For example, it has been shown by deRose and Freed that microbial action results in a destruction of this material in the soil. Since we must rely upon the residual action of carbamates in the soil, the conditions favorable for the destruction of these chemicals would make for poor results.

Soil pH has been shown to supposedly have no effect on the toxicity of IPC, but it has been observed that the addition of lime shortened the residual effect. This was accounted for by two possible explanations, one being the alkaline hydrolysis of the carbamate or secondly stimulations of organisms bringing about rapid destruction of the chemical.

Moisture is required to bring IPC into intimate contact with the roots. If moisture is insufficient to accomplish this, tillage may be necessary to bring IPC into the necessary zone of the soil. Moisture also plays an important role in rendering IPC ineffective by leaching the chemical from the root zone or providing proper environment for micro-organismal action.

It has been shown that age of plant is extremely important in relation to effective treatment. Application of any of the carbamates should be before or during the early germinating and seedling stage at which time cell division is most rapid.

As has been demonstrated, species response to the carbamates is extremely important to the success of a treatment. Thus it has been shown that the festucoideae are more susceptible to IPC, whereas panicoideae are generally most susceptible to 3-chloro IPC. Further distinction can be made of these plants in their response on the basis of growth habit. Thus, winter germinated annual grasses generally are best controlled with IPC, whereas summer germinated annuals are more effectively controlled by chloro-IPC. This response in part can be shown directly related to the physical properties of the compound and the rapidity with which they are attacked by micro-organisms. Field observations have also tended to show that the volatility may be related to this problem.

Since it is readily apparent that there is specificity of response among the weedy annual grasses, it is patent that one could reasonably expect some specificity of response of crop plants, including even some of the dicotyledonous plants, both crops and weed, that are seriously affected by these materials, particularly in the germinating and seedling stage. Most species of polygonaceae, including perennials, are seriously affected by the carbamates. Similarly, certain species of the portulacaceae and of the caryophyllaceae are likewise affected. In the case of chloro-IPC certain of the annual malva, chenopods, and amaranthus are likewise affected. Most legumes are quite tolerant of the carbamates as are most species of rosales and other dicotyledonous plants. Perennial grasses that

have become well established will tolerate selective dosages of these chemicals when applied in water or in low volumes of oil. Only a limited few of the row crops have shown themselves to be particularly susceptible to carbamates, among these are all species of cucurbits.

The carbamates have come into general field usage as herbicides for two major problems. They are: first, the control of weedy annual grasses and a few broad-leafed annual weeds in legume, grass, and horticultural crops, and secondly, for the control of weedy perennial grasses when used in an oil carrier.

The carbamates are enjoying wide usage in the west for the selective control of weedy annual grasses in legumes. Advantage has been taken of the selectivity of these materials to reduce grass competition in the establishment of stands of legumes. Twenty to forty per cent better stand establishment has been accomplished by early application of carbamates. Most spectacular use of these compounds has been in selective control of weedy grasses in legume seed crops. Increases in seed yields by reduction of grass competition has amounted to from 100 to as much as 500 per cent in certain situations. This has been true of Ladino clover, Lotus, and Alfalfa. In studying the control of weedy annual grasses in alfalfa for forage production, it was found that there was a direct correlation between forage yield of the alfalfa and the grass alfalfa ration in the composition. Thus, as the percentage of grass in the ration increased, forage yields of the alfalfa declined immensely.

Seed crops, particularly grass seed crops, are an important item of agricultural commerce in the northwest. In these crops a high quality material is desired, if not absolutely essential. Frequently weedy annual grasses such as ryegrass, rattail fescue, and annual bluegrass become severe contaminants in these grasses. Unfortunately, the seed of these weedy annual grasses so nearly approach the size and shape of the desired crop seed that it is impossible to clean them out with present day equipment. In recognition of the differential response between grasses and grasses of different ages, the carbamates were tried for selective control of these weedy annual grasses. This treatment was found extremely successful resulting in a seed crop of much higher quality. It is interesting to note that of several rather extensive acreages that were treated in Oregon in the season of 1950-51 that practically all of the seed harvested from IPC treated fields gave blue tag seed or highest quality, whereas the same fields the year before had at best made red tag or second quality seed.

In the study of the control of weedy annual grasses in perennial grass seed crops, it was found that timing as well as dosage and formulation was an extremely critical factor. Under conditions of western Oregon it was found necessary to limit the applications made in November and December gave greatly decreased yields; however, a slight increase in yield of December treatment over November treatment was noted. There has also been a rather consistent increase in yield amounting to as much as fifty per cent in treated fields over untreated fields as well as an increase in the quality of the product. This problem is receiving considerable additional attention.

The carbamates have been found to be effective for the control of weedy grasses and dicotyledonous plants in many of the vegetable and horticultural crops. There is some indication that IPC can be effectively used for the control of wild oats and other grasses in peas and extensive use of it has been made for the control of weeds and grass in strawberry plantings in the Northwest. The material must be used cautiously and the application properly timed to avoid injury to the crops. In two years of trial however, with strawverries, yields were maintained equal to or slightly greater than untreated controls with a net saving of \$80 to \$95 per acre in hoeing cost.

The control of perennial grasses with the carbamates plainly calls for a different technique of application than in the case of annual grass. In the case of the perennial grasses they are allowed to attain a growth of 8 to 10 inches at which time the carbamate is applied in dosages of 12 to 16 pounds per acre in 50 to 100 gallons of aromatic oil per acre. Within a week or ten days this should be followed up by cultivation to insure intimate contact of the roots. Under conditions of dry summers this treatment is most effectively made in the late summer or early fall, but the timing will have to be adjusted to the area. Most effective use for the control of perennial grasses with these materials comes from fall or winter applications. Here the material is dissolved at a ratio of 16 pounds per 100 gallons of oil and applied to the emergent grass while it is still green. Very effective control of grasses has been achieved in this manner. This program has a special appeal for use in orchards and berry planting.

While the results for weed control with carbamates has been erratic in different places, it is felt that more detailed attention to the proper use of these materials would assure them of their rightful place in the family of weed killers in these areas.

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THE COLUMBIA BASIN WEED COMMITTEE

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The job of delivering water to 1,029,000 acres of sagebrush and dry farm land and the development of 13,000 to 14,000 family-sized farms is no small task for the Bureau of Reclamation and the State of Washington. This development of the Columbia Basin Project presents hundreds of problems the solution of which will have an important effect upon the economy of this project and the welfare of residents of the State of Washington and the Pacific Northwest.

This conference will be quick to agree that the weed problem in this area is of major importance. The next 5 or 6 years are the most critical periods, insofar as weed control is concerned. What we do about weed prevention and control during this period may determine our success in keeping the weed problem under control. It is believed that many of you can point to areas which were not seriously infested with weeds at the early beginning of development. In areas where little concern was had for the weed problem during the development period and where small patches of noxious weeds were permitted to spread, now, hundreds of acres are covered and the infestation has become so firmly entrenched that control by individual farmers and local organizations is questionable. It is indeed a sad situation to find potentially high productive lands which have become so infested with weeds that the cost of their eradication is more than the farms can pay. Such farms are not assets to a State, county, or community. This must not happen on the Columbia Basin Project.

If such a condition is to be prevented on this project, we must have the support and active participation of every organization in the State of Washington, together with cooperation from the other states in the Pacific Northwest. The initial step in obtaining such support and cooperation was the organization in 1950 of a Columbia Basin Weed Committee. Dr. Lowell W. Rasmussen is chairman of this committee and represents the State College of Washington and Experiment Station; Mr. Henry Wolfe represents the Washington State Extension Service; Mr. V. F. Bruns represents the Weed Division of the Bureau of Plant Industry and the Irrigation Experiment Station at Prosser, Washington; Mr. A. L. Norris represents the State Department of Agriculture with headquarters at Yakima; Mr. John Toevs represent the Bureau of Reclamation project office at Ephrata, Washington; and I represent the Regional office of the Bureau of Reclamation at Boise, Idaho.

I shall discuss each phase of the weed program proposed by this committee, including surveys, weed control on Bureau lands, weed control on lands in private and in local Government ownership, the research program, and regulations and law enforcement.

A Bureau weed survey of the project area, completed about 5 years ago, while of a reconnaissance type, provides a fair record of weed infestations. Surveys, more complete in nature, will be required as organizations and facilities for weed control are established. The Bureau's survey reveals that the present weed infestation is not extensive but is limited largely to natural waterways, feed yards, and the relatively small acreage of land which is already under cultivation. This includes, of course, the lands to be covered by water in the Equalizing Reservoir where irrigation water will be stored after being pumped from Lake Roosevelt.

The Bureau's weed control program on Government-owned lands was begun about 3 years ago. The initial meeting on this problem was held in connection with the Western States Weed Conference at Bozeman, Montana. Some of you participated in this meeting. At that time we were concerned about the spread of weed seeds to farm lands from the Equalizing Reservoir. As an explanation for you who are not familiar with the reservoirs on this project, the Equalizing Reservoir covers approximately 27,000 acres at 1570-foot elevation and will store the water pumped from Lake Roosevelt back of Grand Coulee Dam. As you might guess, persons in that meeting considered those factors which would influence the amount of weed spread with water from a reservoir. Among the questions considered was the buoyancy of the several varieties of weed seed known to be in the reservoir area, and since water outlets are near the bottom of the dam, it was also important to know if these seeds might be suspended somewhere between the bottom and surface of the reservoir. Another important consideration in this meeting was the effects of water soaking, over various periods of time, upon the viability of these weed seeds. Unfortunately, these questions could not be answered and on further search, it was found that there had been little research on these particular questions.

Mr. Bruns with the cooperation of Dr. Rasmussen undertook a study of these questions, in 1949, and preliminary results obtained by the spring of 1950 indicated that the particular noxious weed seeds under study maintained sufficient buoyancy and viability under fresh water storage to provide a source of infestation. It is understood that a report on this study will be published sometime this year.

Since our schedule of delivery of water to farm lands required that we begin storage of water in 1951, it was necessary that we begin our weed control before the research was completed. Thus, based upon initial findings, the Bureau started and carried on a control program during 1950 and 1951 which has prevented seed formation on approximately 4000 acres

of weed-infested land within this reservoir area.

While discussing the Bureau's program for preventing the spread of weeds from this source, you may be interested to know that we also have an aggressive weed program under way which will prevent the spread of weeds from our rights of way. As the construction of canals and laterals are completed, they are being seeded to grasses. Three power spray rigs capable of reaching most areas are on hand and more will be provided as need arises. Mr. Delbert D. Suggs, an Agriculturist who is attending this conference, has been employed to supervise the Bureau's weed program on this project, and we have irrigation operation and farm development staffs who are determined to keep the weed problem on Bureau lands under control.

Now, I shall discuss the problems and the program proposed by this committee for the prevention, eradication, and control of noxious weeds on farm lands and lands held by municipal, county, and State governments within this project.

Like all new areas, this project and its 13,000 to 14,000 new farms will require tremendous quantities of seed and feed. Imagine the demand for seed and feed by approximately 1000 new farms each year, or approximately 5000 new farms by 1956. If we are not careful, this could be a dumping ground for thousands of pounds of weed seed carried in the crop seeds and feeds purchased by these farmers. Many of these settlers, coming from practically every state in the Union, will, unless encouraged to do otherwise, bring or obtain from any source, a supply of their favorite seed, much of which may be weed infested. Weed seeds will be carried into the area in old sacks, equipment, and other possessions of the new settler. Weed patches along natural waterways which drain into the project area are another serious source of infestation, and we must not forget the weeds already established within the project.

Old and new settlers must be trained in identification and methods of weed control. Weed districts and weed extermination areas, adequately financed, must be organized just as fast as possible.

It is believed that this program of education is largely the responsibility of the State College Extension Service with the cooperation of other agencies, particularly the State Department of Agriculture. The initiative for organizing the farmers within and adjacent to the project into action organizations must come from the State College and the Department of Agriculture. Land owners will not see the need until the weed infestation has reached advanced stages. Mr. Wolfe, Extension Weed Specialist, and Auburn Norris, State Weed Specialist, introduced earlier, are heading up these programs for the State College and the State Department of Agriculture, respectively, and we will all agree that they hold one of the most challenging positions in the West. Some meetings have been held in the area, and it is understood that two weed control districts are in the process of formation. Literature, dealing with this weed problem, including precautionary and control measures, is being distributed to settlers as a part of the contribution by the Columbia Basin Weed Committee, and it is understood that other methods of carrying out this educational program are being planned.

As indicated earlier, Mr. Bruns and Dr. Rasmussen are directing a large portion of their research programs toward the prevention and solution of weed problems on this project. It is the responsibility of all organizations to see to it that this research program is adequately financed and able to continue this important phase of the program.

Now, we come to the problem of obtaining legislation and regulations supporting the weed program. We can treat weeds, we can organize weed districts, we can carry on an effective research program, and we can sell the farmers on

prevention and control of weeds, but if legislation and regulations providing adequate finance and enforcement are not carried into effect, the entire program will fail.

Neither time nor information at hand will permit me to discuss in detail the weed laws of the State of Washington or the regulations dealing with the prevention of the spread of weed seeds through seed and feed. The state laws insofar as they provide for the organization of weed districts and weed extermination areas are probably adequate. However, provisions for financing the programs to be carried on by these districts are inadequate. It is understood that one weed district, two years after organization, has but \$7000 to spend in 1952. Funds for these districts are obtained only by direct assessment against the land. Regulations and orders have been put into effect for the purpose of controlling the sale and shipment of weed infested feed and seed, and there is no doubt that these regulations and orders will do a lot of good. However, as the State Department of Agriculture will tell you, the legislature has not seen fit to authorize a strong hand in dealing with this traffic of weed seeds. It is understood that an order was issued sometime ago prohibiting the inclusion of seed screenings or waste in manufactured feeds, but before this order could be enforced, it was necessary that the feed and flour milling industries of the State be consulted. A parallel situation would be a requirement that we consult all food and drug manufacturers and obtain their consent to the enforcement of the pure food and drug laws. This problem is drawn to your attention for the purpose of emphasizing the need for requests from farm organizations, irrigation districts, and others for legislation which will permit the establishment and enforcement of regulations which will stop the traffic of weed seeds through feed and seed.

It is understood that the State Department of Agriculture is responsible for the establishment and enforcement of regulations as permitted under the laws of the State. This phase of the program must be fearlessly carried out.

In this discussion I have pointed out the responsibility of each organization represented on this Columbia Basin Weed Committee, but let us not forget that we must continue to work together. We have one goal and that is to prevent the contamination of these 14,000 new farms with noxious weeds.

The Present Status of the Halogeton Problem

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All of you are aware that much, sometimes perhaps too much, has already been both written and said on this subject. Essentially we have had too many words and not enough work. Some irresponsible reports have been made which were based neither on correct observations nor on research results. This subject has had a peculiar appeal to both technical and general writers. During the past year, I have had no less than twenty requests from persons who wanted our data so they could write a "Scientific article in a popular manner". Without our assistance there have still been enough "Scientific articles presented in a popular manner" to cause a grand state of confusion. I need not say this to this audience but it has become a habit. Be objective in your interpretation of what is said here today and what you might say of your own volition.

I believe that the most objective report ever made on the subject, despite the fact that I disagree with the main thesis, is the historical sketch prepared by William A. Dayton, Chief, Dendrology and Range Forage Investigations, U.S. Forest Service, entitled,

"Historical Sketch of Barilla". I recommend it to you for background reading.

The literature available indicates that *H. Glomeratus* is indigenous to the Kirghiz-Sungaria area; which is the desert to semi desert area of southwestern Siberia and northwestern China, respectively. Many revisions and re-classifications of the genus *Halogeton* have been made throughout the years. As many as twenty-four species have been named, the more recent works, however, indicate that there are three principal species, *H. glomeratus*, *tibiticus*, and *sativus*, all native to this area.

With reference to the general progress on the study of this plant in the United States, the records show:

1. On June 20, 1934, Ben Stahmann, U.S. Forest Service, collected specimens of *H. glomeratus* which were subsequently submitted to the U.S. Forest Service, Washington D. C. for identification.
2. Numerous other collections were made in short succession and the first botanical manual to include *H. glomeratus* was Holmgren's processed handbook, 1942.
3. In 1944, Fleming, Miller, Vawter, et al., of the Nevada Agricultural Experiment Station, reported on the toxic properties in their annual report.

How It Got Here

Considerable publicity has been given to the idea that *H. glomeratus* was introduced in Crested wheatgrass seed. There is little evidence that such is actually the case. We do not know when the importation was made. But among the possibilities we must consider the importations of karakul breeding stock, which came from the designated area. Such importations were made in 1908, 1912, and 1914. Pelts and unprocessed wool may be other sources, and in this we might consider mohair, cashmere, and other wools produced in this Region. Agricultural statistics show that from 1910 to 1933 we imported an average of 171 million pounds of wool per year. This figure includes mohair and the other fine wools. The Kirghiz-Sungaria area is reported to support 14 million sheep, 9 million cattle, 7 million horses, and 1 million goats. The probability is that the actual source has not yet been mentioned and therefore, we would be wise in saying that we don't know. But that it did arrive sometime prior to 1934. Whether that sometime was nearer 1933, 1923, or 1913, we may never learn.

Present Problem and Acreage

In Idaho we do not know what our livestock losses have been to date. We do know that the total would be in the thousands. Our largest single sheep loss figure still stands as 1,620 head in 1945. We know also that the area now infested with *Halogeton* once supported 10 sheep outfits and now that figure is zero. How many sheep outfits this area ever could or should have carried, I am not in a position to say.

According to 1950 estimates, the Western states harbor the following approximate *Halogeton* acreages:

.....California.....	4,000 acres
.....Idaho	268,050 "
.....Montana.....	2,500 "
.....Nevada.....	2,000,000 "
.....Utah.....	2,000,000 "
.....Wyoming.....	300,000 "
Total	<u>4,574,550 acres</u>

I have no figures of increases in acreages except for Idaho where we had an extension in the main infestation area in 1951 of approximately 20,000 acres, plus two new infestations each 100 and 200 miles, respectively, from the Cassia infestation. These new infestations cover 100 and 80 acres, respectively.

Potential Future Adaptation

I speak humbly to you on this phase because like in most all other respects no one knows what the future has in store for us.

Some are of the opinion that Halogeton has already reached its so-called ecologic limits, and considerable vocal force has been given to this point. On checking the literature you will find that the same thing was said of Russian thistle, about the turn of the century when it could be found only in South Dakota. I need not say more on that point.

What is its area of adaptation? Observations show that at the present time it is doing quite well in an area ranging from 4 to 15 inches in annual precipitation, and at altitudes from 3,000 to 6,000 feet.

1. Superimposing the annual precipitation map over the present Halogeton area, we see that this precipitation area extends roughly from: the Dakotas, eastern Colorado, and western Texas; to the Cascade and Sierra-Nevada mountain ranges, with the Halogeton area approximately at its center.

2. Superimposing a map showing average relative humidity as of 8 a.m. for the month of July, we find that Halogeton now exists in the area indicated as 50 to 60, and the recent infestations are in areas approaching 70 percent. The 50-70 percent relative humidity area being practically synonymous with the 4-15 inch precipitation area, with the major Halogeton area at its center.

3. Soils and Men, show a map of the Sage Brush area of the United States. This area is usually considered as constituting about 120 million acres. The present locations of Halogeton are in about the center of the Sage Brush area except in one instance in Montana where it approaches the "short grass" vegetation type.

4. A map titled "Soil Associations of the United States" also from Soils and Men shows that three and possibly four major soil types for Nevada, Utah, Idaho, and Wyoming harbor Halogeton. These soil types are:

- A. Portneuf-Sagemoor: Elevation-200 to 6,000 ft.; precipitation - arid, 5 to 12 inches; vegetation - sagebrush, shadecale, rabbit brush, greaswood, etc.; location - Nevada, Utah, Oregon, Washington and Idaho.
- B. Navajo-Chipeta: Elevation-4,000 to 7,000 ft.; precipitation - arid, 5 to 10 inches; vegetation - shadecale, saltbush, sagebrush, and rabbit brush; location - Arizona, eastern Utah, western Colorado and Wyoming.
- C. McCammon-Duschutes: Elevation-3,000 to 7,000 ft.; receiptation - 10 to 15 inches; vegetation - sagebrush, Juniper and bunchgrass.
- D. Underwood Babb: Elevation-1,000 to 8,000 ft.; precipitation - 20 to 30 inches; vegetation - pine or fir with some sagebrush.

Conclusions

1. Evidence indicates that Halogeton has not reached it's growth limits with reference to any of the factors; precipitation, humidity, vegetation or soil type.

2. Our present knowledge indicates that the possible extension of the infestation, in so far as Idaho is concerned, is not limited. There is a total of 53 million acres in the state, we have about 25 million acres designated as range land. An ample vegetative cover--a well managed range--is the best insurance against a Halogeton invasion. Unfortunately, the quantity of range in such condition is very limited. The area open to invasion is, therefore, possibly 10 to 20 million acres. Our Department of Range Management, which is a cooperater in this project, is especially anxious that any vegetative cover be maintained except in areas where successful grass reseeding can be made. Sagebrush areas should not be cleared unless the area can and will be reseeded immediately to a more desirable forage.

3. Our policy to restrict the extension of Halogeton is, therefore:

- A. Continuous vililance for new infestations.
- B. Chemical treatment for all small, new, or non-adjacent patches.
- C. Reseeding larger Halogeton areas or reseed buffer zones to such areas.
- D. Possible combinations of reseed and chemical control.
- E. Improved management to provide natural re-vegetation of desirable forage species.

4. Mr. Howard Morton, Research Fellow in Weed Control, will now give the results of his past two years' work. He will emphasize the use and place of the low volatile esters in Halogeton control. To avoid confusion you will note that his work applies to only Halogeton control and to dry range conditions and not to other weeds and other high soil moisture conditions.

Biological Control of Klamath Weed in California ^{1/}

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It was my privilege to talk to this group in 1948, regarding the initial progress and our hopes and plans with respect to this attempt to control Klamath weed by the use of imported weed-feeding insects. At that time we were able to report that two species, Chrysolina hyperici and C. gemellata, had been released and had become established. Our first desire was to obtain sufficient numbers of the beetles so that importations would no longer be necessary and distribution could be made to all of the infested counties of California and to other States of the Northwest. After completion of the distribution program we were then to study the effect of feeding on the plants, to obtain information on control.

^{1/} This is a cooperative project with the University of California.

We are pleased to say that the beetles did multiply very rapidly. All the counties in California that are infested with Klamath weed now have many successful colonies and the distribution has become almost entirely a county function.

In cooperation with the State experiment stations, State departments of agriculture, and the United States Forest Service, releases have been made in Oregon, Washington Idaho, Montana, and Nevada. The progress following these releases will no doubt be reported by the cooperating agencies in the near future.

I am also pleased to say that the ability of the beetles to destroy Klamath weed has now become apparent. In Humboldt County 125,000 acres of grazing land have been essentially freed of Klamath weed, and equally promising results are being obtained in other counties in the coast range. The progress has been a little slower in the Sierra foothill areas. However, the indications are that eventually the weed will also be controlled in the inland counties.

Klamath weed control by insects has now reached a point where success in general may be assigned to the action of Chrysolina gemellata, and the primary reasons for assumption of the dominant position by this species over C. hyperici have become apparent. The balance between the propagative ability of the weed and that of its insect enemy is the result of forces exerted upon both by soil condition, meteorological circumstances, and the associated living environment. The biological control of this weed is a striking example of this principle. The two species of Chrysolina differ only slightly in their environmental requirements. Yet that small difference permits the enormous multiplication of the one species and curtailment of the other.

In general, the growth phases of the plant and the climate in Klamath weed areas in California are very favorable to Chrysolina gemellata and unfavorable to C. hyperici. After the fall rains begin, the weed develops a dense, prostrate rosette of basal foliage. C. gemellata readily comes out of aestivation and begins to reproduce immediately, whereas C. hyperici reacts to moisture very slowly. As a result of this delay, the latter species is deprived of an opportunity for propagation at a season of the year when the plant's growth is in ideal condition. C. gemellata deposits most of its eggs in the fall and early in the winter, and its larval brood is often at an advanced stage of development by the time C. hyperici begins to oviposit in quantity.

As a result of its delay of reproductive activities in the fall, the developmental phase of Chrysolina hyperici is projected so far into the summer that the dry-soil conditions that prevail from about April to October destroy a large portion of each brood. Because of its failure to utilize the full annual span of moist conditions and favorable temperatures, C. hyperici does not have sufficient time left to complete its development. Only individuals from the very first eggs deposited, or those able to locate the limited number of favorable moisture niches, are able to mature. The total effective egg-laying period of this species is thereby reduced to a very small fraction of what it would be if the beetles came out of aestivation early in fall, or if ample rainfall were prolonged later into the spring. Huge egg and larval populations of this species late in the spring produce rather insignificant numbers of adult beetles. No significant parasitic or predatory action has been observed; furthermore, such agents would hardly be expected to operate selectively to the disadvantage of C. hyperici, as compared with its very close relative, C. gemellata.

The natural dispersion of Chrysolina gemellata has been very satisfactory. Close observations have shown that during the early stages of an initial colonization the beetles move outward from a release center primarily by walking. Preaestivating adults in such an environment, where food is abundant, exhibit little inclination to fly or to walk. However, after aestivation they walk rather rapidly, laying eggs as they progress outward. During the first winter following a release, eggs have commonly been found for distance of 50 to 100 yards from a release center. A progressive decrease in the numbers of eggs and larvae is common as the distance from a release site increases. Some plants

at the original sites were slow to develop in the fall, owing to poor exposure or otherwise; therefore the beetles moved away. The heaviest concentrations of eggs were then found in nearby locations that supported favorable plant growth early in the fall.

On the other hand, if a population has reached an advanced stage in a certain infested field and the larvae have defoliated nearly all the weeds, the issuing adults may be stimulated to flight by their hunger and by the bright sunlight on warm days.

Natural movement of the beetles proceeded at a rapid rate after the third or fourth years. The third generation, two years after liberation of beetles at Blocksburg, removed the weed for a distance of 100 yards. By the following year, 1949, the beetles had moved outward and almost cleared an area within the radius of a mile from the release site. In 1950 this control area had been increased, primarily through natural dispersion, to about 100 square miles, extending to points 6 or 8 miles distant.

The ability of the beetles to destroy weeds and to rapidly disperse and the apparent absence of natural enemies to prey upon them indicate that a satisfactory control will probably be effected in all areas within four years from the time of beetle releases.

The ecological studies by C. B. Huffaker have shown that in an area in which Klamath weed has been removed for four years there has been no increase in the ratio of weedy species to the grasses and other forage plants.

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CHEMICO-ECOLOGIC SUPPRESSION OF RIBES IN FOREST AREAS

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Chemico-ecologic suppression of ribes means the use of chemicals for damaging or killing the weed plant by procedures designed to encourage a desirable course of plant succession. This succession should be directed towards the end result of "replacement control," a term suggested by Piemeisel and Carsner (Science 113. p. 2923, 1950). Replacement control of ribes in forest areas is achieved when the intolerant ribes plant has been shaded out and its site has been occupied by a tree or by a more tolerant shrub.

Recent reports on the control of weeds show many examples of an interest in plant ecology. Timmons' Newsletter of Oct. 5, 1951, to weed control workers in the Western States, contained (according to my marking) 12 references to ecologic aspects of various weed control jobs. These references emphasize comments often made by Crafts, Van Overbeek, and other plant physiologists working on weeds of the Western States and who have

pointed out the profound systemic effects induced in certain plants by the timely application of small dosages of 2,4-D.

Many of you are familiar with the work of Bonner (Bot. Rev. 16, pp. 51-55, 1950) and other investigators who call attention to toxic substances produced by such plants as guayule, Encelia sp., and Artemisia sp., and who suggest that these toxins may influence plant succession. Unpublished results of our greenhouse tests on ribes show that cold water extracts of Castanopsis sempervirens (chinquapin) are toxic to seed and seedlings of Ribes roezli. On the other hand, Ceanothus cordulatus, as reported by Quick (Journ. Forestry 42, pp. 827-832, 1944) favors the growth of R. roezli.

In some situations the best way to eliminate one species from a community of two or more plant species might well be to direct initial attention to the suppression of another species. The idea of getting nature to help with pest control work is certainly not new, but too often ecologic goals are not clearly defined or given adequate study before a weed control program is initiated.

The objective of artificial ribes suppression is to reduce the population of plants and soil stored seed to the point where the species will be gradually replaced by useful trees and shrubs. Over a 21 year period, ribes ecology studies have shown us that suppression of this plant can be achieved by widely varying amounts of eradication effort provided this effort is related properly to the size, vigor, and ecologic development of the ribes population. Briefly, and in blister rust terms, we establish control standards that are based on an understanding of the status of the rust, the ecology of ribes and white pine, and immediate attainable goals in ribes suppression.

The scope and timing of protection work in the case of a tree crop, or any crop that takes a long time to mature, markedly affects costs and returns. For example, in California we are presently charging the costs of ribes suppression with compound interest at the rate of $2\frac{1}{2}$ percent over the anticipated 110- to 130-year pine rotation. For this suppression work you can readily see the advantage of a small recurring charge over one or two high costs incurred early in the life of the timber stand. At $2\frac{1}{2}$ percent compound interest, \$1 of protection cost becomes \$1.28 in 10 years, \$3.44 in 50, and \$11.81 in 100. Improvement of forest and range land often requires capital investment on which little return can be expected for many years.

For the reasons just outlined the suppression of a virgorous, widely distributed weed plant that is well adapted to its environment on noncultivated land should be regarded as a long term job of applied ecology. The control job should be planned first to take advantage of all natural factors favoring suppression of the weed and then to use artificial control methods with a realistic understanding of how much can be accomplished within a certain period of time and what it will cost. Let us examine the ribes suppression problem in more detail to see how a knowledge of ribes ecology can aid in the effective use of chemical methods for the control of this plant.

THE ECOLOGY OF RIBES

Salient points in ribes ecology pertinent to this discussion are:

1. Ribes is a deeprooted perennial woody plant. It sprouts vigorously from the root-crown though not from true root tissue and reproduces both vegetatively and by seed.
2. Ribes is a pioneer plant entering on ground freshly disturbed by fire, logging, animals, chemicals, wind, and erosion.
3. Ribes seed is hard-coated and long-lived. Under favorable field conditions seed may remain dormant and viable in the forest floor for many years. Germination tests on recovered samples of buried seed have shown that 17-year-old R. roezli seeds

are viable (83, 92, and 98 percent germination in three samples).

4. Under conditions of full stocking of the forest, ribes plants begin to be shaded out 15 to 25 years after their establishment.

5. Ribes produces some fruit and viable seed the third year after germination and establishment of the seedling plant, or on two-year-old wood from a sprouting root crown. Significant fruit production takes place from the 4th or 5th year until the plants lose vigor.

6. The major part of the ribes population is established the first year after fire or chemical eradication and the second year following mechanical disturbance. Fire and chemical are more likely to bring about a single crop regeneration than mechanical disturbance which usually results in intermittent regeneration over a period of years.

7. Native ribes species so far tested show a high degree of selfincompatibility in fruit production. Thus any eradication effort that reduces the number of individuals and increases the distance between them will result in progressively smaller fruit crops.

8. By alteration of soil moisture, soil temperature, and light in the forest stand by prescribed methods of logging, it is possible to affect the germinative response of soil-stored ribes seed. In even-aged and fully stocked forests heavy cutting favors germination of ribes seed and light cutting minimizes it.

RELATING THE CHEMICAL METHOD TO ECOLOGIC OBJECTIVES

Consideration of the eight points just outlined suggests that there are two periods in the life cycle of a ribes population when eradication effort can be advantageously started. The first occurs 1 to 5 years after the new population has become established on a freshly disturbed area and prior to heavy fruit production. During this period bushes are small, are easily sprayed, and are markedly sensitive to low dosages of 2,4-D or 2,4,5-T. The second period occurs 15 to 25 years after ground disturbance when the pioneer ribes is beginning to lose out in competition with more tolerant and longer-lived vegetation. At this time the old mature ribes can be defoliated and the live stem killed to the ground by dilute aqueous sprays of 2,4-D with a high degree of uniformity in results and with very little chemical. One spraying, however, will seldom kill a high percentage of the root crowns of these old slow-growing ribes. The results are likely to be spotty over the several ecologic types involved and costly dosages of toxicant are required for uniform kill.

In 2,4-D, 2,4,5-T, and similar herbicides we have the means to induce a wide variety of changes in the form and vigor of weed plants, often on a highly selective basis. As a legitimate objective we might set out to kill the weed or merely to induce damage varying from defoliation or leaf modification to killing of all above-ground portions of the plants. In many of these tasks it is easy to obtain about 85 percent damage or kill by surprisingly small amounts of chemical and difficult, to put it mildly, to improve results of large-scale operations beyond this level. The importance of relating the chemical method to ecologic objectives, is illustrated by data from field tests on R. roezli, having the following objectives:

- (1) killing or damaging mature plants by spraying.
- (2) defoliating young plants by fogging,
- (3) killing mature plants by basal stem treatment, and
- (4) destroying the viability of seeds.

KILLING OR DAMAGING MATURE PLANTS BY SPRAYING

It is paradoxical that Ribes roezli, the most sensitive of all ribes to the toxic action of 2,4-D, has given us more problems and disappointments in large-scale operations work than any other ribes. Apparently the more sensitive a plant is to a toxicant, the greater is the possible variation in the damage resulting from a specified dosage. This variation is directly chargeable to such ecologic factors as age class, vigor, and plant associates. In the case of the sensitive plant it is especially desirable to know the type and extent of damage that can be easily obtained and the effort that will be required to improve this result significantly.

The results of tests made in 1948 illustrate this point. From August 5 to 10, light, medium, and heavy treatments of 2,4-D sprays were applied by power sprayer and crew labor to mature Ribes roezli on the Sierra National Forest, California. The spray contained the sodium salt of 2,4-D plus a sticker-spreader plus summer-oil emulsion. Light treatments wet all foliage and stems thoroughly to the ground line, and medium treatments in addition wet the principal root crown. The latter procedure is usually followed in large-scale field work. Heavy treatments were the same as the medium treatments plus a heavy drench of the soil about all root crowns. The volumes of spray solution used in making light, medium, and heavy treatments were approximately in the ratio of 1:2:4.

The percentages of bushes killed by various dosages of 2,4-D were as follows:

<u>Treatment and p.p.m. of 2,4-D (acid equivalent)</u>	<u>Percent of bush kill</u>
Heavy:	
1,000	92
500	96
250	95
Medium:	
1,000	95
500	96
250	94
Light:	
1,000	94
500	94
250	91

A uniform rate of bush kill was obtained in all tests. The treatment "heavy at 1,000 p.p.m.", which killed 92 percent of the bushes, is about 16 times that of "light at 250 p.p.m.", which killed 91 percent. You can see the opportunity here of regulating the selectivity of the spray by adjusting the volume and dosage.

In 1949 we started a series of spray tests designed to study the effectiveness of aqueous 2,4-D when used at concentration known to be minimal for systemic damage. We scheduled treatments so that results of one spraying could be compared with those of two or more sprayings in successive years. From 1949-51 about 200 plots were sprayed according to schedule. In terms of the ultimate suppression of R. roezli, impressive results have been obtained in favorable ecologic niches by one spray treatment with 2,4-D at 50 p.p.m. acid equivalent. All individuals did not respond

uniformly to sprays of such dilution but many plants were killed and live stem and foliage kill was close to 100 percent. After the second spraying with 2,4-D at 50 p.p.m. the percent of bushes killed was about comparable with average results of operations spraying in which a 500 p.p.m. solution was used.

DEFOLIATING YOUNG PLANTS BY FOGGING

At Pescadero, California, in the spring of 1950, we tested a thermal fogging unit installed in a helicopter for broadcast application of low dosages of 2,4-D. The purpose of this work was to study the use of aircraft for suppressing ribes by a series of low cost treatments designed to defoliate and damage ribes without harming associated white pine. Results of eighteen flight tests in which 2, 6, 9, and 12 ounces of 2,4-D per acre were applied to potted ribes and pine are detailed in a report published in Weeds 1, pp. 61-69, 1951. Nearly 100 percent defoliation of ribes was obtained by the 6-ounce per acre treatment which did not significantly damage the test white pine. Three ounces of 2,4-D per acre caused surprisingly good defoliation. In moist, cool air and with air movement of 2 m.p.h. or less, a fog of 2,4-D capable of defoliating and damaging sensitive plants can be deposited by helicopter from a height of 20-30 feet at speeds of 20 and 25 m.p.h. and probably from a height of 100 feet, provided speed of the ship is 15 m.p.h. or less.

Another approach to ribes defoliation by fine-particle dispersion of 2,4-D was tested during the summer of 1951. Paper pellets and small pieces of cardboard soaked with the isopropyl ester of 2,4-D were scattered by hand on the ground under R. roezli plants. A month after treatment many of the test plants had been defoliated and had suffered systemic damage. For broadcast treatment by aircraft and selective damage of a low-growing shrub such as ribes, it might be practical to pelletize a herbicide of suitable volatility and thus get the toxicant down through the canopy of trees and shrubs to the ground where it could act on the ribes. If the status of the pest permits postponement of the big capital investment needed to eradicate the weed plant in one or two treatments, then suppression by repeated low cost treatment may offer economic as well as practical advantages.

KILLING MATURE BUSHES BY BASAL STEM TREATMENT

The treatment of individual bushes by basal stem or cut surface method often serves desirable ecologic objectives in that these methods can be made highly selective. Since they usually call for oil-phenoxy concentrates this selectivity is related to the method of application rather than to the toxicant. Because of the high concentration of toxicant used it is essential to know what can be done with minimum dosages. In working with ribes we find that 85 to 90 percent of the bushes can be killed by an average dosage of 0.1 ounce of 2,4-D or 2,4,5-T per bush. Doubling or trebling that dosage does not provide a reasonable expectancy of increasing bush kill by more than 5 percent. In operations work we are presently using 5 percent acid equivalent (AE) solutions of 2,4-D for basal stem and 1 percent (AE) for cut surface treatments. These concentrations permit us to operate within the range of 80 to 90 percent bush kill with the smallest volume that can be used effectively by average woods labor. Increased kill when needed can be obtained by taking more care in preparing the bush for treatment and in removing leaf mold and ground litter when it forms a protective and sponge-like cover of the stems at ground line and about the root crown.

DESTROYING THE VIABILITY OF SEED

In attempting chemical control of a perennial plant that reproduces largely by seed, one should understand the effect of the toxicant on seed viability and on the establishment of seedling plants. Ribes seeds will retain their viability through several weeks of immersion in dilute solutions of many of the inorganic acids, alkalis, and plant poisons. Immersion of dry, unplumped R. roezli seed for 24 hours in aqua regia containing some 15,000 p.p.m. of total acid just slightly reduced germination from a normal of 90 percent to 79 percent. By contrast, 24 hours immersion of dry, unplumped R. roezli seeds in 200 p.p.m. (AE) of 2,4-D for 48 hours prevented germination. Results of other germination tests show that the sensitivity of ribes seeds to various growth-regulating substances correlates closely with the sensitivity of the mature plant to the killing action of the same chemicals.

Although the low dosages of 2,4-D and 2,4,5-T are toxic to ribes seeds it does not seem to be economically feasible to broadcast sufficient toxicant in the regular spraying operation to destroy all soil-stored seed. Regeneration is spotty and often unpredictable. Moreover, newly established ribes can be sprayed easily on a subsequent working. In favorable ecologic niches numerous R. roezli seedlings have been noted under parent plants killed the previous year by 2,4-D sprays applied in May and June. By contrast, mid-July and August killing of mature R. roezli with 2,4-D has resulted in little or no establishment of seedlings the following year. To a limited extent, therefore, we can control the germinative response of ribes seed by selecting the time of year for the initial spray work.

SUMMARY

Chemico-ecologic suppression of ribes means the killing or damaging of a weed plant with chemicals to the extent compatible with the age class, vigor, and stage of ecologic development of the weed population in relation to associated vegetation. On non-cultivated lands the scope, timing, and immediate objective of chemical work should be adjusted to economics of the control job and to attainable goals in plant succession. Results of 21 years' study of ribes ecology have served as a background for judging the effectiveness of 2,4-D for (1) killing or damaging mature ribes by aqueous sprays, (2) defoliating young ribes by fogging, (3) killing mature ribes by basal stem treatment, and (4) destroying the viability of seed. Stop, look, and listen if considered in the reverse order is as good a rule for the weed control expert as for the pedestrian. Listen to the best information available on the ecology of the weed plant, look at all phases of the proposed job (economics, ecology, methods, and apparatus), and stop at the point where returns in terms of effective suppression are not commensurate with the effort being made.

STUDIES OF HERBICIDAL ACTION ON AQUATIC WEEDS USING RADIOACTIVE 5-I, 2,4-D

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The use of radioactive isotope tracer technique is becoming an increasingly important tool in many industrial, engineering, and scientific applications. The use of these "tagged" atoms has become almost a byword in agricultural chemistry, petroleum technology, and many other fields. Our present paper offers some tentative findings, which we believe of interest, on the use of this technique in studies of certain aquatic weeds. The authors wish to state at the outset that what follows should be considered

rather in the light of an interim or progress report and that our results are not necessarily conclusive or final. However, if some contribution is made in enlarging our theoretical knowledge, we believe the purpose of advancing more effective weed control field practice will have been well served.

This investigation is a part of the mutual and cooperative research program being conducted by the United States Department of Agriculture, Bureau of Plant Industry, Soils and Agricultural Engineering, Division of Weed Investigations, and the United States Department of Interior at the Bureau of Reclamation's Engineering Laboratories located near Denver, Colorado.

GENERAL ASPECTS

The problem of determining the factors that are important in the control of aquatic weeds with systemic herbicides, characterized by 2,4-D, has proven to be complex. Results of field tests on such resistant species as the cattails have in general been somewhat erratic and in certain cases apparently contradictory.

One of the most characteristic properties of systemic herbicides is the relatively small quantity of the active material that is necessary to bring about metabolic disturbances in the plant. Through the use of radioisotope techniques, investigators have in recent years been able to detect radioactive substances in growing plants even when minute quantities of these substances are present. In this method, individual atoms of any particular radioactive element present in the plant parts may be counted. In addition to the ability to detect relatively small quantities of tagged compounds, radioisotope techniques thus permit detection of the tagged compound in situ. Thus, by proper procedures, distribution of tagged compounds can be rather accurately followed within the plant.

To understand why herbicides in certain formulations are effective on some plants under certain prescribed conditions of growth and not effective on others, we must learn the relative facility with which herbicides are absorbed and translocated within the various plant parts under varied external conditions and how the physiological processes of the plant affect and are affected by the action of the herbicide.

MATERIALS

Since broad-leaved cattail is representative of the emergent type of waterweed infestation and American pondweed of the submersed type, these plants were chosen as the principal ones for the investigation of the translocation studies. Other aquatic weeds were included for comparison.

The aquatic plants used in this study were as follows:

1. Emergent
 - a. Water sedge, Carex aquatilis Wahl.
 - b. Narrow-leaved cattail, Typha angustifolia L.
 - c. Broad-leaved cattail, Typha latifolia L.
2. Submersed
 - a. True waterweed, Anacharis canadensis (Michx) Planchon
 - b. American pondweed, Potamogeton nodosus Poiret

The herbicide selected for use was 5 iodo 2,4 dichloro phenoxyacetic acid butyl ester with iodine 131, which has a half life of 8 days. This can be considered to be 2,4-D with the iodine added to the benzene ring in the No. 5 position or 2,4,5-T with the chlorine in the 5 position replaced by iodine.

It has been shown ^{*1,2/} that 5-I,2,4-D is similar to 2,4-D in its action on navy beans but that somewhat more 5-I,2,4-D is required to obtain the same effect. It has also been shown by Fults ^{3/} that the change in the metabolites of castor bean plants treated with 2-I,2,4-D is essentially the same as that with 2,4-D. It is part of our continuing program to compare the action of 5-I,2,4-D and 2,4-D on aquatic plants.

The iodine compound was chosen for the pilot studies because of the ease and precision with which iodine 131 may be detected and measured. This compound was synthesized ^{4/} by the Texas Research Foundation, Renner, Texas, from iodine 131 supplied by the Atomic Energy Commission, Oak Ridge National Laboratories.

In most of the formulations, the 5-I,2,4-D containing radioactive iodine 131 was diluted with 5-I,2,4-D containing stable iodine 127. This was to reduce the fraction of the 5-I,2,4-D that disintegrated during the course of the experiment.

The 5-I,2,4-D was made up into various formulations generally containing a co-solvent, a carrier, and a surface active agent.

Cosolvents used were:

Tributyl phosphate
Triethanolamine
Carbowax and ethanol
Ethanol

Carriers used were:

Xylene
Kerosene
Water

Surface active agents used were:

Tween 85
Span 85
Oronite petroleum sulphonate L

Application of the herbicide to the emergent plants was accomplished first by using a small camel hair brush and later by a glass applicator made by forming a 1-mm-diameter eye on the drawn end of a 3-mm glass rod. Application was made to the American pondweed either with this glass applicator or by pipetting with a micro-pipette.

*Numbers refer to list of references at the end of report under "Literature Cited."

Autoradiograms were made with Eastman Kodak no-screen X-ray film and developed in Kodak D19 developer.

For plant assay, material was dried in a Cenco drying oven, ground in a small Wiley mill, weighed on an analytical balance, mounted on scotch tape discs held in aluminum rings and counted in a massive lead shield using a thin-end window geiger counter and a Berkeley decimal scaler.^{5/} Where very low activities were involved, counting was done in a Nuclear Measurement Corporation continuous-flow proportional counter.

For assay on water samples, liter volumes were concentrated by evaporation, transferred to small aluminum dishes, and evaporated to dryness. Counting was done as noted above.

A geiger counter made sensitive to a narrow conical region with lead shielding was used to measure the movement of the tagged herbicide through the plants. See Figure 1. The counts were integrated in a Nuclear Instrument and Chemical Corporation rate meter and recorded on an Esterline Angus recording milliammeter. One-fourth of a double-edged razor blade held in a pair of pliers was used in sectioning the plant material. A small piece of cardboard was used to hold the material during sectioning. Each cardboard and razor blade were used for only one cut each to avoid cross contamination. This technique was found necessary because of the high sensitivity of the methods of detection and because of the large differences in concentration of the tagged compound along the leaf.

METHODS

To prepare the autoradiograms, the plants were cut into convenient lengths, usually 2-3/4 inches long, and mounted to a warmed microscope slide using a thin film of paraffin as an adhesive.

In the darkroom a sheet of Kodak no-screen X-ray film was placed over the plant and a second glass slide placed on top, and the assembly taped together with scotch tape. The sandwiches thus formed were placed in a light-tight box and placed in a refrigerator maintained at 40° F for a period of several days. The time for comparable exposures was determined by the date at which the autoradiograms was started, longer exposures being required at later dates because of the natural decay of the radioactive iodine.

The beta and gamma radiations emanating from the iodine atoms cause an exposure of the silver halide grains in the photographic emulsion which, when developed from black grains, indicate the location of the radioactive compound in the original material. It should be clearly understood that this is neither an image as in a conventional photograph nor a shadowgram as in an X-ray picture but that the source of the radiation is contained within the object itself. The fact that the radiations from any source point are given off randomly in all directions and that they are decreased in number and intensity and can be changed in direction in passing through material must be recognized in interpreting the autoradiograms.^{6/} In spite of these limitations, the autoradiogram is a concise too, as can be seen from Figures 2 and 3.

Lateral buds of the broad- and narrow-leaved cattails used in this study were dug from the edge of the Denver Federal Center lake in a growing site inundated the year around. Lateral buds of the American pondweed were obtained from the Denver Federal

Center lake bottom. Both the true waterweed and water sedge plant materials were obtained from cultures maintained in the laboratory greenhouses.

During the investigation, most of the cattail buds were grown in soil placed in the bottom of metallic buckets of 5-gallon capacity. After the buds were planted in the soil in the bottom of the buckets, the containers were flooded with water. On the other hand, water sedge, American pondweed, and true waterweed were planted in 6-inch flower pots which in turn were placed in 5-gallon buckets.

Those plants grown in the laboratory were illuminated with 750-watt incandescent lamps in reflectors, resulting in a measured light intensity of approximately 90-foot candles at the plant surface. The lights were permitted to burn for an average of 8 hours per day. The herbicidal treatment was made when the plants reached the desired degree of maturity, and after application the illumination was continued on the same schedule until the time of sampling. While initially some cattail lateral buds were washed free of soil before planting, in most instances the soil around the fibrous roots was left intact in order that root disturbance during transplanting might be held to a minimum.

For comparison with the plants grown under laboratory conditions, a series of tests was conducted on cattails growing undisturbed on the edge of the Denver Federal Center lake.

The formulations containing the herbicides were applied to the plants in several different ways, depending on the plant and the nature of the information that was sought. In the cattails where direction and rate of translocation were of primary interest, the application was usually made to a half-inch band encircling the leaf, 2 inches from the tip. The technique first tried was to apply a band of lanolin, stained red for better visibility, about 1/8 inch wide, encircling the leaf at the top and bottom of the 1/2-inch high area to which the herbicide was to be applied. A small camel hair brush was used to apply the herbicide formulation to the demarked area. The container, herbicide, and brush were weighed before and after the application. It was found difficult to make the application in this manner without some run-down of the herbicide on the plant leaves. To reduce the run-down the glass applicator was developed. With these applicators, the formulations could be picked up and transferred to the plant leaves with negligible run-down. An attempt was made to simulate spray applications, avoiding the uncertainties and hazards of spray application. With the glass applicators, the lanolin bands were found unnecessary and were discontinued. It was also found that the transfer of the herbicide formulation from the small vials to the plants was sufficiently quantitative that measured volumes could be used.

In order to determine if the pattern of entry and translocation from separated small spots of herbicide on the leaves would be the same as from bands of herbicide completely encircling the plant, one series of plants was treated by applying small spots of herbicide formulation randomly distributed on the leaves of the plant.

American pondweed was treated in one series by stamping a lanolin ring onto the upper surface of a floating leaf and applying a measured volume of the herbicide formulation within the ring by means of a micropipette. The lanolin rings were placed either near the petiole attachment, near the center, or near the tip of the leaf. Another series of the pondweeds was treated using the glass applicators previously described and omitting the lanolin rings. It was found that with appropriate formulations, e.g., carbowax, that the application remained localized without the lanolin ring.

Cattails were sampled according to the method of detection that was to be used. Where it was desired to assay the whole plant to get a quantitative measure of the distribution of the tagged compound in the plant, the whole plant was dug up, care being exercised to recover as much of the root as possible. The plant was then divided into upper leaf, middle leaf, and lower leaf above waterline, stalk below waterline, rhizome, and roots. In some cases, the portion above the waterline was divided into only two parts; i.e., upper and lower. The plant portions were then cut into pieces about 1/2 inch long, weighed, oven-dried at about 80° C, weighed and ground to 40 mesh in a Wiley mill. A small quantity of the ground material was weighed and distributed on a scotch tape disc and counted with a thin-end window counter.^{4/}

Where the distribution of the tagged compound within the cattail plant was to be determined using autoradiograms, the plant was either uprooted or just the treated leaf cut off, depending on the distance and direction of translocation expected. The plant or leaf was laid on a fresh strip of white paper which had been previously marked at 2-3/4-inch intervals. The leaf or leaves were then cut into sections 2-3/4 inches long, using the marks as a guide. The leaf section was then transferred to a warmed microscope slide on which had been brushed a thin film of melted paraffin. The leaf section was held to the slide for the few moments it took the paraffin to solidify. All manipulations of the leaf sections were performed with the small cardboard strips which were used only once. The time between sectioning and mounting was kept to a minimum to avoid the distortion of the leaf comes on drying. The film was mounted with the leaf section within 4 hours of the time of cutting to minimize distortion and possible relocation of the tagged compound due to decomposition of the plant tissue. The other plants were sampled in a similar manner.

Wash waters from pondweeds treated with herbicides containing 5-I,2,4-D were used to flood-irrigate 6-week-old cotton and tomato plants growing in the greenhouse. Dilutions of the radioactive material with nonradioactive 2,4-D were so great that it appears desirable to repeat this phase of the work, using stronger concentrations of radioactive chemical.

DISCUSSION

It was found that 5-I,2,4-D applied to the castor bean leaves in a xylene carrier caused a wilting of the leaf within a few hours and subsequent necrosis of the leaf but that no evidence of 5-I,2,4-D was found in the other portion of the plant, and none of the symptoms of 2,4-D poisoning such as node fibrosis, stem and petiole curling, or terminal bud retardation was observed. In contrast, the same concentration of 5-I,2,4-D in a carbowax and water formulation caused no wilting of the leaves to which it was applied but did cause all the regular symptoms of 2,4-D poisoning. From this observation, it may be concluded that the xylene caused immediate local physiological changes in the plant leaf that prevented further translocation of the 5-I,2,4-D. With this information in mind, a series of tests was made on cattails and American pondweed using formulations of 5-I,2,4-D in xylene and in carbowax but no analogous phenomenon was observed. It appears that the xylene effect on cattails is quite different from that on castor beans.

Of particular interest is the extent of the variation in the observed translocation of the 5-I,2,4-D in cattails under different conditions.

Cattail plants taken as rhizomes from the field at the Federal Center, Denver, Colorado, in December, were planted in soil and water in the bottom of 5-gallon buckets in the laboratory and grown under 750-watt incandescent bulbs. These laboratory plant growths showed rapid downward movement of the 5-I,2,4-D applied near the leaf tip, with

little translocation in the upward direction. Radioactive sodium applied under similar conditions moved principally in an upward direction. Translocation of 5-I,2,4-D toward the rhizome was found to persist even when the herbicide was applied near the tip of a broken leaf so that for the initial portion of its travel, movement went against gravity. With this series of plants, translocation was found to extend below the waterline and into the rhizome and roots but not upward into untreated stalks growing attached to the same rhizome.

In specimens treated in a similar manner but transplanted from the field into the laboratory after field growth was renewed in the spring, a pronounced upward translocation of the 5-I,2,4-D with negligible downward movement was shown. The same tendency for predominantly upward movement of 5-I,2,4-D was observed on treated cattails growing in the undisturbed field growth situation.

For cattails growing in the field, in only one instance was the 5-I,2,4-D found to translocate downward to a considerable degree and this was on a plant where the entire emergent portion of the leaf was treated. In this one instance, translocation was found to extend down to the crown just above the rhizome. See Figure 2. However, for both the emergent and submersed plants treated under laboratory-controlled conditions, the compound 5-I,2,4-D readily passed the water line both when applied to emergent broad-leaved cattail and the floating leaf of the submersed American pondweed. Excellent distribution of at least the radioactive iodine of the applied formulation was obtained throughout the submersed portions of the plants. Perhaps one of the most important developments from this study is the establishment of the fact from autoradiograms that the water line, as such, does not act as a barrier for passage of systemic herbicides through the plant system.

In order to determine the effect of various ingredients of herbicidal solutions on the absorption and translocation of the 5-I,2,4-D, an experiment was conducted using a systematically varied series of formulations on individual cattail plants at various stages of development growing undisturbed in their natural habitat.

Each solution contained the same quantity of radioactive 5-I,2,4-D. The cosolvents used were tributyl phosphate, carbowax 1500 with a small amount of ethyl alcohol added, and 95-percent ethyl alcohol. The surface active agents used were Tween 85 as a typical nonionic agent and oronite petroleum sulphonate L as a typical ionic agent. The carriers used were kerosene as a typical aliphatic carrier, xylene as a typical aromatic carrier, and water as a passive carrier. In this series of solutions the concentration of the active ingredient, cosolvent, surface active agent, and carrier were kept nearly constant, the only intentional variable being the choice of material for each function. Of the 18 theoretically possible combinations (three carriers, three cosolvents, and two surface active agents) in this set, 14 were actually prepared and used.

Broad-leaf cattail plants in three stages of development were treated with each solution. These were immature plants with leaves from 8 to 10 inches long above the waterline, mature but nonfruiting plants with leaves from 40 to 60 inches long above the waterline, and fruiting plants with maturing fruiting stalks.

Five days after treatment, the plants were harvested and autoradiograms made of the leaves. The translocation pattern was generally the same in all plants, and predominantly upward. The difference in absorption and translocation between plants was small, and what differences were observed could not reasonably be correlated with the formulation used. From these observations, it is indicated that

variation in ingredients of formulation within the range included in this experiment are relatively unimportant in influencing the direction and rate of translocation.

It was noted that on some of the autoradiograms the radioactive material appeared to be concentrated in small spots along the leaves. In other cases the radioactive material appeared to be evenly distributed in the regions of the plant it had reached with some concentration in the vascular bundles. An investigation of this spotty distribution indicated that the areas of high concentration of radioactive material corresponded in position to fungus rust on the cattail leaf. The fungus has been tentatively indentified as Phoma sp.

A review of the autoradiograms showed in general that the ratio of the radioactivity in the spots to the activity in the plant as a whole increased with time. This is illustrated in Figure 3. Figure 3-A shows a leaf section 40.5 hours after an application where the radioactivity is principally in the vascular system with no perceptible amount in the fungus colonies. Figure 3-B shows a similar leaf section 114 hours after an application where the radioactivity is in both the plant tissue and in the fungus colonies. Figure 3-C shows a similar leaf section 200 hours after an application where the radioactivity is predominantly in the fungus colonies.

This fungus appears to be a common parasite on cattails in the Denver area.

The importance of these phenomena remains uncertain. Some questions suggested by these observations are:

1. Does the presence of the fungus concentrate the 5-I,2,4-D or does it concentrate some metabolite of a degradation product of the 5-I,2,4-D containing the iodine?

2. Is the iodine containing compound concentrated in the fungus or is it in some fluid in the plant immobilized by the presence of the fungus?

3. Does the presence of the fungus disturb the physiology of the plants so that the translocation pattern in infested plants differs from the pattern in non-infested plants?

4. Does the fungus concentrate other growth regulating materials, such as 2,4-D and 2,4,5-T?

5. Does the ability of the fungus to concentrate the herbicide protect the plant against the herbicidal effects of the compounds?

6. Does the fungus play any role in the normal physiology of the plant, i.e., is the fungus-cattail association mutually advantageous?

These phenomena should be given recognition in the interpretation of the results thus far obtained. By simply measuring the quantity of tagged compound in various sections of the plant after various times, we might very well be measuring the abundance of fungus colonies in those sections. By making autoradiograms of each section where we can observe the distribution of the tagged compound in the plant and in the fungus, we can arrive at a more accurate evaluation of the translocation. It also appears that these phenomena extend the sensitivity of our technique. Thus, in some instances where there was a barely detectable amount of tagged compound in the plant tissue of a section, there was an easily detectable amount in an adjacent fungus colony which would support the conclusion that translocation had extended to that point.

SUMMARY

The work so far has demonstrated the complexity of the problem of formulating and applying effective herbicidal controls for aquatic weeds. It is believed that the study to date has helped in the isolation and/or identification of some of the significant factors involved. Experimental means are available for determining the role of these and other factors separately and in combination as they determine the reaction of the plants to the herbicide.

The rate and direction of movement of radioactive iodine, applied to the plant in the form of 5-I,2,4-D movement in both emergent and submersed aquatic plants have been measured and recorded.

Autoradiograms of both the treated emergent and submersed aquatic vascular plants indicate that the water line, as such, does not act as a barrier for passage of systemic herbicides through the respective aquatic plant systems.

Carefully controlled investigations should give us the better understanding we must have if weed control efforts are to bring about the desired effects in the field.

In conclusion we would like to express our sincere appreciation to Dr. Jessie Fults and his associates at Colorado Agricultural and Mechanical College for their part in the work involving castor beans, and to Messrs. Edward Lyons and William Mercer of the Bureau of Reclamation laboratories for their laboratory assistance.

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IMPORTANT RANGE WEEDS OF THE GREAT BASIN FROM THE ECOLOGICAL POINT OF VIEW

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INTRODUCTION

Had I been preparing a paper under this title for presentation at the meetings of the American Society of Range Management at Boise last week, I should have selected a different group of plants for discussion. The subject assigned me is, "Important Range Weeds of the Great Basin from the Ecological Point of View." From the range science viewpoint weeds are herbaceous, broadleaved plants, sometimes called forbs. But we here today are thinking of weeds as any plants, with the possible exception of fungi and bacteria, which are potentially harmful and undesirable.

We must then consider among the grasses, forbs, and shrubs, as to which are the more undesirable and so the more important, from the standpoint of range users, principally the stockmen.

In passing the Great Basin range vegetation through our line up, we recognize the following as outstanding undesirables.

Shrubs

Sagebrush (Artemisia tridentata)
Rubber rabbitbrush (Chrysothamnus nauseosus)

Forbs

Halogeton (Halogeton glomeratus)
Larkspur (Delphinium spp.)

Grasses

Broncgrass, cheatgrass brome (Bromus tectorum). Many stockmen may object to having broncgrass termed a weed in either sense of the word.

General nature of weed environments

Consideration of weeds from the ecologic viewpoint requires us to think about the reciprocal relations between plants and their environments. How do they alter their environment, and in what ways does the environment influence them? Answers to these questions help understand why some plants are more objectionable than others and give us leads as to control measures.

We see here the familiar duo, hereditary and environment. The weeds have their genetically controlled potentialities as expressed in ecologic life cycles peculiar to each ecotype. Weed environments, on the other hand, consist of factors, all of which interact.

Our task, then, is the examination of the important range weeds in the light of these ecological factors.

Before dealing further with these potentially limiting habitat factors, let us look again at our weeds.

General nature of range weeds

Range weeds waste precious moisture or more precious soil, in addition to being either poisonous, mechanically injurious or merely unpalatable.

The five range weeds previously named all have the tendency to form communities, that is, to group themselves on establishment in new areas. Perhaps this is a good weed characteristic.

If so, may we generalize to the effect that every attribute of a weed which enhances its ability to form communities also makes it potentially more harmful? How then, do weeds form communities?

First, propagules must be moved into a habitat where factors are available at critical stages for germination, growth, and reproduction. Note how these processes are strictly dependent upon the habitat factors. Following reproduction, the grouped seedlings produce families. These families soon become too large for the house (or habitat) and the result is loosely referred to as competition. Successful competition by the weed consists of making the habitat unfit, temporarily, for other plants and results in dominance. The whole process of invasion has been completed - from migration through competition to formation of a community.

Some range weed communities are successional and hence transitory. It is, however, small comfort to today's range stockmen to know that range weed communities are making their habitats less suitable for themselves, and hence will be replaced in time by climax vegetation, provided, of course, that biotic factors (including man), fire, climatic and soil factors are favorable.

Ecology of certain important range weeds

Using the habitat factors: soil, water, light, temperature, atmosphere, fire and biotic with the autecological requirements of migration, germination, growth, reproduction and competition as a framework, let us attempt to work out some of the weed reactions.

Sagebrush in the Great Basin is in two successional roles. It is the climax dominant over most of the area of occupancy. As such, it is the most typical shrub of the northern desert shrub type. Here it can be held in check only by constant efforts against nature. This is certainly not a typical ecological status of a weed.

In its other role, as a subclimax species sagebrush dominates on several million acres where 100 years ago it was absent or sparsely mixed with grasses, forbs and better shrubs. Prolonged grazing has weakened the best forage species and opened the stands to invasion. Here one works with nature in trying to control sagebrush because the climate is more suitable for the original botanical composition.

Sagebrush must be classed as a weed because it is unpalatable to domestic stock. Light utilization of sagebrush indicates overutilization of other species. High competitive ability is another weed character found in sagebrush. The finely branched roots of sagebrush are concentrated in the surface foot of soil where they grow and absorb vigorously during the summer. Sagebrush thus prevents establishment of more desirable plants, or, allowing their establishment, it permanently reduces

their production. Artificial seeding of adapted grasses in sagebrush stands has been proved unreliable by many plot experiments by the Intermountain Forest and Range Experiment Station in the Great Basin. Average success ratings on a scale of 1-10 are given below. A rating of 1 is very poor, 5 medium and 10 represents complete occupancy by the rated species after 4 years. The plots were not paired.

Species planted	Sagebrush undisturbed		Sagebrush eradicated		L.S.D. 5% level
	No. of plots	Mean rating	No. of plot	Mean rating	
Crested wheatgrass	15	2.9	13	8.9	1.5
Bluebunch wheatgrass	9	1.9	11	5.3	2.2
Slender wheatgrass	13	1.4	11	4.8	2.7
Bulbous bluegrass	12	1.5	10	4.7	2.0

Many grasses established by reducing sagebrush competition were found to yield only 1/3 as much after three years, as with complete brush eradication. Grass growing under sagebrush is inaccessible to stock while grass in sagebrush openings has lowered grazing resistance because of sagebrush root competition.

If we return to the beginning of the ecologic life cycle we find sagebrush to be very capable of migration by wind-carried and animal-carried seeds. Hosts of seedlings appear on denuded or disturbed areas when good seed years are followed by good seedling years. Wetter and drier than normal years in the Great Basin usually occur in groups. The seed matures late in the fall and appears to germinate or die the next year.

First year seedlings are at a disadvantage in good stands of grass, either perennial or annual. They either fail to survive the first season or remain dwarfed.

During the second and third year they become deep-rooted without much top development if competing with parent plants. This stage is hard to eradicate mechanically because of flexibility. It is more resistant than older plants to 2,4-D, perhaps because of the slow growth and low top to root ratio. But it has no defense against a ground fire.

Sagebrush begins flowering at 3-4 years after which it is less sensitive to grass competition. Individual plants in rigorous habitats will exclude all vegetation except sagebrush seedlings from an area about 2½ times their own crown projection. Thus, on abandoned fields sagebrush sometimes becomes the sole species.

Height growth may be from 1/4" to a foot per season, depending upon moisture supply. No sprouts grow from roots or stem bases. The three-year-old leaves dry and drop. The species is flammable during the summer and plants never recover from a burn sufficient to kill the leaves. Hail sometimes kills sagebrush by knocking off the leaves. Insects which eat the leaves or girdle the twigs also kill it.

The active mid-summer period of root growth points to a high root respiration rate and oxygen demand. Sagebrush grows only on well-drained ground and readily succumbs if flooded in hot weather. One rarely finds growth rings indicating ages of 100 years but 50 rings are commonly found. Heights of 12' are rarely found as are basal trunk diameters of 12". In the older plants most of the trunk wood is dead and

well preserved above ground, but below ground the dead wood decays. This makes feasible mechanical eradication by disk-type equipment operating at 2 -4 inches below the surface, even in the heaviest brush stands. It also explains the greater effectiveness of rail drags in old stands.

Dense, old stands suffer too much interspecies or intraspecies competition to flower in years of subnormal precipitation. The late season reproductive habit is a weak link in the armor of the weed because of the long period for plowing or burning to head off seed production.

The migration, germination, growth habits, reproduction, competition and survival of sagebrush have been shown to be dependent upon soil, water, temperature, atmosphere, fire and biotic factors of the environment. Manipulations of the factors provide means of control, e.g., fire, water or grazing.

Rabbitbrush

Rubber rabbitbrush affords some interesting contrasts to sagebrush although it is a common co-dominant in the northern desert shrub type. This is the least palatable, most robust and most aggressive of the *Chrysothamnus* species.

Its modifications for migration by air are better than in sagebrush. Disturbed areas such as roadsides, gravel pits, reseeded areas, and burns are quickly colonized. No data are at hand on the suppressive or competitive strength of this weed toward forage species. Such a study would be complicated by the presence of its numerous ecotypes. It does overtop grasses and forbs, making them inaccessible.

The seedlings often appear in large numbers where competing vegetation has been reduced, or soil has been moved. Relatively pure stands are strong indicators of fire. They slowly give way to sagebrush in its climax area.

Rabbitbrush is much more of a pioneer and less exacting in its soil requirements than sagebrush. This is evidenced by a salt tolerance which enables it to grow with greasewood and saltgrass. It occupies dunes ahead of sagebrush and is a first invader behind retreating dunes, and on the infertile bottoms of gravel and borrow pits. Rising water tables in the spring are no hindrance. It is thus one of the species which dissipate valuable ground water.

Stem bases and larger branches have many dormant buds which are awakened by mechanical or chemical injury to the tops. This is a free-sprouting species, at least in most of its ecotypes. Fire is rarely fatal and often results in rabbitbrush dominance. Clean burning followed by dragging, seeding and mowing is effective but not economical except where waterspreading is possible.

Until growth regulating herbicides appeared, no feasible method of controlling it had appeared. Because of the cost of chemical control, a study of control by burning at times of low carbohydrate storage and minimum soil moisture is called for. Until such a combination is found, attempts at control by fire may produce more fire hazard and injury to other vegetation than warranted by the chances of getting a good kill.

Woody range weeds are worse in certain respects than are the perennial herbaceous forms. They are physically more objectionable in pulling wool, hiding or

repelling livestock, or preventing utilization of herbage. Because of their great longevity, replacement successionaly by desirable species as a result of improved management is very slow. An last, special equipment, not commonly used on the ranch, is required for mechanical control.

The Larkspurs

Western species of Delphinium contain over a score of toxic alkaloids. This genus has long been the most destructive on Great Basin Ranges, although sheep and horses are not poisoned under range conditions. Fifteen to 18 species are recognized in the Great Basin. They are perennial herbs. The usual division of the genus into tall larkspurs and low larkspurs is based on stature of the plants and coincides with elevation.

The tall species occur in the moister habitats of higher summer ranges. They commonly grow in definite patches where the soil is moist but well-drained. The larkspurs are often associated with snowberry aspen, sweet anise, gernaum, mountain brome and slender wheatgrass. Their abundance appears to depend upon the presence of suitable habitats more than upon man's activity. However, Sampson found that tall larkspur was less abundant in a 5-year-old exclosure than where grazed during that period. The small -community habit indicates narrow ecological amplitude but this is overcome to a degree by the ecological difference in species.

Low larkspurs are restricted to foothill ranges, being commonest in sagebrush and yellowbrush spring-fall range types. They occur thinly dispersed through the brush, never in dense stands. Prolonged heavy grazing is a probable cause of abnormal abundance. Permanent exclosures on low larkspur infestations would help provide a more definite answer to this question. Sampson recognized a low larkspur as an indicator of the late weed stage of secondary succession.

Larkspur migrates only by seed dispersal. The seeds float on water, which may be of slight advantage to tall larkspur. They are rough, ridged, or frilled in the various species. The seed coats are thin, allowing rapid penetration by water. There is no obvious modification for dissemination by winds or animals. Seeds of perennial larkspurs lose their viability in less than a year unless stored at low temperatures.

Germination is slow, occuring in either fall or early spring. The seedlings are hardy. This is by analogy with cultivated perennial larkspurs.

An important fact about the larkspurs is their early inception of growth and early maturity. They usually have a period of summer dormancy. Heavy woody or tuberous fleshy roots contain the food used to furnish the quick start in the spring. This is the time of greatest danger because of the high palatability of the new growth and scarcity of other forage.

Studies of soil requirements for domesticated species show that larkspurs require neutral to moderately alkaline soil. Good drainage as obtains on sandy loam is essential. Either full sunlight or partial shade are suitable.

Low larkspur matures in June and dries down. Tall larkspur matures 4 to 6 weeks later but remains standing till winter. Neither is dangerous after seed maturity although the alkaloids are concentrated in the seeds.

The perennating buds are below the soil surface and protected from fire. Disk plowing during the dormant period is not effective. Good stands of well-adapted grasses,

such as crested wheatgrass will suppress low larkspur and provide early feed so that other infested parts of the range can be grazed after the larkspur blooms. This method has no promise for tall larkspur because of the smallness and inaccessibility of the patches. Use of helicopters for spraying chemicals on these patches appears more practical on summer cattle ranges, than fencing, hand grubbing, grazing with sheep, herding, salt application, or ground spraying. The larkspurs are moderately susceptible to 2,4-D.

Halogeton

Halogeton, though perhaps not more serious than the larkspurs, is more sensational at present. It stands in contrast to larkspur in being an exotic annual representative of the first weed stage. It is more dangerous to sheep than to cattle, and more dangerous after maturity than before. The toxic principle is soluble oxalate rather than alkaloids. Neither poison is cumulative.

Halogeton has extremely efficient means of migration by seeds of two kinds. The smaller seeds are winged by large calyx bracts which carry them through the air or along the ground in a 30-mile wind at such a rate that they cannot be followed. They also float on water. These seeds are easily detached and will germinate at once. Sixty percent in 7 days produced seedlings $3/4-1\frac{1}{2}$ inches long in December. These seeds must germinate on the surface of the soil as the large, persistent wings hinder covering. They are doubtless responsible for colonization of the many small naturally disturbed areas such as rodent mounds, rabbit forms, ant hills, etc. The larger seeds have reduced bracts, are not wind carried, sink in water and do not germinate when fresh. Four percent germination was obtained in 5 weeks in December. A few of these seeds probably lie dormant for a year or more and thus are responsible for seedling emergence after late summer rains. Halogeton seeds are carried by road equipment, tires, and perhaps on the wet feet and coats of animals. They are compact and readily fall into cracks or depressions in the soil.

The ranges of tolerances of halogeton to pH, osmotic pressure, heat, shade, oxygen deficit, soil texture and drought have not been worked out. Field observations are that it will thrive on soils where sagebrush, shadscale or white sage have been dominant. It grows poorly with greasewood, possibly due to poor drainage rather than lack of tolerance to high pH or high O.P. Its response to heat is rapid growth, given adequate moisture. It is not a shade plant. Its altitudinal limit is uncertain but appears to be near 7,000' at this latitude, length of growing season being the limiting factor. In light-textured soils halogeton roots branch sparingly. It does not pioneer on sands as it does so quickly on clays and medium textures where native vegetation has been killed. The drought resistance of halogeton results from an extensive, wellbranched tap root, a low top/root ratio, high osmotic pressure and low transpiration surface. However, in competition for moisture it has not been observed to crowd out any of the native desert shrubs. After sagebrush, shadscale or whitesage are killed by insects or other agents, halogeton often moves in so rapidly as to be mistaken for the causative agent.

Fire helps more than it hinders halogeton. It is green throughout the fire season. The green plant will not burn while dried plants do so only with added fuel. Large-scale burning of range brush opens vast communities for invasion by wind-borne seeds, and perhaps by the heavier seeds carried on fire suppression equipment. Fire prevention and proper grazing practices are thus of great importance in checking the spread of halogeton by preserving the competitive strength of the perennial cover.

Experiments begun in 1944, south of Wells, Nevada, and continued until 1949 by the Intermountain Forest and Range Experiment Station, show conclusively that crested wheatgrass, on an adapted site under light grazing, can prevent both invasion and reestablishment of halogeton. The similarities in appearance of halogeton and Russian thistle, its close relative, are often noticed. Both are summer annuals. Certain differences are of interest, also. Unlike Russian thistle, halogeton is not a tumbleweed. Its behavior when mixed with bronco grass reveals a greater competitive ability than possessed by Russian thistle. The successional stages on denuded land in northern Nevada are Russian thistle followed by bronco grass which is gradually replaced by sagebrush. Halogeton has entered the sequence at the Russian thistle position but yields ground to bronco grass much more stubbornly than does Russian thistle. Actually, it regains dominance in poor bronco grass years, i.e., when fall precipitation is too late to give bronco grass a good start. Regardless of this changing balance, the climax perennials will replace these annuals providing repeat burns, heavy grazing and other disturbances can be avoided.

Bronco grass

Bronco grass is the only grass that can be considered an important weed in the Great Basin. Ripgut and medusa head are more definitely weeds but appear to lack the ecological amplitude to become a serious nuisance in this region.

This Mediterranean annual, spreading from an unknown introduction 40 - 45 years ago, has become the most common species, represented by more individuals and forming a higher percentage of the range cover in the northern Great Basin than any other kind of plant.

The seeds are carried in wool, clothing, hay and by other agents. A close look at the seeds brings out minor reasons for classing this grass as a weed. The hard, pointed callus makes the dry seeds mechanically injurious in the mouths of stock, particularly sheep. Also the thick lemma insulates the seed from injury by fire but the slender pedicel burns quickly dropping the seed. Seeds are usually produced in such abundance that many are covered by others so that they are able to germinate and take root without a covering of soil.

The seeds germinate within a few days after fall rains as winter annuals. But lacking fall storms until the soil is too cold, the seeds germinate early in the spring. Fall plants furnish some early winter grazing and are rooted better than spring plants which pull up too easily during the main grazing period in April and May. This strict dependence of germination upon a favorable combination of moisture and temperature also carries over into the growth period, producing wide annual variation in stand and volume. Stockmen find it impossible to adjust their stocking rates to utilize bronco grass fully in its flush years. This is all the more difficult because it dries up, and loses its nutritive value by June 1 - 15 at most elevations. It is chiefly of value on spring-fall foothill ranges, where its soil preferences are like those of sagebrush. A vigorous stand of bronco grass indicates a good crested wheatgrass site.

Attempts to keep bronco grass forage from going to waste or from remaining to create a fire hazard have increased the bronco grass. Heavy utilization weakens the perennials and may reduce the seed crop on bronco grass. Nevertheless, sufficient seed is cast for a full stand the next year. Weakened perennials, and especially their seedlings are at a disadvantage in competition with bronco grass because its early growth gives it first call on soil moisture in the upper foot or so.

The difficulty of establishing perennial grass seedlings in bronco grass is evident from the average success ratings of experimental plots planted in the Great Basin from 1936 to 1939 by the Intermountain Forest and Range Experiment Station. On some of the plots bronco grass was eradicated before seeding, on others it was not. The plots were not paired but widely distributed in 3 states. The rating scale is from 1 - 10, ten representing complete occupancy by the rated species. Only 3-year-old plots are included here.

Species planted	Bronco grass not eradicated		Bronco grass eradicated		L.S.D. 5% level
	No. of plots	Mean rating	No. of plots	Mean rating	
Crested wheatgrass	25	3.8	19	7.3	1.7
Bluebunch wheatgrass	17	1.9	9	3.9	2.1

There is concern among range users and managers over the continued increase in this annual grass since we now have more of it than we can utilize. Expressions of concern are heard most during the fire season. Since we have a condition that is growing worse, who or what is responsible? We had originally everywhere in the Great Basin broad perennial types. Annuals were conspicuous only on such local disturbance as game trails and rodent workings. True, they flared up in wet years, particularly those years preceded by several years of subnormal moisture which reduced perennial stands and vigor. The low temperature requirements and short life cycle of bronco grass make it ideally suited to the winter precipitation pattern of the northern Great Basin. Thirty to forty years of grazing had opened up the sagebrush-bunchgrass type to easy invasion when bronco grass arrived in the West. It took full advantage, and where the perennials were grazed out, full possession of the ground floor. Sagebrush remained in control of the second story. The battle is now joined. Each weed has effective weapons. Against the advantages of fire and growth at low temperatures by bronco grass, sagebrush has long life, low palatability and superior competitive ability. But for man bronco grass would have to yield dominance to sagebrush. As it stands now, grazing and fire, abetted by man, are tipping the balance toward the annual type, always more and more a fire type.

Range soils developed under perennial vegetation and what may be called a perennial climate. They developed on rolling to rough topography. A good cover of bronco grass litter or growing plants holds the soil in place and checks runoff almost as well as the original perennial grasses. But bronco grass burned off gives no soil protection. Repeated fires have exposed some of our bronco grass ranges to so much erosion that they appear as barren waste with mustards and a few other annuals the only cover. Destroyer of the soil is the worst accusation that can be leveled at a weed.

HALOGETON CONTROL PLANS OF THE BUREAU OF LAND MANAGEMENT

R.K. Pierson, Chief, Division of Soil Moisture Conservation, Washington, D.C.

Those of us in the Bureau of Land Management responsible for developing and directing a program of halogeton control on Bureau administered lands, feel especially fortunate for this timely opportunity to lay before the membership of your Conference, our initial plans for the control of this insidious pest.

We look to your group as embracing the most important body of experience and technical know-how in western weed control, and we are anxious to have your reactions to the type of program upon which we have recently embarked. We have followed closely the activities of your organization and individual members with respect to research and control of halogeton, and wish to lend our support to your efforts.

No one is more keenly aware of the inadequacies of research and general lack of information on halogeton than we are when struggling to get our control program underway. We had no choice, however, but to press for immediate assistance to begin control operations or face the alternative of increased abandonment of much-needed rangeland. Any further delay will only magnify the disaster that will ultimately overtake our management program and nullify many of the management gains we have made to date.

As livestock are forced from infested range areas, adjacent uninfested ranges are subjected to heavier use thus increasing their susceptibility to invasion. Operators are faced with the prospect of changing to a different class of livestock, making radical and expensive changes in ranch organization or going out of business. Serious as death losses from halogeton poisoning have been to date the most serious threat is the major dislocations in use resulting from the abandonment of infested ranges.

The explosive rate of spread of the past few years made it imperative that we proceed with control measures on the basis of information at hand and not wait for the benefits of a comprehensive research program.

Before outlining the details of our control program, I would like to give you a brief description of the magnitude of the problem confronting us. I'm sure many of you are thoroughly familiar with the present distribution of halogeton in the Western States but, for the sake of those who are not, please bear with me. We have been noting the location of infested areas for several years and in 1950 we estimated that 640,000 acres of BLM lands were infested with halogeton. It was not until last summer that we were able to conduct anything approaching a systematic reconnaissance of the infestations on our lands, and get a more tangible idea of the occurrence on intermingled and adjacent lands of other ownerships. Since that time additional observations have corroborated our survey findings here in Nevada and elsewhere. The latest acreage computations show a total of 884,000 acres of infested BLM lands and 667,000 acres of infested lands in other ownerships, principally private, or a total of 1,551,000 acres. These acreages are distributed among the Western States as follows:

<u>Region</u>	<u>State</u>	<u>BLM Lands</u>	<u>Other Lands</u>	<u>Total</u>
I	Idaho	165,000	115,000	280,000
II	Nevada	385,000	267,000	652,000
II	California	10,000	15,000	25,000
III	Wyoming	85,000	--	85,000
III	Montana	5,000	--	5,000
IV	Utah	234,000	270,000	504,000
V	--	0	0	0
	Totals	884,000	667,000	1,551,000

Estimates have been reported showing considerably larger areas of halogeton than indicated above. These estimates are based mainly on observations in the field and are scarcely comparable to a survey, even of the most casual type. The

fact that known infestations are scattered over a gross area in the neighborhood of 50 million acres tends to exaggerate their area.

The main body of the Inter-Mountain infestation occurs in the northern half of Nevada, the West Desert area of Utah extending northward into several valleys in Twin Falls, Cassia and Oneida counties in Idaho. Outside of the main infestation are numerous spot infestations of varying area and distance from the perimeter. The largest of these occur in Emery and Grand counties in eastern Utah over a hundred miles east of the West Desert infestation. Smaller spot infestation occur along the Union Pacific right of way near the southern edge of the West Desert. In Idaho similar infestation have been found in Minidoka, Power, Jefferson and Owyhee counties. A sizeable infestation exists in the vicinity of Honey Lake, east of Susanville, California. In central Nevada, spot infestations have been found along Highway U. S. 6 and along several secondary roads southwest of Ely. A single isolated spot has been found as far south as Panaca. Recently, the Nevada Halogeton Control Committee has agreed on a line running from Lovelock eastward to Ely as the approximate southern boundary of the main infestation in Nevada.

The Big Horn Basin infestation in northern Wyoming covers approximately 90,000 acres and extends for a short distance into Carbon County, Montana. This infestation is scattered over a gross area estimated at 400,000 acres and is almost confined to the saltsage type. The Big Horn infestation is believed to be of independent origin probably resulting from an introduction paralleling the Nevada infestation. There are numerous local reports of its existence prior to the recorded discovery in 1935, that are not documented by identified collections.

It appears quite obvious that the rapid long-distance spread of halogeton has been caused by seed transported by animals and vehicles along highways, railroads, secondary roads and stock driveways. Intensification of infestations along highways has been accelerated by maintenance equipment and gravelling operations. Added to the acreage previously mentioned is an estimated 1,200 miles of railroad and 9,250 miles of road and highway rights of way in need of immediate control to check further spread into new areas.

Needless to say it is almost certain that further spread will continue within the perimeters of the main infestations before effective control can be achieved. In these areas, halogeton is spreading on so many fronts that it is physically impossible to apply control measures rapidly enough to halt the spread. The most extensive infestations occur on the winter sheep ranges in the shadscale, greasewood and saltsage types. These types occupy the valley floors in the Inter-Mountain region and are separated by mountain ranges relatively free from infestation. At the present time there is no practical method known of controlling halogeton in these types. Herbicides that would effectively eradicate it will also kill the indigenous vegetation leaving the area exposed to complete invasion. In most instances rainfall and soil deficiencies preclude successful reseeding to perennial grasses.

The problem of effective control of halogeton presents the most serious threat to the continued orderly grazing use of Federal rangeland now confronting the Bureau. Its phenomenal latitude in growth requirements enables it to thrive on sites so severe that indigenous vegetation is entirely lacking, or at best persists with extreme difficulty. On more favorable sites, yet having soil deficiencies, it has the ability to invade perennial vegetal cover and seems to adjust its growth habit to the degree of competition encountered. Thus, in saltsage, shadscale or

greasewood types, it may be persisting as a single shoot less than an inch high; or, if competition permits, it waxes into a tremendous, densely branched bush as large as the largest tumbleweeds. In either case, it appears to complete its life cycle normally and literally turns into seed at maturity. Competition apparently excludes halogeton from the most favorable sites unless the vegetal cover is disturbed or removed by fire, overgrazing, or mechanical means. Under these circumstances, it quickly invades the area with all the aggressiveness of its close relative, Russian thistle, and proceeds to build up a dense population within a few years.

The foregoing characteristics of halogeton complicate the problem of devising effective control measures. Ranges appearing to be lightly infested and apparently safe for continued use now, may in a few years become so densely infested that exclusion of livestock is necessary. This observation applied particularly to winter sheep ranges where the disastrous experience in the Raft River Valley of Idaho is indicative of what may be expected elsewhere. On the other hand, the effectiveness of grass reseeding and the recovery of browse plants following non-use in Raft River, provide encouraging evidence of practical halogeton control measures.

Halogeton appears to be susceptible to several of the common herbicides now in general use such as 2,4-D, 2,4,5-T, oils, borax compounds, and chlorates. The choice of an effective herbicide for large-scale use is limited by cost and its effect on the associated vegetation. As yet, there is no specific herbicide for halogeton, which restricts the use of chemical sprays to certain types of infestations. Even so, present herbicides, excepting soil sterilants, can be considered as providing temporary control only, since the treated area in all probability will eventually have to be revegetated or it will be subject to reinvasion by halogeton.

Nevertheless, herbicides have a very real place in the general control program. Highway and railroad rights of way have proved to be the main avenues of spread, and it is here that herbicides can be used to check further spread from the main areas of infestation by reducing the volume of seed available for transport. It is estimated that there are 10,450 miles of these rights of way on which the Bureau will attempt to secure the cooperation of the States and railroads concerned in gaining control of long-distance spread. Herbicides will also be used in containing or eradicating spot infestations until suitable revegetation practices can be developed. The areas surrounding range waters have become important sources of infestation, particularly in Utah, and are adapted to chemical control. Caution must be used in the treatment of these areas to avoid the selection of a herbicide that may increase the palatability of halogeton. Two-4,-D formulations are reported to have this property. Other means for the employment of herbicides may include the reduction of halogeton competition on recently reseeded areas and the control of halogeton on small areas unsuited to revegetation, such as gravel pits, which constitute continuous sources of infestation to adjacent lands.

While at the present time chemical control methods can be regarded as only temporary measures, range reseeding appears to be a practical approach to obtaining permanent control. Unfortunately, the area suitable for successful reseeding does not coincide with the present area infested by halogeton, due to soil or moisture deficiencies, or both. This situation applies principally to the Utah and Big Horn infestations where, in the main, other types of revegetation and control practices must be relied upon. Similar situations exist in Nevada and Idaho; but, generally, there are contiguous areas where successful reseedings can be established to isolate the infestations.

Range reseeding accomplish two types of control: they can be located in advance of a spreading infestation to serve as a barrier to intensive spread; they can be employed to choke out and replace halogeton on infested lands. At both locations they serve the dual purpose of control and production of forage needed for livestock removed from infested lands not suitable for reseeding. For this reason, the location and size of control reseeding is governed by the management requirements of the area. Likewise, the location of protective fencing must correspond to the proper pattern of range use.

In formulating control plans for the Bureau, our thinking has been strongly influenced by the information developed by this Conference, the Land Grant Colleges in this area, and by the research work conducted by Dr. Tisdale and his staff at Raft River. In fact, Raft River has proved to be a gold mine of information on the behavior of halogeton in response to various types of treatment. The area is essentially a winter sheep range representative of the bulk of our infested lands and is therefore useful in predicting probable results on similar areas. Since sheep were forced out of most of the valley in 1945 and 1946, about 20 per cent of the range has had little or no use. The recovery of the native forage plants on the nonuse area is becoming evident while the density of halogeton appears less than in 1945.

In view of the distribution pattern of halogeton on Bureau lands, it appeared that good control strategy should begin with eradicating or containing all of the outlying, scattered spot infestations and concentrating efforts on confining the main infestation within defensible boundaries. Coupled with this effort will be an aggressive program of spraying infested rights of way to reduce the volume of seed available for transport into clean areas. Eventually, it may become necessary to reseed some rights of way with stable, competing vegetation. For permanent control along and within the perimeters of the main infestations and relieve grazing use on them.

The appropriation made to the Bureau to begin a control program in the current fiscal year has permitted the programming of 163,000 acres of control reseeding. Of this total, contracts have been awarded to date for reseeding 89,000 acres. A goal of 100,000 acres has been established for 1952 Fiscal Year funds which may be reached with the acreage of force account reseeding now planned. A goal of 1,200 miles of highway spraying has been set, part of which will be accomplished under cooperative agreements. A large quantity of grass seed, supplies, and specialized equipment has been assembled and an order has been placed for the early delivery of 15 spray rigs mounted on reinforced Jeep trucks. Specifications for sprayers were designed following a thorough survey of equipment in use in weed control programs. All phases of the halogeton program are being readied for an early start in the spring as soon as weather conditions permit.

We are looking to the several State halogeton control committees as a medium of integrating Bureau control plans with the plans of other interested agencies. The effectiveness of the entire control effort is dependent upon interagency cooperation and its intelligent coordination. Logically, such coordination can be most efficiently implemented by a state-level group. An opportunity is also provided for the exchange of information and the coordination of weed control surveys. At this point I would like to discuss further the general need for surveys in relation to the control program.

To date information developed by completed reconnaissance surveys is only adequate to institute control measures in some of the most strategic locations,

particularly where the perimeter is reasonably well-defined. Within the perimeter, large-scale, intensive surveys are needed to establish the limits of infestations, determine the land status, plan effective control measures, and make necessary adjustments in range management. Such surveys will encompass more than just weed control information. Dislocations in range use caused by infestations will require additional data to provide a basis for adjustments in use. It is estimated that probably five million acres, and possibly more, will have to be covered by intensive surveys. Scheduling of intensive surveys will be governed by the strategic position of the area in relation to the general plan of control and by the criticalness of the area with respect to use.

Extensive surveys are needed outside the perimeters to define the limits of known spot infestations and to discover the location of any additional infestations which to date have remained unnoticed. Intensive surveys will be conducted on outside areas where the infested acreage is sufficiently large to require major control operations and adjustments in use. The total area to be covered by extensive surveys will remain indefinite until some progress is made; but, undoubtedly, it will reach several million acres.

Information developed by surveys is essential to the proper orientation and direction of future control planning and will profoundly influence present viewpoints. For example, the total area requiring control reseeding is at present indefinite and will not be known until intensive surveys have been completed and the whole problem becomes better defined. Because of the immense area over which the infestations are distributed and the rapid rate at which halogeton is now spreading, as much as three million acres may eventually require reseeding. It is inconceivable that reseeding will accomplish absolute control even if all suitable areas are reseeded. Halogeton is certain to persist in openings in the stands of seeded grasses and to move by various means across barrier plantings. It is believed, however, that the reseeding will reduce the volume of halogeton to harmless and controllable quantities. In the presence of adequate forage, livestock is unlikely to take halogeton in toxic amounts. Through constant vigilance, modification of livestock movements, and the restoration of the native forage cover to full vigor, the escape of halogeton across seeded strips can be held to a minimum. Infestations originating in this manner should be regarded from the same standpoint as the invasion of noxious weeds on cultivated farm land and quickly eliminated by the range user before they have a chance to become established and spread to new areas.

Infestations in areas not suitable for range reseeding, or having only limited opportunities for reseeding, present a real problem. The Utah and Big Horn infestations fall in this category and threaten even larger areas of arid and semiarid rangeland unless effective means of checking spread are found. A control boundary must be located along a defensible position which may be at a considerable distance from the present limits of infestation. Reseedings will be located in order to take advantage of whatever natural barriers might be present, such as the Great Salt Lake in Utah and high mountain ranges. Some opportunities exist for developing supplemental forage through the utilization of excess run-off and relieving the range where the infestation is gaining a foothold. Modifications in management and excluding livestock from infested areas by fencing will also aid in control. In some areas major adjustment in use and supplemental feeding will be necessary, since continued use at the present rate will only hasten the date of total exclusion. Careful herd management and strict observance of precautionary practices will lessen the impacts of adjustments in use until other control methods can be developed.

In any weed control program there are tremendous opportunities for effective educational work and halogeton is no exception. Because it is relatively new to many people there was an immediate need for materials to assist the general public and range users in gaining a familiarity with it. The colleges have made an excellent response to this need with well-illustrated circulars. The Bureau has made a special effort to inform livestockmen and herders on its appearance and behavior and to be on the alert for new infestations. Since we are resigned to the fact that halogeton is here to stay, the next fruitful field for education lies in disseminating information on range practices that will enable us to live with the residue that cannot be eliminated. Much as we hope to be successful in our control programs, ultimate maintenance of control below dangerous amounts will depend upon the cooperation received from range users.

In summary, I wish to emphasize that the Bureau is gravely concerned over the loss of range resource and livestock that halogeton has caused and the potentialities for a major disaster that it threatens. We are fully aware of the deficiencies in basic information on control but are confident of the soundness of available empirical approaches which circumstances have forced us to choose. The Bureau will pursue these measures with diligence while looking to the research agencies for new and improved control measures as they are developed. We are anxious to integrate Bureau plans for surveys and control with State and local agencies and to lend support to unified control programs. Finally, we hope to continue our cooperative relationships with those in the educational fields for therein lies one of the permanent solutions for coping with this problem.

THE WEED CONTROL PROGRAM ON IRRIGATION SYSTEMS

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Weed control is one of the major items of the operation and maintenance budget on an irrigation system. Many irrigation districts report weed control costs of 20% average of the total O&M budget. Even with this high expenditure most irrigation districts report that the weed control program was not adequate for good control. Why was more progress not made? Some of the reasons are as follows.

1. The budget, even though high, was not sufficient to cope with the situation.
2. The problem was attacked at the wrong places and at the wrong time. There was a tendency to wait until the problem became serious before something was done.
3. Specific items in the budget did not receive sufficient consideration. Too much money being spent on ditch cleaning and other items but insufficient amount for actual control of weeds.
4. Probably too much planning and too little doing - waiting for the miracle one-shot control and in the meantime doing nothing.
5. Adverse to changes in methods of control and operation.
6. Spreading the program too thin instead of concentrating the control efforts.

If the job of weed control on irrigation systems is to be done right, it must be one of action and it must be adequate.

The first step in starting a weed program on irrigation systems is to evaluate the problem. This is accomplished by making a survey of the weed problems. This survey should include the noxious weeds of the area, the common weeds of economic importance, and the weeds that cause operational and maintenance difficulties. This includes the land and water weeds. A Canal superintendent is usually concerned about the weeds that cause operational and maintenance difficulties and as a rule has done something about them. Water must be delivered and anything that interferes with that delivery is corrected regardless of cost. The weeds in the first two groups are generally neglected. It is in this group that the program must be expanded.

The next step is to evaluate the present control program and examine the physical features of the system. Is the present program adequate? Is it doing the job? What new methods can be adapted? How much money will be needed to do the job? How long will this accelerated program run before benefits are received? What new equipment is needed? What is the condition of the service road? Are they adequate? These and many other similar questions must be answered if a new program is to be initiated.

The third step is to initiate the new program. This must be more than just a plan. It must be an active and adequate program with sufficient money budgeted so that the new program can be carried on for 3 to 5 years. At the end of this period, benefits will accrue so that at this point a reduction in the budget should be possible. The program should then continue with a reduced but sufficient budget to do the work properly. In relation with the action program, test plots must be conducted so that better and cheaper control methods can be found.

In general, the kind of weed program that is planned, will depend on the age of the irrigation system. On a brand new system it will be primarily a program of prevention. On an old system before much can be done, the system must be repaired and put in order and then a control program can be started. As a rule, service roads will have to be repaired or built. Without them the cost of controlling weeds is excessive. The control efforts must be focused at the top of the system first and then followed progressively downward through the system. While this is in progress the bottlenecks that occur must not be overlooked. By controlling the weeds at the top of the system, the points of reinfestation are eliminated for the lower parts of the canal. By eliminating or correcting bottlenecks the full flow of water can pass through the system and thus deliveries can be made on schedule.

To properly conduct a successful weed control program, requires the cooperation of all parties concerned. This can be accomplished by the formation of a weed control district or by working together as a committee. By concentrating our efforts on specific weeds we can do a better job of cleaning up the troublesome pests. It is a well-known fact that the financial stability of an irrigation district is based on the financial status of the individual water users. So if a community or area is to prosper, it must give careful consideration and full support to a district-wide control program.

How much money can be spent for weed control on irrigation systems? This will depend upon the scarcity of water and the kind of crops grown in an area. Where water

is plentiful any loss of water due to weeds is only worth the cost of the water, usually \$3.00 to \$5.00 per acre foot. Whereas, where water is scarce, any loss of water due to weeds is worth the value of crop grown under irrigation less the value grown under dry farming. This approximates \$75.00 per acre foot of water. Hence, you can see that from an economic standpoint more money can be spent for weed control on systems where water is scarce and crops are of high value.

There is another aspect to this problem that must be considered. New irrigation districts must go through a period of development. It may take 10 to 20 years before a district utilizes its full water supply. Hence, during the early years of development it is necessary that a prevention control program be conducted so that the weed problem would not be serious at the end of the development period. This calls for a larger expenditure than is justified on a short time economic basis.

The control of weeds on irrigation systems is thoroughly discussed in the Bureau of Reclamation bulletin, "The Control of Weeds on Irrigation Systems" and many of the methods can be seen in the Bureau's new weed film. So instead of going into the usual discourse of general weed problems and their control, a discussion of our problems in California on the Central Valley Project might be more interesting.

Summer annuals appeared on the canal banks the first growing season. These were primarily Russian thistle, wild lettuce, five hooked bassis, chenopodiums, and similar weeds. These weeds, aside from being a nuisance to the operation of the canals, were also important from an economic standpoint to the farmers. Russian thistle is the host plant to the beet leaf hopper that spreads a virus disease to sugar beets and tomatoes. The wild lettuce is the host plant to the white fly or bean thrip that causes damage in beans. Our immediate solution was to use chemical control. Tests were conducted to use dinitro selectives but results were poor. The amine form of 2,4-D at the rate of 1 pound in 75 gallons per acre gave excellent results when the weeds were very small. Later in the season contact sprays were used satisfactorily. Since 1949 we have cooperated with the California State Department of Agriculture, Bureau of Entomology, in the control of Russian thistle along the Delta-Mendota Canal. This arrangement has worked satisfactorily and the thistle has been greatly reduced in the areas treated.

The use of chemicals to control the summer annuals was effective but only as a stop gap measure. For more permanent control a grass cover was necessary to provide competition for the weeds and to stabilize the canal banks against erosion. The two major canals, the Delta-Mendota and the Friant Kern, pass through many miles of range land. The dominant cover is primarily wild oats. This is the climax vegetation for this area of low rainfall and high summer temperatures. Wild oat seed was not available but barley seed was, and a lot of it contained wild oats. All lots of seed were cleared through the County Agricultural commissioners before any seeding took place. We have used four stages of seeding from the ancient to the modern. We have seeded by hand, the breast broadcaster or belly grinder, the powered side broadcaster, and by helicopter. Seeding costs for broadcasting are about \$4.00 per acre. On banks that have been compacted harrowing is necessary and this increases the cost per acre by \$4.00. This past fall about 2500 acres were seeded.

In connection with the seeding program 2,4-D spray is used for two years to help eliminate the broadleaf weeds. Ground rigs have been used primarily.

During 1951 we used both the aeroplane and helicopter in applying 2,4-D. This permits us to get the job done in time before susceptible crops are planted in the area. Aeroplanes are satisfactory on straight line flying but along the canals the helicopter has been more satisfactory. On the Delta-Mendota Canal about 1300 acres were sprayed with 2,4-D at a cost of about \$4.00 per acre.

During the summer months the annual grasses and grain are dry and present a serious fire hazard to the wooden structures. Sterilants containing mixtures of borates and chlorates are used to make fire-break strips. Other structures are also kept weed free by using sterilants. For several years we have worked with Dr. A. S. Crafts of the University of California in testing crude or grey arsenic for a cheaper and more permanent type of sterilization. This work is being continued. We are also testing T.C.A. and C.M.U.

We are fortunate that the plant succession cycle has been worked out for our area. If the native range is over grazed or continuously farmed if the practice is continued the vegetation will farther shift to summer broadleaf annuals. Then if the range is allowed to come back the summer annuals will disappear and be replaced with winter annuals. These eventually will be replaced by the annual grasses, chiefly wild oats. The construction of the canals changed, with each bucket of earth, the vegetation from annual grasses to summer annuals. By seeding and using 2,4-D we are attempting to speed nature and shorten the period it would take for the vegetation to shift from summer broadleaves to annual grasses. We also realize that if the annual grass cover is disturbed by graders, discing, over grazing, or continuous annual burning, the summer weeds would appear again and the weed problem would be increased.

Noxious weeds were inherited at several locations when the right-of-way for the canals was purchased. No control was attempted until the canals were completed. The noxious weeds found are alkali mallow, morning glory, Russian knapweed, Johnson grass, Bermuda grass, white horse nettle, and puncture vine. The first year after the canals were completed, seed formation was prevented as much as possible by the use of contact sprays and by mowing. Sterilants have now been applied and it is expected that good results will be obtained. The noxious weeds are not well established and their control should not be too difficult.

Another problem that we were faced with was the development of a spray rig for ditchbank work. The size of the rig and the boom were the two factors we were concerned with most. As a result of this study a formula for calculating output of spray rigs for 2,4-D ditchbank spraying was developed. The factors included are length of boom, speed of rig, rate per acre, size of tank, rate of refill, time worked, and the efficiency. This information was presented at the California weed meeting in San Luis Obispo on January 23, 1952. It should prove valuable in the development of proper size equipment for doing ditchbank spraying efficiently.

Some mechanical developments resulting from our work are as follows:

1. A crank and screw arrangement for controlling the height of the boom.
2. A boom base attachment.
3. A new boom frame structure built from a standard T.V. antennae aerial support.
4. Reversible electric motor to operate the boom by push button control.

The man responsible for this development is J. P. Jeffers, our Delta District weed specialist at Stockton.

Regarding size of rig - I believe a 350 gallon tank mounted on a Dodge Power Wagon is about right. There isn't much advantage in using a larger rig unless high rates per acre are applied (150 gallons or more per acre) or distant to water or oil are great. The Dodge Power Wagon makes a versatile rig and can operate under difficult conditions. For small canals a tank size of 100 or 150 gallons should be satisfactory. One thing apparent about spray rigs for ditch-bank spraying is that they must be built to fit the conditions of a canal system.

We are also interested in having our water users control weeds on their distribution systems. An educational program is in process of development in cooperation with the California Extension Service. In most cases, weed surveys have been conducted and the information has been presented to the water users, County Commissioners, and the Extension Service. Several of the districts have activated control programs.

In closing I would like to leave this thought with you. The lifeblood of Agriculture in the West is water. Water that is stored behind dams and delivered to parched land through systems of canals. It is costly water and every drop must be conserved. Of the many problems facing a canal superintendent weed control is one of the biggest. We can do our part by finding cheaper and better ways of controlling weeds, so that the lifeblood does not become a trickle but a river that will make our West even greater than today.

DEVELOPING HERBICIDAL FORMULATIONS

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This opportunity to talk to you about agricultural chemical formulations is sincerely appreciated.

Rarely can one take a chemical as such and apply it as a herbicide. The natural form of many such chemicals is a big water-insoluble chunk, a sticky syrup or a dusty powder. Usually diluents and conditioners must be mixed with such chemicals to make products which are more convenient to use in application equipment. Finding the most desirable mixing ingredients from the chemical, physical and biological standpoints is a job for formulation research. This talk will point out a great many of the formulation studies that should be done with a chemical before one sees it as a convenient and practical wettable powder, paste, water-soluble salt, dust, aerosol, or emulsifiable liquid.

Formulation work is necessary in three stages of development of agricultural chemicals: The initial stage for screening and exploratory programs; the intermediate stage for further evaluation of the best chemicals and finally, intensified formulation work to produce a salable product. At the initial stage a standardized formulation which is practical for the end use desired is worked out by the cooperative efforts of the people involved in the screening programs. When promising chemicals are found, compounding development work is done on each specific chemical to allow the biological groups to evaluate it in a number of different ways. Derivatives such as esters, salts and others are studied. Various additives and solvents are

investigated. In this way one learns, for example, that 2,4-D esters are more toxic than their salts under certain conditions.

Formulation work is intensified for chemicals which are considered worthy of field experimentation. A number of primary objectives become important. Several good compositions are necessary so that field evaluation can be expedited for the purpose of learning desirable formulation modifications from a biological standpoint. However, they must be good, usable ones because the progress of field research cannot afford to be hindered by formulations which are chemically or physically unsound. Research with adequate formulations makes it possible to develop a potentially salable product early in the field research program. In this way the development work which follows will not have to be repeated as a result of a last minute change in the formulation.

A major objective is to have all concentrates contain the maximum amount of toxicant consistent with satisfactory composition and practical usage. It is often desirable to strive for the most economical formulation consistent with these objectives. Therefore, many different solvents, emulsifiers, wetting agents, and other so-called inert ingredients are tried to be reasonably certain that the best practical choice is made for each from both a physical and biological standpoint. Usually it is essential to have second and even third choices for each inert ingredient in case of supply difficulties.

When selecting solvents the formulator must be certain the ingredients remain dissolved at low temperatures. Even in California, formulations freeze. Sometimes a user doesn't realize that part of the contents in a container is frozen until most of the liquid is out and the can still feels heavy. This partial freezing is often a problem with liquid formulations because of the basic way in which most of them are made. Usually the active ingredient is a solid dissolved in a solvent with other compounding ingredients. As the temperature decreases there is a point at which the solid theoretically begins to crystallize out. As the temperature further decreases, more and more toxicant comes out until often the liquid phase is very dilute as far as toxicant goes. The solid that comes out is nearly always pure toxicant which may have a fairly high melting point. Thus it is not enough to simply warm the contents up to 20 or 30°F. or whatever is stated as the minimum specified temperature on the label. Big crystals that often form in freezing formulations are difficult to dissolve, particularly in a nearly saturated solution. To do a job the drum should be warmed up to summer temperatures, being careful of a possible fire hazard. Then vigorous agitation may be necessary for several hours. Some toxicants may have a relatively low melting point and melt when warmed up. Then the solution job is much simpler because it is only a matter of mixing. Although vigorous agitation with a stick or rolling the drums often does a fair job, to be really efficient one pumps the heavy liquid from the bottom and dumps it at the top of the drum until a constant specific gravity is attained.

How does one tell if the contents in a drum are partially frozen? Probing with a stick usually gives the answer. By this technique one often runs into the problem of supercooling. That is, some drums may have solid in them and others from the same batch won't. This situation results because crystals are built up from dissolved molecules which build up on top of one another like a bricklayer building a chimney. If there aren't any nuclei of crystals started for a foundation the solution may cool considerably below its freezing point and still show no precipitation. Sometimes a little shake is enough to push a few molecules together and start crystallization. Very effective is a stick which is moved from a drum having crystals to one which hasn't because it usually carries a few crystals

which act as seeds to start the crystallization process.

A formulation which has good low temperature stability isn't the only physical consideration. For example a typical problem arose with isopropyl-N-phenyl carbamate or IPC. Some of the best solvents for this product are also soluble in water. What happens when a concentrate is made which carries as much IPC as is soluble at 20°F. or some low temperature with such solvents? On dumping in the spray tank, the solvent dissolves in the water and the IPC crystallizes out. Often the crystals get so big they clog screens and nozzles. Such troubles can be overcome by making less concentrated formulations with non-water soluble solvents. Another technique is to mix diesel or another oil with the concentrate before adding it to the spray tank. The oil will hold the IPC as an emulsion instead of letting crystals form.

The possibility of using two separate materials for a single purpose spray is sometimes desirable. To be sure, it is inconvenient for the user. However, in the case of an emulsifiable concentrate of dinitro-o-sec butylphenol it is desirable. The product is very concentrated to lower shipping and handling costs. Furthermore it allows for a more versatile use of the formulation. To kill young broadleaved weeds, it can be used by mixing with water alone. For grasses and tough old weeds it is desirable to mix a small amount of oil with the concentrate and water to accomplish the desired kill. In other words, the amount of oil needed varies with the problem.

Many organic herbicides are made into emulsifiable liquid formulations. However, there are so many different emulsifiers on the market that it is almost impossible to evaluate them all. Because there is so much competition the manufacturers are constantly bringing out better ones for specific problems and the spiral goes on until the formulator often wonders when to stop. Theoretically an emulsifier must do several things. It should make the liquid composition break up into very small droplets of desirable size and then keep them apart so that they won't coalesce and either sink to the bottom or float to the top. To be most efficient it must orient itself at the interface or boundary between the oil and water. This means that the emulsifier molecule as a whole must not be very soluble in either water or the composition. It is not hard to compromise on low water solubility. However, it isn't always easy to get an emulsifier which is soluble enough in a liquid composition so that it won't separate out in cold weather yet is insoluble enough at working temperatures so that most of it stays at the surface where it can do a job and not stay lost in the middle of the oily droplet.

There are many materials added to emulsifiers and compositions to achieve the desired ends. Two or three emulsifiers may be mixed together. Extra solvents called coupling agents sometimes are added to the emulsifier to make it more soluble in the composition. When the composition is dumped into water the coupling agent often goes into the water phase and the emulsifier is left stranded at the interface where it is needed.

Another technique used in making emulsion concentrates is to adjust the solvents so that the composition has the same specific gravity as water. Then when it is mixed with water the droplets will tend to stay suspended in the water even though they are too large to be kept suspended by Brownian movement or the moving water molecules.

It is not enough to find good emulsifiers on the basis of chemical and physical evaluations alone. Field men must help in developing compositions by

determining the optimum amounts and most synergistic emulsifiers from the practical biological toxicity standpoint. Their problem is much more complex than the chemist's. There are so many factors that compromises are usually necessary. For example it is known that some leaves wet easier than others. Even for a single plant the ease of wetting often depends on the age of the leaf, seasonal weather conditions and the previous things it may have been treated or contaminated with including dirt dust. This factor is correlated with the type of application equipment used, the volume of spray used, the amount retained, the amount that drips off and the amount of spreading. The problem is quite complex even for a single plant let alone the fact that most products are used on many weed species and often mixed with other products in the spray tank.

The chemist becomes further involved in this problem by collecting leaf samples at various time intervals from plots for chemical analyses and microscopic examination. The chemical residues are correlated with biological activity and resistance to weathering.

Detergents and soaps are not the only wetting agents. For example, you know that ammonium dinitro-o-sec-butyl phenate (DNOSBP) is a good selective spray for control of annual weeds in peas. However, when 10 percent oil was added to a batch of ammonium DNOSBP it was found that the toxic action was increased 10 times. Analysis for DN immediately after treatment showed that the peas retained 3 times as much ammonium DN from the oil emulsion as from the straight water solution. Incidentally the same experiment on mustard showed that the toxicity was also increased 10 fold by the oil but in this case no more was retained so that it is assumed that the increase in toxicity for mustard is probably an increase in wetting and penetration while for the peas it was wetting, retention, and penetration.

The spray volume for a given quantity of herbicide per acre is often of considerable importance. Using sodium MCP in white charlock, English workers learned that optimum spray volume was around 33 gallons per acre. However the optimum volume varies with different plants, their condition, state of growth and the weather. Of course one also has to consider what volume is safest to the crop plants. Formulation-wise there are stumbling blocks to how concentrated a spray one can make with a given formulation. Sometimes a material simply isn't soluble enough to use in low volume and some other derivative and formulation must be used.

The formulator must keep the application equipment in mind. Formulations that work fine in paddle agitated tanks might look mighty deficient in a tank with only a bypass system. Those of you who use formulations help us a lot by supplying us with information about the trends in application equipment. For example the use of airplanes has increased the last few years and the trend has been to use more and more low-volume sprayers instead of dusters. We are also told that more and more low-volume sprayers instead of dusters. We are also told that more and more low-volume, automatic, air-blast, ground sprayers are being used. Usually formulations must be modified to keep pace with such developments. For example, hard water precipitates must be avoided in low volume equipment. Wettable powders must be soft and ground fine to give better coverage and to reduce orifice corrosion. More concentrated formulations are usually preferred. A good old product may fall by the wayside if it isn't reformulated for new equipment and uses.

An extremely important phase of compounding work is the storage test. The effect of iron, water and heat must be studied with various impurities to learn if any of these catalyze its own decomposition and that of the containers. If iron containers are inadequate, other containers or inhibitors must be found. From experience it is desirable

to have at least a year's aging data under a variety of conditions for any product which is sold. Only in this way can we recommend proper containers and be certain that a product will have an adequate shelf life.

As in other phases of formulation work it is most important to know what and if possible how many impurities are contained in the products being studied for shelf life. Otherwise one can get fooled quickly and report erroneous conclusions. One very treacherous impurity is a trace of water in the formulation. In many chlorinated products, corrosion is due to the formation of hydrochloric acid by water hydrolysis. Temperature is also critical in such studies because it regulates the amount of water which dissolves in the product. With a given concentration it is possible to get severe corrosion at one temperature and none at another. Thus with this one variable alone, it is necessary to study a wide range of known water contents at several different temperatures before reliable conclusions can be drawn on water tolerance.

Sometimes emulsifiers have additives such as coupling agents, which may act as corrosion catalysts in certain compositions. For this reason it is essential to run aging tests on any changes in emulsifying agents or other raw materials despite the fact that the performance of a freshly prepared formulation may look better than the old one and production departments are applying pressure for approval.

Physical and chemical compatibility with other formulations is still another factor to study before putting a product on the market. It is often desirable to mix two or more formulations in the same spray tank. The pitfalls are many. Later the desirability of mixing powders with water in the spray tank before adding oils will be discussed. Sometimes even this technique fails to work because some ingredient like certain wetting agents or emulsifiers tend to stick the powder particles together and much of the active ingredient may end up in a gooey mess on the walls and bottom of the tank. Accordingly the compatibility of wetttable powders must be studied with various oils to make certain that the wetting agent used is satisfactory in this respect.

The research work all leads up to a potentially salable formulation which must maintain a standard minimum uniformity when manufactured for sale. Therefore, finished product and raw material specifications must be developed. They should be simple enough for rapid control procedures yet adequate to cause rejection of batches which are below normal in any respect. Specifications are an important compounding problem which have any ramifications. The problem would be simplified by using absolutely pure raw materials. This is not a practical solution to the problem since technical materials are less expensive. If technical chemicals are used it becomes desirable to have analyses which show exactly what the impurities are. To carry things to the extreme we would obtain samples of all these impurities and set up a number of variations and combinations of each with the pure toxicant. These variations coupled with variations in the inert ingredients might amount to thousands of separate combinations. Naturally some compromises must be made. From experience one frequently can predict impurities which might cause trouble. To illustrate the point, a typical example may be cited. A formulation of the isopropyl ester 2,4-D was developed which usually worked very well but the emulsifier partly precipitated from certain batches. It was finally learned that isopropanol acted as a coupling agent to solubilize the emulsifier and that many batches of isopropyl 2,4-D had enough of this impurity to hold the emulsifier in the formulation. The field men are also involved in the specification work, particularly in regard to biological side effects resulting from impurities.

It may be worthwhile to discuss some ways in which users of formulations have overcome some of their shortcomings. Most wettable powders and emulsifiable formulations are best added to the practically empty tank which is then filled with water while continuing the agitation. When oil is to be used with a liquid concentrate as is the case with a dinitro-o-sec-butylphenol concentrate it is best to mix the formulation with the oil and then add the water with agitation. However, with some kinds of emulsifiable liquids it is possible to obtain an invert or mayonnaise type of emulsion when the amount of water used to dilute it is not much greater than the amount of concentrate. In these cases it is better to add the concentrate last unless you want such a water-in-oil emulsion.

Sometimes users have trouble when oil or any liquid is used with a wettable powder. The oil seems to make little pasty balls out of the powder and these in turn clog screens, nozzles, and build up on the tank walls. Usually trouble is avoided if the powder is added and thoroughly dispersed in the water before the oily material is poured into the tank.

Excessive foam in the spray tank is another complaint of herbicide users. Formulators can often minimize such problems by using different wetting agents and incorporating antifoaming agents in the product. However if one is confronted with a foaming problem in the field there are a number of things that can be done. Certain commercial antifoaming agents are very good. If these aren't handy, a pint or two of diesel oil on top of the tank does a lot of good. Incidentally, kerosene is more efficient than diesel oil, and gasoline is still better, but it has a definite fire hazard. The manner of adding the concentrate to the spray tank is important. Waiting until paddles are covered with water before adding a bad foaming formulation to the tank will tend to minimize the amount of foam formed. Sometimes it is possible to reduce the degree of agitation and thus decrease foaming troubles.

Variations in water in different areas of the country are often important factors in the way formulations perform. In very hard water many chemicals form water insoluble calcium and magnesium salts to clog screens and cut down the activity of the product. Such problems are usually overcome by incorporating a sequestering agent in the formulation which ties up the calcium and magnesium ions as water soluble compounds. If precipitates form with compositions one uses, there are a number of water softeners such as the polyphosphates and ethylenediamine tetraacetic acid that can be added to the spray tank before adding the herbicide. The use of these materials in the right concentration should considerably reduce hard water precipitates.

In liquid compositions that are measured out by volume for use in the spray tank it would seem desirable to follow the system used by many for liquid 2,4-D formulations. The pounds of 2,4-D acid equivalent per gallon are shown. To be sure, this doesn't assure the user that one product won't be more effective pound for pound of active ingredient than another. For example the copper content of fungicides is not correlated with effectiveness according to Dr. Horsfall of Connecticut. Some may be formulated to make the active ingredient more effective. However, it does make products easier to compare. For example, one having 50% active ingredient and weighing 8 pounds per gallon would have 4 pounds of active per gallon. Another having heavier solvents may weigh 10 pounds per gallon. Thus the same four pounds of active material would only show 40% active on the label despite the fact that both compositions have the same amount of the chemical wanted.

All this points out that there are many variables to consider and evaluate in the laboratory and field before one can be certain that he has a practical herbicidal formulation.

WEED CONTROL IN NORTHERN EUROPE

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This past summer I had the good fortune of being invited to participate in an international crop protection conference which was held at Fernhurst in Surrey, England, in connection with the Festival of Britain. This conference was organized and sponsored by Plant Protection, Ltd. of London, a commercial organization that is the European leader in formulating and developing insecticides, fungicides, and herbicides, and an organization which is unique in the field in the extent to which it has carried on extensive basic research, extensive field testing of its products, and an educational program to develop uses for its product in every country in the world. I am confident that no other single commercial enterprise would, or could, have undertaken the organization of a conference of the type held at Fernhurst, and which brought together entomologists, plant pathologists, physiologists, and weed control specialists from practically every country in the world. Not only did they organize and carry through the formalities of the conference; but they housed, fed, entertained, and provided transportation for the entire conference group for the week or more that the delegates were in Great Britain. As an example of the scope and efficiency of operation of Plant Protection, Ltd., they provided for the conference, and from their regular office staff of employees, men who could fluently handle the languages of delegates from all corners of the world and representing all of the romance languages, Hebrew, Russian, and a number of Asiatic and African native dialects.

While in Britain I took advantage of the opportunity to visit a number of agricultural experiment stations, universities, and actual farmer's operations, and also extended the advantage to visit agricultural experiment stations in several other north European countries.

The northern European countries have weeds and weed problems very similar to those which we have in the northern states, and in this region are quite comparable to those of the Pacific Northwest with a few exceptions. Canada thistle (C. arvensis) and quack grass (A. repens) are present throughout the area. Canada thistle easily ranks first as their most serious perennial weed species. I noted a great deal of variability in Canada thistle, even in localized areas. Individual clumps or clones of this weed varied greatly in height, leaf type, and vigor within the same pasture or enclosure. I should add that Canada thistle in northern Europe is almost exclusively a weed of meadows and pastures and was seldom observed in cultivated crop area. Having had long experience with field bindweed (C. arvensis) I was particularly interested in noting its extensive infestation in the northern European countries. I noted field bindweed in Ireland, England, Sweden, and Denmark; yet never did I see it in stands, or vigor, that represented any real competition to cultivated or forage crops. Throughout the area field bindweed lacks the vigor in growth and development that has made it such an important weed species in the western part of the United States. In fact, the most vigorous plants that I saw were growing in a garden of Windsor Palace where I collected and preserved a plant in full bloom. Other perennial species found throughout the northern European area are ox-eye daisy (C. leucanthemum), dandelion, several plantains, and sheeps sorrel (R. acetosella). Due to the fact that most of the soils in northern Europe are highly acid, the latter species, and several perennial buttercups, (Ranunculus spp.) are universally present in meadows and pastures.

In common with the northern areas of the United States, and in Canada, wild oats (A.fatua) is at the present time a serious pest in cultivated crop production from Sweden to Ireland. As here, this weed is responding to control methods very poorly and a number of their weed research men are placing major effort on its control at the present time. Annual grasses, other than wild oats, are not as much of a problem in the northern European countries as they are in the States. Our most troublesome northern species, such as Setaria and barnyard grass (E.crus-galli), were observed only as incidental species, and in no area were they reported as being a serious problem. In the southern areas of England and Denmark, crabgrass (Digitaria spp.) and Panicum spp. are a considerable problem, but not to the extent that we have in the central and southern states.

The annual broad leaved species found throughout northern Europe are almost identical in association, and seriousness as a problem in crop production, with those of the eastern and western coastal states, here. A list of the most troublesome weed species which I have attached as an appendix to this paper, will read very much like that found in "Weeds in California".

We have for many years heard much of the highly intensified and highly developed systems and rotations used in agricultural production in England, Sweden, and Denmark and it seems reasonable to assume that this high level of husbandry would, over a period of years, entirely eliminate weeds as a factor in crop production. I was quite surprised to find; in these countries where in certain localities the intensity and refinements of crop production have been developed to a degree far beyond anything that we have in the States, that many of our common annual weeds were still a major factor and consideration. I am convinced that regardless of intensity of cropping or efficiency of cultivation; and in spite of heavy input of hand labor, weeds will always be a problem in agricultural production conducted on any reasonable scale of operation. In connection with these observations, it was interesting to note that through long periods of intensive cropping to the best adapted crops in limited areas, that a definite weed association had developed with the culture. A good example of this development was evident in the winter wheat producing area in the rolling hill country, - country very much like the Polouse area in Buckingham and adjoining counties in England. This area has very heavy clay soils underlain with chalk and wheat fields in the area are perennially and solidly infested with goosegrass (Galium aperine). I know of no other area in my experience where this species is the major pest on cultivated land. In the Buckingham area it has become established through several hundred years of intensive wheat production and certainly is a major problem with farmers in that area. This weed is highly resistant, or tolerant, of the action of the growth promoting substances and its control is most successfully undertaken with sulphuric acid sprays. The selective dinitro compounds are intermediate in their efficiency as herbicides. During the past several years with sulphuric acid in limited supply, this weed has become a limiting factor in wheat production in this quite extensive area. Outside of this quite sharply defined area, goosegrass was noted only as an incidental and occasional species.

A conspicuous feature of Ireland, England, and the Scandinavian countries, is the formal appearance of forest woodlots and hedge rows. Woody plants as weeds are not a problem in any of the area that I observed, except perhaps in the western part of Ireland, Wales, and Scotland on rough and rocky terrain where gorse (Ulex europeans) covers extensive grazing areas. The only evidence of control measures for gorse was occasional burning, which is undertaken in late spring and before the gorse has developed flower buds. These measures are usually employed only on the margins of gorse infested area and appear to be highly successful in limiting the range of this woody species. I did not have explained to my satisfaction the causes, or reasons, for the lack of brush and seedling woody plants along hedge rows, woodlots,

and forest plantings in England and Ireland. The extensive vast forests of the northern and central areas of Sweden are so carefully managed or "farmed" that weed species such as alder, weedy birch, dogwoods, hazel, and even the less desirable commercial species, are so efficiently controlled or eliminated that the forests look like city parks. I should add that through Denmark, England, and Ireland, hazel and elm are commonly used for hedge rows, are heavy seed producers, and yet I found no evidence of seedlings of these species becoming established as weeds. The seasonal distribution of rainfall in the areas, and the climate in general, is conducive to year round growth of perennial grasses, and undoubtedly the competition of the grass prevents establishment of trees or brush seedlings in meadows and pastures. This does not explain the absence of these shrubs as weeds along canals, ditch banks, and roadways, where they become a major pest in the States and Canada.

I was particularly anxious to observe the research and practice in weed control of the northern European countries in order to rationalize, or justify in my own mind, their almost exclusive use of MCP rather than 2,4-D as a selective herbicide and also to discover why rates of application of either MCP or 2,4-D are so much higher; --in Great Britain in particular, than in the States and Canada. While these were my major objectives throughout my trip through northern Europe, I am yet not entirely satisfied with the explanations that I derived in talking to research people, to commercial formulators, and to farmers who had these materials in field practice.

Why is MCP more widely used in northern Europe than is 2,4-D? In the first place, MCP was first discovered by British scientists and was in commercial production and field use in England before 2,4-D was widely used here. Northern European commercial formulators are in a better position on cresol than are American formulators and this is a basic material of MCP; phenol in shorter supply in Europe, is a basic ingredient of 2,4-D. In the second place, MCP is doing an excellent job of weed control in the northern European countries and research people and farmers are in general convinced that it is safer to use on a wide variety of crops and weeds than is 2,4-D. Legumes such as clovers, peas, and beans are universally grown and commonly underseeded in cereals and flax in the northern European countries and the British, Swedish, and Danish scientists early found that the legumes and flax were more tolerant of MCP than 2,4-D. Our recent promotion of the use of MCP here in the States and Canada for control of weeds in flax and grains underseeded with legumes justifies this wide acceptance of MCP in Europe. Another factor that has entered into the wide distribution of MCP is that its sodium salt is generally more soluble in water of a wide range of hardness than is the sodium salt of 2,4-D. To the British manufacturer a sodium salt of 2,4-D or MCP is the most economical formulation to produce. Amine or ester formulations are definitely more expensive to produce in Britain or Sweden and this factor alone is important enough in these countries to preclude their limited manufacture, sale, and use. I should add here that the only formulation of 2,4-D generally available in northern Europe and for export from Great Britain is an 80% sodium salt of 2,4-D. The factors which I have cited combine to satisfactorily explain the preference for MCP as a selective herbicide in northern Europe.

Now why is it necessary to use $1\frac{1}{2}$ to 2 pounds of the sodium salt of MCP per acre for the control of weeds such as mustard, lambs quarters, spurrey, and similar species in flax in Great Britain, when $1/4$ to $1/3$ pound of the same material is considered an efficient level of application here in the States and Canada. Further, why does Redwing flax, grown in Great Britain, tolerate $1\frac{1}{2}$ to 2 pounds of MCP per acre or, 1 pound of the sodium salt of 2,4-D per acre, when the same variety treated at the same stage of development here in the States or Canada shows marked and detrimental effects following the application of rates above $\frac{1}{2}$ pound per acre of either material?

In the first place, I checked and found that rainfall during the growing season, average daily temperature during the growing season, and length of day in the flax growing area of Great Britain, are closely similar to like factors of weather and growth in parts of Oregon, and not too dissimilar to conditions under which flax is grown in some of the Canadian provinces. The only variable in weather conditions apparently is the daily fluctuation in temperatures. Night temperatures in the British area do not drop as low as night temperatures in comparable flax producing areas in the States and Canada. This may be the critical factor in predisposing both flax and weeds in Great Britain to a higher tolerance of the action of 2,4-D or MCP. The effect of temperature on other plants can be well illustrated by the fact that in southern England field grown tomatoes seldom ripen fruit, whereas growing tomatoes in unheated glass houses where the mid-day temperature can be considerably raised and represents considerable variation from minimum night temperatures, predisposes the tomato plants to mature fruit in abundance. This is the common practice in extensive tomato production in England.

This theory, regarding the possible effect of variation in daily temperatures on the tolerance of plants growing under these conditions to 2,4-D, was bolstered by the fact that Dr. Aberg of the Royal Agricultural College and Experiment Station at Uppsala, Sweden, has found that in the area of central and northern Sweden damage resulting from spraying flax, peas, and other legumes underseeded with flax or small grain by MCP is greater when the applications are made at temperatures above 25° C. In fact, his field recommendations specifically state that farmers should undertake their spraying operations when temperatures are most likely to be between 15° to 20° C.

In investigating the use of high rates of application of MCP or 2,4-D in England, I discovered some possible interesting associations between the volume of spray solution applied per unit area and the effect of MCP or 2,4-D on crops and weeds. In England, spray solutions of 2,4-D or MCP are generally applied at a volume of 100 gallons per acre. I noted that a number of investigators in Great Britain had observed that they had damage in flax, and clovers underseeded in cereals of flax, where they had used low volumes of spray solution. In fact, in a table of recommendations published by Dr. Home of Plant Protection, Ltd. and under the section devoted to linseed, and the varieties Canadian Royal and Redwing, he recommends treating when the flax is between three inches and eight inches in height, and states: "Use 80 to 100 gallons of water (not less) per acre. Low volume spraying is not at present generally recommended. "Agro" users should use not more than --- 1 gallon single strength "Agroxone" in at least 35 gallons of water." The general recommendations for control of weeds in linseed suggest using 2 gallons single strength "Agroxone" per acre, which is equivalent to approximately 1-3/4 pounds sodium salt. Note that in using a volume of 35 gallons water spray solution - which we consider high volume here; that Dr. Home specifically recommends only 1 gallon per acre of the single strength "Agroxone" or slightly under 1 pound sodium salt per acre. I should add the "Agro" is the trade name of a low volume sprayer, and a machine that is quite widely used by commercial pest control operators in Great Britain.

In connection with the association between volume of spray solution and rate of application of 2,4-D as determining the action of the herbicide on crop plants and weeds, I should bring out here the fact that considerable work is being done on this problem at the Royal Agricultural College at Uppsala, Sweden, under the direction of Dr. Aberg. One of Dr. Aberg's students and assistants, Mr. Helge Helquist, has some most interesting investigations and data on this problem. Helquist is using a standard rate of application of MCP and 2,4-D on a variety of crops and weeds, in the greenhouse and under field conditions, but varies his volume of water spray solution

from a minimum of about 8 gallons per acre to a maximum of approximately 90 gallons per acre. Helquist has devised some clever techniques for developing and measuring spray volumes and spray droplet size, and an analysis of the data which he is accumulating will of a certainty throw some light on the problem of interaction of volume of spray and rate of application of 2,4-D or MCP. I should add here that in Sweden and Denmark, low volume spraying in the range of from 25 to 50 gallons per acre is generally employed and that rates of application of MCP or 2,4-D recommended by the experiment stations, and in field practice, are considerably lower than those used in Great Britain. Aberg of Sweden recommends not in excess of 5 liters of a 10% sodium salt of MCP solution per hectare, which on conversion is slightly less than $\frac{1}{2}$ pound salt of MCP per acre. He stated that he found that weeds commonly associated with flax; such as mustard and lambs quarters, are satisfactorily controlled with these rates of application and that rates of application in excess of this level; especially when temperatures are above 25° C., may result in variable injury to flax raised either for seed or fiber. He indicated that in the southern and central part of Sweden where Centaurea cyanus and poppy (Papaver rhoeas) are commonly found in cereals only partial control of these somewhat tolerant species was obtained. In wheat and other cereals he recommended rates of application equivalent to $\frac{3}{4}$ pounds of the sodium salt of MCP, or 2,4-D, per acre.

This entire consideration brings up the point that even here in the States and Canada where rates of application of herbicides such as 2,4-D and 2,4,5-T are, we believe, at a minimum effective rate with present application equipment and techniques; that under ideal conditions and methods of application perhaps only a fraction of the herbicidal material now being applied would be needed on a unit area to control weeds. Our methods and techniques are still very wasteful of materials. I believe that we in weed control have a distinct advantage over the workers in the field of insecticides and fungicides in this respect, and we note that even today entomologists are reluctant to modernize their equipment and devise methods which would permit of lower volumes of spray solution in field use. This point was emphasized by Dr. A. E. Galley of the Office of Lord President of the Council of Great Britain, when he stated that in Great Britain two-thirds of the plant protection chemical products are now wasted in application. He cited the fact that in production of tea or rice in Malaya, a Chinese farmer, or coolie, will by 1 pound of an 80% sodium salt of 2,4-D and that this quantity is sufficient for his entire season of weed control activities. Dr. Galley and others at the conference recalled that the Chinese coolie applies this material as a spray solution which is held in his mouth and individually squirted on each weed plant in the rice paddy, in the same way that the old time Chinese laundryman applied starch to shirt collars.

Another interesting point that Dr. Galley made at the Fernhurst Conference was the fact that in Great Britain previous to World War II, for every \$100.00 spent in crop production, \$2.00 to \$3.00 was invested in crop protection chemicals, whereas by 1950 the British farmers were spending approximately \$9.00 for agricultural chemicals and application for every \$100.00 invested in total crop production costs in the United States or Canada, I am certain that the relative investment in crop protection chemicals here is far below that in Great Britain.

Commercially available equipment for application of herbicidal chemicals in Great Britain is in some respects inferior to that we have here; in other respects superior. As I have indicated earlier, low volume sprayers: ie, sprayers constructed or designed to apply from 5 to 20 gallons of spray solution per acre, are not common in Great Britain and this is due to the fact that there is little demand for this type of equipment. I would estimate that from 60 to 80% of the chemicals used for crop protection in Great Britain are applied by commercial pesticide operators.

Only on the larger farms and estates does the operator own the machinery necessary for the complicated and varied procedures entailed in applying plant protection chemicals to the variety of crops commonly found on a single operational unit. Commercial pesticide operators need equipment to undertake a variety of spray and dust applications to a wide variety of crops grown in their operating area. In general these commercial operators have machines that can be adapted to a number of different operations. Some of the finest field sprayers that I have observed in Great Britain were designed to apply both sprays and dusts to a variety of crops. I have indicated that the use of dinitro selective weed killers is wide in Great Britain and the commercial operator has equipment that will handle the high volumes of spray solution necessary in applying the dinitro compounds and the tendency is to use similar volumes for the application of the hormone herbicide. The same operator generally applies a variety of insecticides and fungicides to crops infested with insects and diseases and commonly uses the same sprayer for all operations. Another factor that has been operative in maintaining the high volume sprayers in Great Britain is the comparatively small size of fields and general availability of ample water supply.

In specialized spraying equipment, particularly in the field of small units adapted to man operation or mounting on donkeys, horses, carts, or even mounting on the backs of camels, the British manufacturer has an array of equipment that surpasses that which we have available in the States. This development of specialized small unit sprayers has, of course, been brought about largely by the fact that the British manufacturer serves a world wide empire trade which covers a diversity of crops and production variables.

This wide and diversified field of consumer trade has not developed the variety and diversity in herbicides that we would expect, however. As indicated earlier, the sodium salt of MCP is most widely manufactured and sold as a liquid formulation with 10% sodium salt of MCP by weight, or, as a triple strength solution containing three times the concentration of the standard formulation. They also formulate and market a 1% MCP sodium salt dust as an herbicide for local consumption and a 5% sodium salt dust concentrate; largely for export trade. In addition, most of the large formulators produce an 80% sodium salt of 2,4-D which is packaged as a dry powder and intended for foreign consumption. Esters and amines of 2,4-D and MCP, as far as I know, are only laboratory produced for experimental application. 2,4,5-T likewise is only available in experimental quantities and much of this is of American manufacture. Low volatile esters of 2,4-D and 2,4,5-T; which have been so popular in North America for control of woody weed plants, are not commercially formulated in any of the northern European countries. This is likewise true of TGA; experimental applications of this material having been made with products of American formulators.

Borax and sodium chlorate are of no importance as herbicides in Ireland and Britain. In the Scandinavian countries sodium chlorate - of Swedish vintage - is used in considerable quantities. Sodium arsenite is widely used for control of vegetation on railroad beds, dock areas, and similar situations throughout Europe. The arsenicals are again, largely from Swedish works.

Most of the northern and western European countries have in the past years been importers of herbicides such as MCP, 2,4-D, and dinitro compound. Great Britain supplied the exports for this trade but in the past two years, the situation is rapidly changing. A rough survey, which I made of delegates attending the Fernhurst Conference, indicated that Sweden, Denmark, and France are now producing 90% of the 2,4-D and MCP that they consume. Germany is producing 70%;

Belgium 60%; and Italy 40%; of their own consumption respectively. Holland is yet importing a large proportion of the hormone herbicides and dinitro compounds used in weed control.

The dinitro compounds; both the ammonium-dinitro-ortho-cresol and dinitro-secondary-butyl-phenol, have been, and are, more widely used in weed control in the northern European countries than in the United States and Canada. In England in 1950 and 1951 an alarming number of deaths of commercial operators applying dinitro compounds have occurred which threatens to strictly limit and curtail the use of these materials in Great Britain. While it has been officially established that ten or more deaths occurred in Great Britain from contact with dinitro sprays in 1951, it is difficult to rationalize the fact that in Holland, Sweden, Denmark, and France; where proportionally large quantities of the same dinitro compounds are used in weed control there have been no reported deaths due to the toxic action of these materials. This phenomena was, and is, receiving wide and thorough investigation by British research specialists.

Both TCA and IPC have been quite widely tested in Great Britain, Sweden, Denmark, and Holland and while TCA has given results about equal to those of similar trials in the north central states area of the United States, there is little enthusiasm for the development of field uses for this material. IPC has been widely tested for a variety of possible weed control uses and in general the results of the investigations have been indefinite or inconclusive and there is no field scale application of this material being made that I know of. Chloro IPC has not as yet been tested by the northern European investigators.

Limitations of this assignment do not permit me to give you a complete account of the interesting investigations on weed control and herbicides under way in the several experiment stations and universities that I visited. I was impressed by the fact that in Great Britain, industry finances and undertakes the lions share of the agricultural chemical research and effectively carries the findings of this extensive research into field practice through extension and demonstrational procedures that in the United States and Canada are inherently the function of tax supported governmental institutions. I should add here that this picture is rapidly changing, however, and government agency sponsored and supported research and extension in agricultural fields is rapidly coming to the fore. The research group headed up by Dr. Geoffrey Blackman at the University of Oxford and under the sponsorship and direction of the Agricultural Research Council of Great Britain is a good example of the trend toward wider government participation in agricultural research. Dr. Blackman is well known to a number of you and is well qualified by training and experience to head up this important development. He has a group of the finest young research men in Great Britain working on his research team and the training and diverse interests of this group serve as surety of the promise that they will develop some far reaching and worthwhile contributions to our field of chemical weed control. The laboratory at Oxford is very well equipped and in addition this group has at its disposal a large tract of suitable field area adjoining the city of Oxford on which they are carrying out wide and diverse investigations with chemical herbicides.

A comparable group, sponsored entirely by Plant Protection, Ltd., - an industrial organization, is located at Jealott's Hill Research Station and headed up by an equally able leader, Dr. Templeman. Templeman is likewise well known to many in this group and his reputation and respect in weed research fields is well established. The Jealott's Hill Research Station is as well equipped with facilities for laboratory and field investigation as any state agricultural experiment station in the United States. In addition to the ingenuity and abilities of the four or five man team

which makes up the group working on herbicides at Jealott's Hill, this group has the distinct advantage of having the services and facilities, of a large number of highly trained chemists, physicists, physiologists, and engineers of the sponsoring commercial company available for consultation and suggestions; facilities and advantages which few tax supported research groups in either Britain or the United States can muster.

Research on development and use of herbicides in weed control is under way at the University of London, at Cambridge, and at a number of commercially and governmental sponsored field research stations throughout Great Britain. Some of the workers, and stations, are highly specialized in their field and as an example, I would cite Dr. R. B. Dawson of the St. Ives Research Station at Bingely, Yorks., who has the most extensive investigation on weed control in golf green and turf management under way of anything that I have had an opportunity to visit.

In Sweden I spent several days with Dr. Ewert Aberg of the Swedish Royal Agricultural College at Uppsala. Dr. Aberg and his coworkers have extensive investigations concerned with weed control practices, several of which I have mentioned earlier in this talk. Dr. Aberg has kept abreast of the developments in the United States and Canada and has currently tested many of the new herbicides being developed by workers in this country. In Sweden most of the work in development of agricultural chemicals is under the direction of state supported research institutions such as that at Uppsala. While with Dr. Aberg we visited Linnaeus' Gardens and also the old summer home where Linnaeus did much of his early work. I was particularly interested in one room in this old summer home which is beautifully preserved and which was entirely papered with some of the original drawings used in his Species Plantarum (1753). Linnaeus' summer home was in one of the most beautiful settings that we saw in northern Europe and as he is reported to have selected the site and designed the house himself, it bears witness to the fact that Linnaeus was an artist as well as a scientist.

Denmark with its highly intensified agriculture has a large number of small experiment stations, each highly specialized in research objective. We spent several days at the Royal Agricultural College at Copenhagen, which has the largest agricultural research station in Denmark and it was particularly interesting to me in that Andersen and Hermansen are at the present time continuing their fine work there on the varietal responses of field crops to 2,4-D and MCP. I am sure that many of you are familiar with the work of these men, which has been published in an English version and widely distributed in the United States and Canada.

At the experiment station of the Royal Agricultural College, near Copenhagen, I had the rare opportunity of looking over a field experiment in the breeding of winter wheat by the controversial methods and procedures of Lysenko. I assure you that in field practice the methods and procedures represent quite a departure from the conventional techniques used by plant breeders in the United States and Canada. I must also add that I was unable to determine whether these procedures were attaining the goal or not.

The Danish investigators in weed research have some unusual investigations under way which would indicate that very low concentration of 2,4-D may speed up germination and seedling development of crops such as peas and barley. They further have quite substantial evidence that bees feeding on common mustard treated with 2,4-D or MCP may be killed. The investigations leading to these conclusions have been undertaken by Mr. Ole Hammer and Palle Johnson of the Statens Biavlfsorsog

of Lyngbi. If any of you are especially interested in these rather unusual research developments I will be glad to give you the reference to the Danish journals in which they have been published.

Knowing your general interest in weed control problems associated with irrigation culture I believe you would be interested in reports that I had during the conference at Fernhurst and further in discussions with Dr. A. E. Andrews who is a senior economic botanist from Wad Medani of the Sudan. Dr. Andrews is primarily interested in the production of cotton and sorghums in his area. In the southern part of the Sudan sufficient rainfall occurs to produce dry land cotton and sorghum, but in the northern Sudan the water for cotton and sorghum is taken from a complicated irrigation system deriving its water from the blue Nile. About 200,000 acres of cotton and about half that many acres of sorghum are grown in the northern Sudan. In this area seasonal rainfall occurs shortly after planting of the cotton in mid-August, growers often find it impossible to use machinery of any type in the cotton fields and in the past weeding and cultivation of the seedling cotton has been undertaken by native hand labor. Due to the expansion of agriculture and other industries in British Africa, labor is becoming annually more scarce and cotton growers in the area have found it increasingly difficult to obtain labor at a reasonable wage to control the weeds in their crop. Dr. Andrews was very much interested in the report on the American use of highly refined oils and oils fortified with dinitros or pentachlorophenol for control of weeds in seedling cotton of recent development in our southern states. To date, he has been limited in his experimental work to the selective weed killers, 2,4-D and MCP, and we know that these materials are not well suited to any use in cotton culture. Andrews indicated that nutgrass (C.rotundus) has widely invaded the cotton area in the Sudan and threatens to become the most serious weed factor that they have to deal with. He has found that 2,4-D or MCP can be successfully used for control of weeds in sorghum but due to the fact that this crop is generally grown adjacent to cotton, its use has been limited and further, due to the fact that sorghum is raised largely as a staple native food source and is considered a very low value crop, they have found that spraying weeds with 2,4-D or MCP often entails a cost equal to the value of the harvested crop.

You may be interested in knowing that Andrews has found that they can secure excellent control of the parasitic weed Striga spp. in sorghum and maize with 2,4-D. Dr. Andrews asked me whether we had this parasitic weed, and to my knowledge it is not a problem in our southern states. It seems odd that this weed, which is widely distributed through tropical Africa and Asia, has not become established here. Andrews indicated that plants of sorghum or corn attacked by Striga generally produce no grain whatsoever.

Dr. Andrew's major weed control problem is associated with the submersed aquatics in the 3,000 miles of canals which make up the irrigation system on his project. He indicated that at least two-thirds of the canal in the area were so heavily infested with water plants that flow of water was greatly impeded. The canal system is unique in that it provides for storage of water by night and the application of the water only occurs by day. This results from an agreement with Egypt where the waters of the blue Nile are likewise used for extensive irrigation. The semi-ponding of the water during twelve hours of each day provides ideal conditions for active weed growth and at present water plants are removed from canals by hand labor using long handled rakes and during the mid part of the irrigation season this removal must be repeated every fourteen days.

A further complication in Dr. Andrew's problem is the fact that the canal water is the only source of domestic supply for all the inhabitants of the area and also for the cattle maintained in the area. It is, therefore, of extreme importance that aside from the question of irrigation of crops the canal should be kept as clean as possible of weed growth and that any chemical control used must be such that the water is not made unfit for human and animal consumption.

The principle weeds in the irrigation system are pondweed (Potamogeton spp.) and a stonewort (Chara fragillis). In an area where canal water would be used only for irrigating sorghum and for drinking purposes Dr. Andrews had an interesting experience in attempting to control these two species. He applied 2,4-D at a rate determined to provide 8 to 10 parts of 2,4-D acid per million parts of water in the canals. In one of these applications the 2,4-D was applied as a liquid solution, whereas in another experiment the 2,4-D was applied as a 5% sodium salt dust. He used comparable treatments of MCP in these investigations. The unusual part of this investigation was the fact that where 2,4-D or MCP was applied as a liquid spray he secured only partial and unsatisfactory control of the pondweeds, but where these herbicides were applied as a dust the destruction of the weed was so complete that the disintegration of the plants formed a black slush on the bed of the channel and Dr. Andrews believes that all rhizomes of the pondweed were killed by the single treatment with the 5% dust of 2,4-D or MCP. Following up on these investigations Dr. Andrews used an 80% sodium salt of 2,4-D mixed with fine silt to form a 5% acid dust and treated a larger area of an adjacent canal with a concentration that would bring the 2,4-D to 10 ppm of water. Results in control of the pondweed were as striking as in his initial experiment but in this area, the water became badly fallowed by the decomposing vegetation and two natives, who used the water for drinking, died. In spite of the fact that their death was subsequently proved to be due to cerebro-spinal meningitis, a somewhat common result of drinking canal water when ponded under a tropical sun, local authorities were not convinced and would not permit further use of 2,4-D in control of these weeds in the canal. I should add that stonewort in all investigations was unaffected by the 2,4-D and actually increased in intensity of infestation when the competition from the pondweeds was removed. Andrews stated that stonewort can be controlled on his project by the use of 30 ppm of copper sulphate and that this same treatment effectively controlled the snails which have been established as carriers of the Bilharzia disease, which is common in the area.

Dr. Andrews was greatly interested in the reports of your developments in the use of solvent naphths and rosin amine D acetate for the control of water weeds. Since reporting your developments in this field at the Fernhurst conference I have had letters from all parts of the world requesting information on the use of these materials and for references to literature on your general development in control of weeds on irrigation systems. From my conversations with people familiar with irrigation systems in areas outside of the United States I am convinced that your developments in this field are less known outside of the United States than any other comparable field of development in weed control. This is the only area in the world where research and development in control of water weeds had demonstrated real progress.

In closing this talk I would like to bring to you a few statements made by Sir John Russell who was a keynote speaker of the Fernhurst conference and is certainly one of the outstanding agricultural scientists in the world today. Sir John Russell has perhaps traveled more widely and visited more fields of agricultural production and has a more keen insight into the scientific aspects of food and fiber production than any other man in Great Britain. He indicated in his discussion that a figure of 10% is frequently quoted as representing the annual loss of crops from insects,

diseases, and weeds, but that he believed that losses of this magnitude prevailed in the countries of advanced, modern and enlightened agriculture of Great Britain, the United States, and Canada, even in 1951. He stated that he believed a more accurate estimate of these losses would be at least 20% of the total world's food and fiber production annually. He added that in the world today there is an average annual food shortage of approximately 20% of our total world production and that if we could efficiently and universally use our presently available knowledge, materials, and methods, in control of insects, fungi, and weeds, that without expanding our present crop acreage there would be no shortage of food and fiber throughout the entire world.

List of herbaceous weed species observed in Ireland, England, Sweden, and Denmark and the reported reaction to MCP or 2,4-D.

Weeds. <u>1/</u>	Reaction to 2,4-D or MCP <u>2/</u>
Bindweed, Black	
A. Polygonum Convolvulus	III
Bindweed, Field	
P. Convolvulus arvensis	III
Bracken	
P. Pteris aquilina	R
Brambles	
P. Rubus spp.	R
Buttercup, Bulbous	
P. Ranunculus bulbosus	III
Buttercup, Corn (Starveacre)	
A. Ranunculus arvensis	I
Buttercup, Creeping	
P. Ranunculus repens	II
Cabbage, Field	
A. Brassica campestris	I
Charlock	
(Yellow Charlock Wild Mustard Kilk)	
A. Brassica Sinapis	I
Chickweed	
A. Stellaria media	III
Cleavers (Herrif Goose Grass)	
A. Calium Aparine	R
Coltsfoot	
P. Tussilago Farfara	III
Cornflower (Blue Bottle)	
A. Centaurea Cyanus	II
Corncockle	
A. Agrostemma Githago	R
Corn Marigold	
A. Chrysanthemum segetum	R
Crane's Bill	
A. or P. Geranium spp.	III
Daisy, Ox-Eye	
Chrysanthemum Leucanthemum	II
Dandelion	
P. Taraxacum officinale	II

Weeds	Reaction to 2,4-D or MCP
Day Nettle (Hemp Nettle)	
<i>A. Galeopsis Tetrahit</i>	II
Docks (Young)	
<i>P. Rumex</i> spp.	II
Docks (Mature)	
<i>P. Rumex</i> spp.	R
Fat Hen (Goosefoot Dungweed)	
<i>A. Chenopodium album</i>	I
Fumitory	
<i>A. Fumaria officinalis</i>	III
Grasses	
<i>A. or P. Gramineae</i>	R
Gromwell, Corn (Bastard Akanet)	
<i>Lithospermum arvense</i>	III
Groundsel	
<i>A. Senecio vulgaris</i>	III
Hardheads (Knapweed)	
<i>P. Centaurea nigra</i>	II
Heartsease (Corn Pansy)	
<i>A. Viola tricolor</i>	III
Hoary Pepperwort (Hoary Cress Chalk Weed)	
<i>P. Lepidium Draba</i>	II
Horsetail	
<i>P. Equisetum</i> spp.	II
Knotgrass (Knotweed)	
<i>A. Polygonum aviculare</i>	III
Mouse-Ear Chickweed	
<i>A. Cerastium vulgatum</i>	III
Nettle, Annual	
<i>A. Urtica urens</i>	III
Nettle, Perennial	
<i>P. Urtica dioica</i>	III
Orache	
<i>A. Atriplex patula</i>	I
Parsley Piert	
<i>A. Alchemilla arvensis</i>	R
Pennycress	
<i>A. Thlaspi arvense</i>	I
Persicary (Redshank Willow Weed)	
<i>A. Polygonum Persicaria</i>	III
Plantain	
<i>P. Plantago</i> spp.	II
Poppy	
<i>A. Papaver Rhoeas</i>	I
Ragwort	
<i>P. Senecio Jacobea</i>	II
Rushes	
<i>P. Juncus</i> spp.	II

Weeds	Reaction to 2,4-D or MCP
Scentless Mayweed (Feverfew)	
A. <i>Matricaria inodora</i>	III
Sheep's Sorrel	
P. <i>Rumex Acetosella</i>	III
Shepherd's Needle (Venus's Comb)	
A. <i>Scandix Pecten-veneris</i>	II
Shepherd's Purse	
A. <i>Capsella Bursa-pastoris</i>	I
Silverweed	
P. <i>Potentilla Anserina</i>	III
Sorrel	
P. <i>Rumex Acetosa</i>	III
Sowthistle, Common	
A. <i>Sonchus oleraceus</i>	II
Sowthistle, Corn	
P. <i>Sonchus arvensis</i>	II
Speedwell	
A. or P. <i>Veronica</i> spp.	III
Spurrey (Sandweed Yarr)	
A. <i>Spergula arvensis</i>	III
Tares (Vetches)	
A. or P. <i>Vicia</i> spp.	II
Thistle, Creeping	
P. <i>Cirsium arvense</i>	II
Thistle, Spear	
B. <i>Cirsium lanceolatum</i>	II
Treacle Mustard	
A. <i>Erysimum cheiranthoides</i>	I
Wild Onion (Crow Garlic)	
P. <i>Allium vineale</i>	III
Wild Radish	
(White Charlock Jointed Charlock Ranch)	I
A. <i>Raphanus Raphanistrum</i>	
Wood Sorrel	
P. <i>Oxalis</i> spp.	

1/ Common name or names generally applied.
Capital letter A. - annual, P. - perennial.

2/ I - Very susceptible - killed at basic rate of application.
II - Suseptible - controlled, but seldom killed at basic rate of application.
III - Partially susceptible or resistant.
R.- No practical economic reaction.

REGULATION OF AGRICULTURAL PEST CONTROL OPERATORS

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The present laws and regulations governing agricultural pest control are the result of efforts to cope with the many new problems that have occurred with the rapid development and use of the new pest control materials. In 1947, Congress passed a new Federal Insecticide, Fungicide and Rodenticide Act which included herbicides among the products being controlled. The Federal law requires all pest control materials to be registered and properly labeled before being shipped in interstate commerce. It has served as a basis for uniform action among the states.

At the same time that the Federal act was passed, the Council of State Governments prepared a model uniform state economic poisons law to serve as a guide for state legislation to supplement the Federal legislation. Some states, such as California, have had laws regulating the sale of economic poisons, including herbicides, for many years while other states have taken no action in this field. At present only about nine states do not have laws governing sale of economic poisons but rely solely on the Federal act. The model act has been widely adopted by the different states as laws were modernized and at present about twenty-three states have followed its principles. These laws have required uniform labeling information on the different products and users can now be assured that, generally, weed control materials and other economic poisons will be in accordance with the guaranteed composition on the label and carry adequate directions for use.

As everyone knows, use of a proper chemical does not in itself always guarantee perfect results. The problems of proper application of the material to secure adequate control of a pest without drift to adjoining properties have become more difficult with increased usage of agricultural aircraft. There has been a demand for regulation of agricultural pest control operators in order to assure good work being done. There are no Federal laws with regard to licensing of agricultural pest control operators other than the provisions in the civil aeronautics laws affecting flying. A Joint Legislative Committee on Agriculture and Livestock Problems of the California Legislature made a two-year study of the problem. The recommendations of this Committee were enacted in 1949 in the form of three new provisions of the Agricultural Code of California. The provisions are, first, to license and regulate the business of pest control, second, to provide for regulating the use of injurious herbicides, and third, to provide for regulating the application in pest control, or other agricultural operations, of any materials determined to be injurious to persons, animals, or crops.

The National Association of Economic Poisons Control Officials, in cooperation with other interested groups, also studied the problem and there was drafted a model act relating to application of insecticides, fungicides and herbicides. The provisions of this act were intended to serve as a guide for state legislature that might find it necessary to pass laws regulating agricultural pest control. In general, the provisions of the California act follow the same principles set forth in the model act. The California act requires each agricultural pest control operator to be licensed before engaging in the business of pest control for hire in the State. The fee is \$15 for each calendar year, payable on or before

the last day of January. A penalty of \$5 is incurred for late filing. An applicant starting in business for the first time may avoid the penalty by submitting a statement that he was not engaged in business prior to application. The applicant is required to describe the type of pest control in which he intends to engage and his license limits him to the types described in his application. A person who is not regularly engaged in the business but who occasionally accommodates his neighbors, is not required to secure a license but may instead obtain a permit to operate without a license. Such permit is issued without fee but in all other respects the same requirements apply as to one who holds a license.

In addition to securing a State license, county registration is required of each person who operates for hire in any county whether under license or permit. County registration may be refused or cancelled, subject to appeal to the Director, if the equipment is unsuitable, or if the persons employed to operate it are incompetent or unqualified, or if the applicant has refused or neglected to comply with the laws and regulations, or with any lawful order of the agricultural commissioner. The county agricultural commissioner is authorized under the act to make rules and regulations governing the application of methods of pest control under local conditions and the Director of Agriculture makes rules and regulations governing the conduct of the business of pest control. This provision has permitted the Director to make rules and regulations on a statewide basis and the agricultural commissioner to take care of special problems in his locality under his own regulations.

All pilots operating aircraft in agricultural pest control are required to pass a State examination to demonstrate their ability to conduct pest control operations and their knowledge of the nature and effect of material used in pest control. The fee for examination is \$25 and if successful, a certificate of qualification is issued to the applicant. A certificate may be renewed annually upon payment of \$5 renewal fee.

The 1951 California Legislature recognized the necessity of providing a program for training crop-dusting pilots. The law was amended to provide for issuance of an apprentice certificate in order to permit a pilot to qualify in a limited field and operate under personal supervision of a person holding a valid certificate of qualification. The examination for an apprentice certificate was designed to demonstrate the candidate's ability to conduct specific pest control operations listed in his application.

Pilots' certificates may be refused, revoked or suspended, after hearing, upon a finding that the applicant or holder of the certificate (1) is incompetent, (2) has violated the laws or regulations applicable to the pest control business, or (3) has failed or refused to comply with any lawful order of an agricultural commissioner.

In addition to these laws requiring a pest control operator to be an experienced, responsible person, the legislature recognized the need for special consideration to be given to application of injurious herbicides. Accordingly, the 1949 State Legislature amended the Agricultural Code to give the Director authority to make rules and regulations governing the use of 2,4-D and other herbicides which he finds and determines to be injurious to crops that are being grown in any area of the State. After hearings held in 1949, the Director issued rules and regulations establishing 2,4-D, 2,4,5-T, and MCP as injurious herbicides and setting up hazardous areas for protection of the grape and cotton

growers from drift from weed control operations. These regulations required each person, whether a farmer or a pest control operator, to secure a permit from his county agricultural commissioner before 2,4-D or other injurious herbicides could be applied. Within the hazardous area there was a limit of one pound that could be applied a day without the necessity of a permit. Outside the hazardous area this was increased to five pounds a day to permit farmers to treat small acreages without the necessity of securing a permit. Obviously, any extensive operations, such as would take place if aircraft were used, would require a permit to be secured.

The regulations seemed to serve a useful purpose as the number of complaints from 2,4-D injury dropped sharply during 1950. The grapegrowers in the Lodi area in Central California made no complaints during 1950. In 1951, complaints were received from this area indicating that symptoms from 2,4-D on tokay grapes were again appearing, although not nearly as severe as those that appeared in 1948 and 1949. The cause of these symptoms has not been determined, although extensive investigations have been made. They occurred in vineyards in an area about five miles square and, although quite light, seemed to indicate that they might have been caused through 2,4-D being carried in the air. This could have been either through use of highly volatile formulations or actual drift during application, although no such operations were found within the hazardous area which extended several miles from the grapes. These symptoms occurred even though the corn growers and grain growers in the hazardous area had been prohibited from applying 2,4-D after March 15. Representatives of the grain growers petitioned for hearing to revise the regulations with the hope that regulations could be drawn that would permit use of 2,4-D under special conditions and at the same time not cause symptoms to develop on grapevines. Hearing was held on December 18, 1951, and again on January 31, 1952, to review various proposals for regulations and it is anticipated that revised regulations will be issued in time to become effective before March 15, 1952. It is also anticipated that these revised regulations will permit application of 2,4-D and other injurious herbicides under closely regulated conditions with regard to pressure and nozzle size and height above the ground in order to prevent drift to neighboring crops. It was also proposed at the hearing that highly volatile forms of 2,4-D, 2,4,5-T and MCP, such as the methyl, ethyl, isopropyl, butyl, and amyl esters be prohibited from use throughout the State. There was no opposition to this proposal.

Witnesses at the several hearings held with regard to injurious herbicides have repeatedly pointed out that additional research is needed with regard to the nature and effect of 2,4-D and similar growth-regulating substances. Research work should be conducted to determine whether there is any significant volatility of 2,4-D products from land or from water surfaces such as rice fields after application under our hot western conditions. Work should be done to determine methods of applying 2,4-D sprays so they will be confined to the property being treated. It has been claimed that 2,4-D might be carried on soil blown from treated fields in sufficient quantities to cause symptoms to grapevines, cotton, or other susceptible crops and we believe research work should be done to determine if this is possible. These are problems of great importance to farmers and should receive prompt attention. In the regulatory field this basic information is needed before sound regulations can be drawn that will assure fair treatment of the many various interests involved in the use of injurious herbicides.

Recognizing that accidents do occur, even though every effort is maintained to keep them at a minimum, the 1951 California Legislature amended the pest control law to provide for filing of reports by any person suffering loss or damage resulting

from use or application by others of any pesticide. Report is to be made to the county agricultural commissioner within sixty days from the time that the occurrence of such loss or damage becomes known or in the event of a growing crop, prior to the time 50% of the crop has been harvested. The law specifies the information to be supplied to the agricultural commissioner in order that investigation may be made. This provision has not been in operation long enough to demonstrate its value but it is hoped that it will aid not only farmers, who may suffer injury, but pest control operators and their insurance carriers who may be responsible for such injury or damage.

The legislature in adopting the recommendations of its Joint Committee on Agriculture and Livestock Problems, rather than some of the more restrictive measures that have been proposed, has indicated confidence that the Department of Agriculture and the various agricultural commissioners working together can correct and prevent abuses without unnecessary interference with essential and proper pest control. At the recent 2,4-D hearings, representatives of the various growers groups have shown a sympathetic understanding of each others problems and demonstrated a very cooperative spirit in recommending to the Department regulations to protect each others interests.

Manufacturers, dealers, and pest control operators have shown a cooperative attitude in assuming their responsibilities under the laws.

SOIL STERILANTS

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The use of soil sterilants in present day weed control is most extensive. Greatest use of this group of herbicides is made in industrial weed control for which purpose millions of pounds are used annually on industrial sites, railway ballast, military installations and other areas. Large quantities are also used for perennial weed control in agriculture as well as on irrigation ditch banks and roadsides.

The term soil sterilants, as applied to various herbicides, is often misleading. Commonly speaking, we think of soil sterilants as chemicals which render the soil unfit for plant growth. In practical use, the application of such chemicals does not always create a sterile soil, which sometimes causes considerable disappointment on the part of those not too well acquainted with the nature of weed work and the action of some chemicals classified as soil sterilants. Some plant species are tolerant to some of the chemicals recognized as soil sterilants; some soil types influence the degree of sterility, and the amount of the chemical applied may destroy unwanted plant species and not effect others. Probably a more specific definition for soil sterilant would be a group of chemicals which applied to the soil under given conditions may either destroy all vegetation or a selected plant species. Some of the soil sterilant chemicals may be used either as a temporary or a relatively permanent sterilant depending on the purpose for which the chemical is applied. For example, in some types of industrial weed control it is desired to achieve soil sterility as long as possible, whereas in agriculture it is generally desired only to control or to destroy a specific weed.

The arsenicals and sodium chlorate are the oldest soil sterilants as far as general use is concerned. The arsenicals are both effective and long lasting under most conditions, if sufficient quantities are applied. Sodium arsenite has been the compound most extensively used, as this product is soluble and may be applied as a spray. White arsenic, which is insoluble and is applied in the dry form, is offering good possibilities and may receive more attention, if less hazardous application methods are developed. Arsenicals are very poisonous and extreme precautionary measures must be taken in the application and handling of these products. There have been many cases of illness among those applying arsenicals and much livestock has been lost in past years as a result of the use of arsenicals in weed control. It is interesting to note that white arsenic is not so attractive to livestock as is sodium arsenite and may be less hazardous to use. Application rates of the arsenicals range from 300 to 1000 pounds per acre depending on soil types, the heavier the soils the higher the application rates must be. Since the arsenicals become fixed in the upper surface of the soil, their use has not been too effective on deep-footed perennials. The arsenicals, when applied in sufficient quantities, hold up longer as soil sterilants than most other chemicals being used today. Arsenicals have been used extensively by railroads for track spraying.

Sodium chlorate has received much attention and has been widely accepted as a herbicide. This product is used both as contact spray and as a soil sterilant. It is being widely used for the destruction of deep-rooted perennials such as wild morning glory and Canada thistle. In general, application rates of sodium chlorate range from 2 to 8 pounds per sq. rd. Recommended and accepted rates of application, on deep-rooted perennials in the middle western states, are from 4 to 6 pounds per sq. rd., whereas rates in the western group of states, under more arid conditions, appear to be from 6 to 8 pounds per sq. rd. In many localities the 8 pound rate appears to be the standard rate of application on deep-rooted perennials. Soil type is an important factor with the use of sodium chlorate - soils high in organic matter or nitrate content require heavier rates of application than those of low content. Those of you who were in weed work when straw stacks were prevalent, will recall that it was almost useless to treat a noxious weed patch on an old straw stack bottom with sodium chlorate. You probably also recall that many farmers located their straw stacks on noxious weed patches, hoping that the stacks would smother and destroy the infestation.

In discussing rates of application with sodium chlorate, it was noted that roadside treatments of noxious weeds generally required heavier rates of application than agricultural lands under cultivation. It was also observed that best results with sodium chlorate were obtained when applied on firm and compact soils rather than on loose or recently plowed soils. As with the use of other chemicals, favorable moisture conditions are important in the use of sodium chlorate. Fall applications on perennials weeds usually gave better results than those made in late spring or summer. Sodium chlorate may be applied either as a spray or in the dry form. There is apparently little difference in effectiveness on deep-rooted perennials by either method, but, the fire hazards in the application are reduced considerably by applying in the dry form. Since sodium chlorate is fire hazardous, it must be used with discretion.

Carbon bisulfide is a popular soil sterilant where very short periods of sterility are desired. It is mainly used on highly productive agricultural lands where the loss of a crop is an important factor. Although the use of carbon bisulfide is costly, effects in the soil may not last over six weeks - at least not long enough to interfere with crop production if application is timed correctly. The income from normal crop production on carbon bisulfide treated areas should be considered in comparing the cost of this treatment with chemicals which bring about soil sterility for one or more years. Best results appear to be obtained with carbon bisulfide if it is applied

during the warm seasons. Soil types and soil moisture are most important factors in the use of this chemical. Dry sandy soils often create difficult problems, in the use of carbon bisulfide. This chemical is more effectively used on the deep-rooted perennials than on the shallow rooted species.

Ammonium sulfamate is being used to some extent as a sterilant, and when used for this purpose application rates are usually from 400 to 600 pounds per acre. Time of sterility appears to be from three to six months.

Trichloroacetic acid (TCA) is being used successfully in various parts of the country for the control of various grass species and if applied at sufficient rates will result in some soil sterilization. Favorable soil moisture appears to be an important factor in the successful use of TCA. Rates of application range from 50 to 200 pounds per acre. Various combinations of TCA with other herbicides are being used, among which are TCA & 2,4-D and TCA & sodium chlorate. TCA as a soil sterilant is apparently short lived, usually from 60 to 90 days depending on soil moisture and soil texture.

A new product that is receiving considerable attention as soil sterilant is CMU (Para-chlorophenyl-1, 1-dimethylurea). This product has been rather extensively tested the past year and has received many favorable comments. Most satisfactory rates of application appeared to be in a range from 20 to 80 pounds per acre when used as a soil sterilant. It is generally conceded that longer observations of the tests should be made before this product may be fully evaluated. Some of the questions yet to be answered are: length of time that sterility is obtained; the carry over effects on crop lands, and the effect of cumulative treatments.

In recent years the use of borate compounds as herbicides has developed extensively. Borate compounds contain boron, an essential element necessary for plant growth. Boron, when available to plants in excessive amounts, is toxic: thus, the use of borate compounds as herbicides. Boron compounds are toxic in proportion to the amount of boron they contain. Since the element boron does not occur free in nature but as boron trioxide (B_2O_3) in combination with the oxides of other elements, the relative strength of the borate compounds for herbicidal use may be denoted by the per cent of boron trioxide in their composition.

Refined borax, in a granulated form (Agricultural Mesh Borax), was one of the first borates to be used extensively as a herbicide. This product has a boron trioxide (B_2O_3) equivalent of 36.5%. The use of refined borax as a herbicide has been generally replaced by the product Borascu, which is a borate ore, the raw material from which refined borax is produced. Borascu contains 93% borax or 34% boron trioxide, and is processed to develop a coarse and granular material adapted for dry application as a herbicide. It should be noted that Borascu is a product distinct from refined borax.

A recent development for weed control use was the introduction of a Concentrated Borascu. This product, having the water crystallization removed, has a boron trioxide equivalent of 61.5%. Roughly speaking, approximately only half as much Concentrated Borascu is required as with the use of Borascu, thus in many areas Concentrated Borascu furnished more B_2O_3 per dollar of delivered material, through savings in transportation and handling cost.

The sodium borate ores, which are applied in a dry form, are widely used by railroads, utilities, petroleum installations and other industries for weed control purposes. They are also being extensively used for the eradication of certain types of noxious weeds in agriculture, among which are: St. Johnswort, leafy spurge, wild morning glory and Canada Thistle. The borate ores are relatively easy to apply, non-fire hazardous, non-poisonous to livestock and non-corrosive to ferrous metals.

Another development in the use of borate compounds as herbicides, is the use of mixtures of sodium pentaborate and sodium tetraborate, giving highly soluble borates suitable for spray application. One of the more recent of the polyborate is a highly soluble product with a boron trioxide equivalent of 66.6%. This product was not commercially available the past year, due to shortages of some chemicals required for manufacturing. Present indications are that this highly concentrated and highly soluble Polybor will be available this year. This product offers excellent possibilities for use on a number of deep-rooted perennials at apparently lower amounts of boron trioxide than is required with the use of the Borascu's or refined borax.

The development of the soluble borates has also brought about the use of these compounds with mixtures of other herbicides, and primarily with sodium chlorate. The borate-chlorate mixtures have, to-date, received the most attention and are being marketed by several manufacturers under various formulations and trade names. The soluble borate-chlorate mixtures appear to combine the effectiveness and the outstanding characteristics of the borates and the chlorates in their use as herbicides. The fire hazards normally associated with the use of sodium chlorate are reduced or may be entirely eliminated depending on the formulation of the product. The soluble borate-chlorate mixtures are being used extensively in industrial weed control as well as for the destruction of perennial noxious weeds.

Borate compounds are generally applied on the basis of their boron trioxide content. Applications on deep-rooted perennials are generally made at the rate of 8 to 10 pounds of boron trioxide per sq. rd. This would be equivalent to 20 to 30 lbs. per sq. rd. of a material containing 34% boron trioxide such as Borascu or would be equivalent to 11 to 16 pounds per sq. rd. of a material containing 61.5% boron trioxide such as Concentrated Borascu. Boratechlorate combinations are generally applied to rates of 6 to 12 pounds per sq. rd., depending on the formulation to be used and the plant species to be treated. Plant species, such as St. Johnswort, and tansy ragwort are destroyed with much lower rates - as low as $\frac{1}{2}$ lb. per sq. rd.

Considerable information has been gained in recent years relative to the more effective use of the borate compounds and the borate-chlorate combinations under a variety of conditions. Soil type, precipitation and time of application are among the important factors that influence the effective results. Fall applications or applications during the dormant season are more effective on the deep-rooted perennials. Where soil sterility and barren surfaces in industrial weed control are desired, the borate ores are most effective when applied before vegetation has emerged or when vegetation is still young and tender. The borate-chlorate combinations are more effectively used on Bermuda grass, quack grass and other grasses that tolerate relatively high boron concentration.

No attempt has been made to cover all of the chemicals being used as soil sterilants in this discussion, but rather those that are in general field use; nor was any attempt made to give specific rates and recommendations regarding the use of chemicals. Since there is such a variation of soil types and climatic conditions in the western states and even within the counties of the states, information regarding specific rates and time of application of chemicals should be obtained from state and county weed authorities and from experiment stations, which information should be to a great extent based on tests and experience within a local area.

The increased interest in chemical industrial weed control has opened up a big field for the use of soil sterilants. Of the chemicals discussed, the borates and sodium chlorate, either alone or in mixtures, are seemingly being used more extensively for soil sterilization purposes. The borates and borate mixtures, because of their fire deterrent action, are widely used on highways, by industries and on other areas where fire or poison hazards are factors. These chemicals are also being used on irrigation ditches for weed control along the ditch banks. Large quantities are also used for soil treatment before asphalt surfaces are laid down so as to prevent premature break-up of asphalt, caused by vegetative growth.

The present day uses of soil sterilants are indeed many and varied.

SOME FUNDAMENTAL PRINCIPLES OF BRUSH CONTROL

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Within recent years widespread interest has developed in the control of undesirable woody plants such as mesquite, sage brush, cedar, chaparral, a variety of oaks and others that infest extensive areas of grassland. This interest is due primarily to the development of 2,4-D and 2,4,5-T, to the realization that some of the older methods formerly advocated and used were either too expensive or did not give effective control, and to the recent economic conditions that have made grassland enterprises more profitable.

Mesquite and many similar brush species have gradually encroached for one reason or another upon open grasslands, frequently to the point where the carrying capacity has been seriously reduced and the difficulty of properly handling and managing livestock has often been more than doubled. In other areas climax brush species prevail that have little or no grazing value, yet potentially the land would sustain more desirable forage plants if the growth of brush plants were controlled.

Grazing trials at Woodward and Guthrie, Oklahoma and Spur, Texas have shown that effective control of sand sage, mesquite and scrub oak on native grassland has increased gains of livestock as much as 30 per cent or more and at the same time has brought about marked improvement in the grass cover. Furthermore, the greater ease of handling livestock on cleared areas, represents not only a saving of labor but also reduces the likelihood of losses due to insects and diseases and permits better range management.

THE PROBLEM

The control of brush on extensive areas of rangeland is extremely difficult since, for the most part, only limited expense may be incurred and because of constant threat of reinfestation of cleared areas by seedlings and regrowth. A practical method of control should be reasonably effective and readily adapted to treatment of large areas with wide variations in topography, growth types and species of brush. It should be free from hazards to livestock and desirable range plants and low enough in cost to permit retreatment within 5 to 10 years. With methods of this type control of brush may be obtained at a cost that can be supported by the livestock enterprise. Complete eradication of brush on extensive areas generally is prohibitive in cost, requires maintenance over a long period of years and usually is not economical. There are opportunities, nevertheless, to eradicate brush on small local areas where the infestation consists primarily of sparse stands of seedlings in the initial invading stages.

The undesirable woody plants commonly found on the range may be divided roughly into three groups: (1) non-sprouting, (2) plants that sprout from the crown tissues and several inches below ground, and (3) plants that sprout both from the crown tissues and lateral roots. The plants in the first group typified by blue berry cedar, and big sage brush offer problems largely of economically destroying the above ground growth, reestablishing grass cover and preventing reinfestation of the cleared area. Controlled fire, plowing and dragging with various types of equipment are means used to control this type of growth. The plants in the second group include mesquite, sand sage brush, red berry cedar and some species of oak. This group of plants is more difficult to control because of the development of sprout growth from crown tissues and because of reinfestation by seedlings. The discussion of control methods will deal largely with this group of plants. The third group of plants includes shinnery oak, liveoak, some persimmon species and many others. These plants are the most difficult to control on native grassland because sprout growth develops from the crown tissues and from extensive lateral root systems. At the present time the most promising methods of control, which leave much to be desired, consist of using repeated treatments in order to destroy the above ground growth over a period of years and thus gradually lower the vigor of the plants. Chemicals, fire and mowing have been used with some success, although none of these offer too much hope of economic control at the present time.

Fortunately, over large brush infested areas single species predominate and a method of control may be used that is effective and economical, as is the case in the control of sand sage, mesquite, cedar, scrub oak and shinnery oak. On somewhat more limited areas, however, mixed brush often prevails with all three general types of brush plants growing in close association. Under these conditions control is more difficult and care must be taken to avoid removing only the more susceptible plants otherwise the more resistant types of brush actually may be increased.

METHODS OF CONTROL THIN STANDS AND INDIVIDUAL TREES

Experience has shown that treatment of individual plants is practical for controlling thin, open stands of brush and for small odd areas where other methods are not feasible. These individual plant treatments must be highly effective in destroying the plants since they are expensive and laborious.

Hand or Power Grubbing. This age old method of controlling thin invading stands of mesquite, red berry cedar and other brush species of similar growth habits is very effective when plants are grubbed deep enough to remove all sprouting tissues. For dense stands costs are often prohibitive, grass cover is largely destroyed and usually many small plants are missed.

Kerosene and Oils. Thin stands of single to few stemmed mesquite and huisache trees growing on porous, gravelly and rocky soils may be effectively controlled by pouring one to two quarts of cheap light oils around the base of the plants. Enough oil must be used to wet the bark thoroughly to the lowest bud on the underground stem. Since oils are contact agents and must come in physical contact with all the dormant sprout buds to prevent sprouting, soil texture, soil moisture content and type of growth are important factors that govern effectiveness of treatment. Most species of oak, cedar, and chaparral are not effectively controlled by use of oils alone.

2,4-D and 3,4,5-T applied with ground equipment. For basal treatment of trees, that is, spraying the lower 12 to 18 inches of the trunk down to ground level, oil solutions of 2,4-D and 2,4,5-T at concentrations of 1 to 2 per cent acid give excellent top kills of a rather wide variety of woody plants. Generally 2,4,5-T appears more effective than 2,4-D on an acid equivalent basis, especially in dormant treatments. On the other hand, these solutions seldom give good kills of the sprouting tissues below ground level unless large amounts of the solutions are used. It appears that these chemicals increase the contact toxicity of oils but there is little movement of these chemicals downward in the tissues from the point of application. For the control of mesquite, scrub oak, chaparral, and many other hardwoods, 1 per cent acid solutions of 2,4,5-T in oils gives low cost control providing sufficient amounts are used around the base of plants to reach all of the sprouting tissues. The volume of solution used appears to be more important than concentration of solution.

For cut surfaces, or stump treatments these chemicals in dilute solutions give results in accordance with volumes of solutions used around the base of the plants. When more concentrated solutions containing from 2 to 4 pounds acid per gallon in water are applied to cut surfaces, frills, etc. movement occurs downward, probably by diffusion. Other chemicals such as ammate, sodium arsenite also move in a similar manner. The depth of the lowest sprouting tissues and ease of thorough application will determine the effectiveness of this treatment. Since movement of chemicals is primarily upward or downward with only limited movement laterally from the point of application, care must be taken to treat a high percentage of the tissues around the circumference of the stem or tree trunk.

Foliage applications. For small plants and sprout growth 1 pound acid of 2,4-D or 2,4,5-T as the ester or amine in 50 gallons of water will give good control when applied in sufficient amounts to thoroughly wet the leaves and stems of a wide range of brush plants. These applications should generally be made soon after the plants reach the first heavy foliage stage in the spring. For sage brush 2,4-D appears more effective than 2,4,5-T, while for mesquite 2,4,5-T appears superior. Mixtures of 2,4-D and 2,4,5-T should be used where mixed species of brush prevail. On extensive areas airplane application is more effective and economical than ground spraying.

Dense Stands

The most economical method of controlling dense stands of mesquite, sand sage brush, scrub oak and other brush species that grow in dense stands on rangeland is the use of swath treatments. These methods lend themselves to the rapid

treatment of extensive areas under widely varying conditions. They are usually more economical yet quite often give less effective overall brush control. Again, the swath type treatments must be used with caution in areas where mixed brush prevails since these treatments may promote the growth of undesirable plants that are resistant and more difficult to control than original stands.

Airplane application of chemicals. Extensive experimental studies have shown that reasonably effective control of mesquite and sand sage brush may be obtained with aerial application of chemicals. For mesquite 2/3 pound of a low volatile ester in 1 gallon of water clear diesel fuel and 3 gallons of water per acre has given excellent kills of above ground growth and root kills of 30 to 40 per cent under favorable conditions. Moreover, highly effective control of most annual range weeds has been obtained in addition to the control of mesquite. The amine salt of 2,4,5-T is almost equally as effective as the low volatile esters of 2,4,5-T but due to prevailing hard water in a greater portion of the mesquite area difficulties are encountered in preparing stable emulsions with diesel fuel. Under optimum conditions 2,4-D approaches the effectiveness of 2,4,5-T, however, due to its rather narrow range of toxicity on mesquite, 2,4-D, under field conditions, usually gives highly erratic and inconsistent control of mesquite. Furthermore, the increased amounts of acid required and the greater hazard of 2,4-D around susceptible crops, such as cotton, preclude its use for control of mesquite. There has been no advantage for the use of mixtures of 2,4-D and 2,4,5-T and these combinations tend to possess all of the disadvantages of 2,4-D.

To further reduce the hazards of aerial application of 2,4,5-T spraying equipment is used that delivers the emulsions in moderately coarse droplets of approximately 450 microns in diameter. Comprehensive tests under field conditions have shown that these large droplets are equally as effective as finer sized droplets and much less hazardous from the stand point of excessive drift.

Sand sage brush has been effectively controlled with 2,4-D ester at rates of 1 pound acid in 3 gallons of diesel fuel or in an emulsion of 2 gallons water and 1 gallon diesel fuel. The amine or sodium salt of 2,4-D has also been effective. Sand sage brush is not controlled with 2,4,5-T

For the control of post and blackjack oaks some promising results have been obtained in Oklahoma and Texas with mixtures of 2,4-D and 2,4,5-T when applied in the first full leaf stage of growth in the spring. The rather highly erratic and inconsistent results of previous experimental applications, however, indicates that further study is needed before effective and economic control is assured. Repeated applications of these chemicals offer a means of increasing the forage production of native grasses in both the scrub oak and shinnery oak areas but the overall control may not be economic.

In general the first heavy foliage stage of growth in the spring appears to be the best time to treat mesquite and sand sage brush. During this season of the year plants have reached the low point of root reserves and probably are in a more vulnerable condition than at any other time. Furthermore, the young growth appears to absorb the chemical in greater amounts since the leaves are not as well protected by leaf waxes, and the plants normally are making rapid growth. Mesquite and sand sage brush usually reach the heavy foliage stage about 6 to 8 weeks after the first leaves appear in the spring. The period when these plants remain highly susceptible to growth regulator chemicals extends over a period of about 50 days. Soil moisture and temperature should be normal to favor rapid development of plants prior to treatment. Small seedling plants or young plants generally are more easily controlled than old less vigorous growing plants.

Effective use of growth regulator chemicals for the control of sprouting shrubs such as mesquite, sand sage and scrub oak is dependent upon translocation of the chemical or its

effects from the foliage through the phloem to the zone of tissues that originate sprout growth. This zone is usually located near the ground level or a few inches below, depending on species of brush and environmental factors including soil deposition, etc. The degree of translocation of growth regulator chemicals is largely determined by the physiological development and condition of plant, chemical formulation, and method of application. With the movement of growth regulator chemicals being closely associated with plant conditions 5 rather distinct types of response occur following application: (1) no apparent effect (2) defoliation (3) kills of above ground growth (4) kills of above ground growth and inhibited sprout growth and (5) complete kill of the plant. A quick test indicator of plant development and condition would do much to explain the inconsistent results frequently obtained. Experience has shown that as conditions become more favorable for growth, translocation of chemical or its effects increases and treatments become more effective. There will, of course, always be differences in response due to plant variation and other factors. Thus, perfect control will seldom be attained with any one treatment. A careful study of the factors that influence the movement of these chemicals probably holds the answer to more effective control of brush with present day chemicals.

Cabling or chaining. The greatest value of cabling, or chaining, is low cost. Generally this method is not very effective, but it opens up brushy areas to permit better management of livestock. If cabling or chaining is undertaken, some plan should be made to treat the area again within a few years to prevent the heavy re-growth of sprouts.

Cabling or chaining consists of two heavy-duty tractors running parallel to each other about 100 feet apart dragging a loop made of 300 to 400 feet of heavy-duty anchor chain or steel cable. In most instances, heavy anchor chains are more effective in uprooting mesquite and are more serviceable than cables. This treatment may be quite effective for the control of large stiff-stemmed trees, especially when the soil is wet. On many-stemmed mesquite, double chaining or cabling rather effectively destroys the top growth but seldom destroys many of the roots, and vigorous sprouting takes place in a few months. When properly used, chaining or cabling in combination with other methods, may reduce the cost of control. This method should be used with caution on areas where mixed brush predominates.

Heavy-duty rolling cutters. The heavy-duty rolling cutter shows some promise for the control of mesquite mixed in with species that cannot be controlled by other methods. In general, the use of the rolling cutter is costly and the benefits obtained are not lasting. Under conditions where repeated treatments are feasible, light-weight rolling cutters give good control of sprout growth.

Mowing, brush beaters, etc. Control of sand sage brush may be obtained by mowing the plants with specially equipped mowers or beaters on two successive years during the month of June when the plants have reached a low point of root reserves. Sand sage brush has a limited storage area for root reserves and since the zone of sprouting tissues is relatively shallow it is quite readily controlled by repeated mowing, etc. Mesquite, shinny oak and other plants with more extensively developed root systems and storage areas are not as easily controlled by removal of top growth.

Brush plows. The brush or root plow is useful for clearing land for cultivation but the operation generally is too expensive and destructive of grass cover for the control of mesquite on range land. On highly productive sites, this method of clearing may be desirable when followed by seeding to nutritious and productive grasses.

SUMMARY

1. Control of mesquite, sand sage and scrub oak has increased steer gains, reduced labor and difficulties of caring for livestock and permits better use of the range.
2. Effective control on extensive areas must be easily adapted to varying condi-

tions of brush and topography and low enough in cost to permit retreatment.

3. Brush species may be divided into three large groups (1) non-sprouting (2) crown sprouting, and (3) crown and lateral root sprouting. The greatest strides in brush control have been made with the non-sprouting and crown sprouting species.

4. For the control of thin stands of brush or initial stages of invading species individual plant treatments appear desirable.

5. For dense stands swath type methods of treatment offer the most economical means of control.

6. The effectiveness of growth regulator chemicals is dependent primarily on susceptibility of the species, physiological condition of the plant and factors affecting the growth of plants. Other factors include methods of application, rate of chemical used, carrier, etc. The control of sand sage and mesquite with growth regulators has been accepted by ranchmen and stockmen.

7. Fire, mowing, brush cutters and brush plows have merit for control of brush under certain favorable conditions.

Further References.

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QUESTION BOX

BILL HARVEY: The idea of this session is to give you folks a place where you can bring up the questions that are bothering you. We will bat them around a bit and see what kind of answers we can come up with. The panel tells me they will not guarantee the answers they give, but they're just going to tell you how they feel about these various questions. Now we do not have too many questions out of the question box which may be fortunate, in view of the time we have, but we'd like to supplement them with questions from the floor. So if the answers which our experts give to the questions suggest other questions, will you please stand up real bravely and ask them because we are going to spend this hour answering questions. A good part of the success of this part of the program is going to depend on you folks so will you join in with us in asking questions and contributing information.

Although we do have a distinguished panel here, I am sure they'll agree they do not have all the answers to all the questions. Some of you boys who are out in the fields spraying every day can pick up a lot of answers. Any one of us, or any half-dozen of us are limited in what we can accomplish, how much work we can do and how much work we can see. Some of you out in the states and out in the counties working have an opportunity to find out things that we don't have and you have a responsibility to us to tell us about these things. Don't let us be ignorant forever if you know better, so we'll expect some contribution out of you folks. Now let us get started with the questions that have come in. Some of them have been directed to particular people. This first one is to Dr. Rasmussen and it says, "On your Canada thistle work, how much water in terms of gallons per acre did you apply and did you try mixtures of 2,4-D and 2,4,5-T?"

DR. RASMUSSEN: The water used the first two years in those tests was 72 gallons per acre. The next two years, since the stands were bigger, I cut that in half, down to 36 gallons per acre. Was there something else?

HARVEY: Did you try mixtures of 2,4-D and 2,4,5-T?

DR. RASMUSSEN: Not on Canada Thistle. I tried that on a tough little plant we have in the Northwest, "Gromwell", which is infesting much of our wheat land and Gromwell is a tough weed to kill in case any of you haven't tried it. It's a close relation to the "Fiddle-neck or "Tar Weed" plant, largely a winter annual, occurring in winter wheat and I tried on that the 50-50 mixture of 2,4-D and 2,4,5-T. The results were just about what you'd get if you diluted the 2,4-D; in other words, the 2,4,5-T was detrimental rather than beneficial in that particular test, but I didn't try the mixture on Canada Thistle.

HARVEY: Do you have some other questions on "Canada Thistle" while we are on this one.

This next question is directed to Jess Hodgson. The question concerns "White Top". "Was or is, 2,4,5-T in combination with 2,4-D better than 2,4-D alone and what rate of 2,4-D per acre do you recommend?" and with how much water?"

JESS HODGSON: We've had 2,4,5-T in our chemical tests about one year. Those initial results show no advantage to a straight 2,4,5-T or a combination of 2,4,5-T with the 2,4-D over the 2,4-D alone. In our work we have been using 2,4-D with 25 gallons of water per acre. I have not run rate tests on that--different gallonages. Perhaps Seely, who has run considerable work with gallonages might give some light on that particular rate of water. What rate of 2,4-D per acre do you recommend? We recommend 2 pounds to the acre on "White Top".

HARVEY: Let's see if there are any other questions on "White Top".

VOICE
(From the floor) What about the heavy Esters?

HARVEY: The question is--"What about heavy Esters on White Top?"

JESS HODGSON: Again, we have just put the heavy Esters into our tests. Our preliminary results do not show any advantages of heavy Ester over the Amine or Ester types. That picture may vary within a year as we get further results from our tests.

VOICE:
(From the floor) Does that same question as a whole, apply to Canada Thistle?

HARVEY: The effect of heavy Ester on Canada Thistles--Dr. Rasmussen?

DR. RASMUSSEN: I am in the same position as Jess, I just put some on two years ago and got some indications or some preliminary results last year, but those showed no advantage of one form over the other. While I'm on that--another point was brought up here. Did I use any Amines? I have one test on which I didn't report this time in that I'll be more ready to report next year in which I have both Amines and regular Esters applied with water and applied in both diesel oil and the lower toxic carrier oils and applied in water with 3% oil emulsification. On that after one year, the results are as uniform as its possible to have them. In other words, it looks like I've used the same material at the same rate on all of them. Now whether they'll begin to differ next year is what we'll see and report to you next year, but so far, they look very equal under our conditions.

ERICKSON: Is there enough growth on White Top in the fall to justify fall spraying?

HARVEY: The question is: "Is there enough growth on White Top in the fall to justify fall spraying, Jess"?

JESS HODGSON: Very definitely, under many situations there is. We have in our tests comparing the spring and fall applications a

little advantage showing up for fall applications only where one application a year is made. However, the plots on which we put two applications, the spring and fall application, there was not a good growth for a fall application. If we had made an effective treatment in the spring the growth was quite erratic in the fall. The results of those treatments over a period of time did not show enough advantage to two treatments a year to warrant using two treatments a year, where we had made them at the right time and had gotten good results. Normally White Top, when it comes out of its dormancy after the hot summer months, if there is any moisture there, will make a very luxuriant growth which can be very effectively treated with 2,4-D in the fall.

HARVEY: Thanks, Jess. Well, we have got some other weed problems that apparently are not as well solved. We might as well see what our experts can tell you on those. This one is a bit broad but I think we can handle it by not trying to cover the whole field. The question is, "Discuss the chemical control of Quack Grass." Now we might share that a little bit with a couple of experts. We might try Virg Freed first. I know Virg has been interested and associated with Quack Grass for a number of years and he may have killed some. Let's see.

FREED: We have been working with Quack Grass -- chemical control of Quack Grass for about four years. We've tried a fairly complete list of chemicals for control. Briefly summarized, I still think cultivation is the most practical means of controlling Quack Grass on any large infestation. Chemical control is best adapted to spots for Quack Grass and special problems. As for chemicals to control it, we have sodium TCA which we find is quite effective for Quack Grass control when used properly. We find that under our conditions, of rather wet winters and spring, we have made most effective use of TCA along in late May or June as it begins to dry up. We don't have too much more rain, but we still have good soil moisture. Applications of about 120 lbs. per acre will give us upwards of 90% control. We have used both IPC and Chloro-IPC on Quack Grass and, I might add, effectively. They are best applied in the late summer or fall under our conditions and probably under any conditions. They are most effective in the late summer and fall as you are going into a lower temperature period. The application there is made with about 16 lbs. of the carbamate in 100 gallons of oil per acre. Where the situation permits, disking within about ten days or two weeks is helpful. We have used that program for the control of Quack grass around trees, in caneberry plantings and so on, quite effectively. We are still screening chemicals against Quack Grass and one of them, CMU, is looking fairly promising at this early date, on the control of Quack Grass. There are other chemicals you can use, but I think your principal ones will be TCA, Sodium Chlorate or Chlorate-Borate mixtures, possibly carbamates and perhaps, eventually, CMU.

RASMUSSEN: Just in addition to what Virg has said and incidentally, I was glad to hear him say that he had to use that much TCA because they have been coming over and telling me that Virge could kill that with just a little bit of TCA, and I find he has to use as much as we do.

We put out some tests in the Ellensburg area which is just East of the Cascade Range. It gets a lot of precipitation in the winter and

the land is irrigated for crop production in the summer time--rather dry, windy summers. On a field of Quack Grass that was very solid we put on rates ranging from 80 to 200 lbs. per acre. First we plowed the area, then laid the application, then disked the area and followed with the second application later in the fall--the first one being made in August, the last one being made the last of September. We had hoped to carry that through last summer, but a farmer got enthusiastic and seeded the whole thing to barley last spring. We didn't completely lose because the amazing thing was, we got sufficiently good control of the Quack Grass that he had a very nearly normal appearing stand of barley with no evidence of residual effect of the TCA. As nearly as we can estimate in trying to reestablish our plots last June in the midst of his barley field where we had used rates in the excess of 100 lbs. we had in the neighborhood of, I'd say, 90% control of the Quack Grass and a very good stand of barley. I just threw that in, I thought you might be interested in that apparent rapid disappearance of the material.

HARVEY: Thank you, Lowell, that's fine. Vic Bruns, from the Prosser, Washington Station has Quack Grass and has been working on it. What can you tell us about control of Quack Grass?

BRUNS: I think quack grass is probably our number 1 problem. At least it's the problem that's hardest to solve up there in our area. Now I can speak only of experience I've had in the Yakima Valley where we have annual precipitation of about 7 inches and most of that comes in late fall and early winter. We also have a very little sandy soil and other varied conditions. Of course, Quack Grass grows under so many different conditions that practically every Quack Grass at the Station is an individual problem. Up in our area a favorite habitat with Quack Grass is along drainage ditches and subby areas or areas with a relatively high water table -- there it's really a problem. There it starts and from there it spreads. I'll handle it this way. I am not going to make recommendations, Bill. I'm going to tell you how I would handle it if I had it on my place. I have some property up there and believe me, I am keeping an eagle eye open to see that it doesn't get started on the place because it's hard to eradicate once it gets started. Now let's assume that we are trying to get rid of small patches on the higher lands - that's on lands where you do not have subby conditions. If it's small patches and you don't mind a sterility period of from 1 to 4 or 5 years, I would use Sodium Chlorate, perhaps, like Virg has mentioned previously. It does a good job when applied in the fall. In all cases, we find up in our area that fall applications are by far the best, simply because we have most of our rainfall in the fall or early winter. We have very little precipitation in the spring or summer. Now if I had Quack Grass infestation in my garden or a nursery or someplace where the land was very valuable to me, I might use TCA. Although I've been working with this material since 1947 I cannot generally recommend it because we have found that as much as 450 lbs. per acre applied over a period of two years will not effectively eradicate Quack Grass on otherwise undisturbed conditions. However, fall applications of over 130 lbs. applied the later part of September or the first part of October will give excellent control of

the Quack Grass until about the first week in June of the following year then the Quack Grass starts to come back. For some reason or other TCA seems to, shall we say peter out, before it gets down and gets the final roots and rhizomes. You get some grow back, but we have found that perhaps 3 maybe 4 cultivations or hoeings will complete the job so I would do this under those conditions; I would put on the TCA in the fall and I would watch the area until about June the next year, take my hoe, maybe one like Lee Burge got, or a field cultivator and wipe it out. I think it can be done very easily that way. Now, if I had Quack Grass in a subby area, I don't know what I'd do. I know that Sodium Chlorate and Atlicite won't do the job there. I'd keep my fingers crossed and hope that this new CMU would do the job. We hope it will, and I think it might have possibilities.

HARVEY: Thanks, Vic. Now there's a story on how to handle your Quack Grass. That answers your question I think. Now let's get down to a weed that's bothering some of you around this part of the country. Fortunately we don't have much of it in California, but I understand there's, oh, as much as 4 or 5 acres up here in Nevada.

There are two question here about the toxicity of Halogeton and we're going to ask Dr. O'Harra who has been working on this very problem, if he'll give us a rather brief answer to these questions. I'll let you read the question, or Dr. O'Harra.

O'HARRA: Maybe if I read it I can have a little time to think. "Do you have any information as to Halogeton toxicity to cattle--that is, amount and or time season?"

We have been doing some work on Halogeton and cattle this fall. We prepared these cattle by feeding them a diet mostly of meadow hay to get them on a low calcium balance - as low as we could and keep them in a strong state of nutrition; then introducing mature Halogeton into the rumen or paunch of the animal through a stomach tube, trying to approximate natural eating as nearly as we could. I found that one kilogram or 2 2/10 lbs. of Halogeton to 500 lbs. body weight, and these are yearling cattle that we are using now, will give symptoms in from 9 to 12 hours and death in from 14 to 48 hours. The first symptoms are those of typical hypocalcemia and are a lack of calcium such as you might see in a milk fever which seems to be corrected quite readily. An injection of calcium gluconate and the reaction is beautiful. In 10, 15, or 20 minutes the animal that we have used have been back on their feet, apparently normal; and then the secondary action takes over which I am not prepared to answer yet today, seems to be a little slower - a little more insidious - and just as just as fatal as any other type of poison.

The second question "What is the minimum tolerance of Halogeton sheep or cattle can eat and live and is the abortion rate increased by heavy feeding on Halogeton infested land?" The work done at the Experiment Station on sheep last year was done on pregnant ewes on a medium or high calcium diet, good alfalfa hay and grain. Of course, a pregnant ewe has a greater calcium need than an open ewe. Dr. Vawter fed these sheep. I believe the heaviest pen of feeding got 100 grams of mature Halogeton each day in their grain ration. They went through normal pregnancy and dropped apparently normal lambs and went on as though they had been eating only a normal diet. This year we have made a change. We started these sheep

early, feeding them the lowest calcium prairie meadow hay that we could find. We're feeding a minimum of grain - only enough - making it with beet pulp to get them to take the Halogeton which they don't like very well, but the amount of grain is small. These ewes bred late and in one pen we started them in 75-100-125-150 grams of Halogeton daily which is quite a heavy dose of Halogeton. In the two heavier pens, the pens getting the greater amount of Halogeton, - at present we have had one abortion in each pen. The controls of these taking the lesser amount of Halogeton have been normal. However, I would hesitate to say yet, that these abortions are due to Halogeton. We haven't had enough abortions and we haven't had any symptoms whatsoever that I would feel free to say that Halogeton is contributing to these abortions. Probably in the next two to three weeks, as these pregnancies advance and the lambs get heavier we may get some results that will give us a little more conclusive evidence.

HARVEY: Thanks very much, Dr. O'Harra. Do you have another question on Halogeton toxicity while we've got Dr. O'Harra here who knows the answers?

VOICE: Did you standardize Halogeton oxelates from these feeder tests?

O'HARRA: Dr. Dye has made chemical analysis of all these Halogetons that we're using in the feeder tests and they are standardized primarily on the amount of oxalate. That is what we have taken for our basis of standardization.

On the blood serums taken from these animals we have been keeping very careful check on both calcium and phosphorous in the blood serum. On a toxic dose of Halogeton the calcium drops very readily. It will drop from a normal of 10 or 11 down to, well, on these animals I'd wait until the very last minute and the symptoms were very advanced, draw a blood sample at that time before administering the calcium and those have dropped to I think, three or less. After administration of calcium the blood serum comes up immediately and the deaths that we've had have apparently not been due to hypo-calcinity because it's been running around seven which is very adequate. The phosphorous maintains itself or even rises a little which I speculate is due to the amount of dehydration in the concentration of serum which brings the phosphorous up on the analysis.

HARVEY: We will go ahead with our next question now. This one is - "What information is available as to the advantage in the use of wetting agents spreaders, and spray adjuvants in herbicidal mixtures. Dr. Crafts will you wrestle with that for a few minutes?"

DR. CRAFTS: We have quite a number of observations and a lot of opinions on this matter, but very little facts and figures. The difficulty is that there are so many of these materials that it is difficult to make any comprehensive studies. I have a boy starting to work this spring on the problem of cuticle and permeability and I hope that he may make some comparative studies on

various adjuvants of this type. We know for instance, that if we are depending on differential wetting for selectivity, we want to avoid the use of any of these materials which will lower surface sensitivity, and increase spread. The place where they seem to fit best is in the control of deep-rooted perennial weeds, or in brushy species where we want translocation. It is a matter of getting material into the plant. By using that bean test which I described yesterday we have done a few comparative tests and if we only run one comparison, say between a dozen different materials of this type, Multifilm, Trem and all of these different wetting agents you can usually arrange their results in some regular order, one being the best and going on down through to the poorest. But then if you repeat the experiment, they don't arrange themselves in the same order in the second test and the more tests you run the more confused you become. I think there are certain logical places that certain materials fit. For instance, if we are fortifying oil with pentachlorophenyl we want a wetting agent in there that is compatible with the oil, and the phenol. Usually the sodium sulfonate-petroleum sulfonate type of wetting agent like the Oronite or R-400 are the best materials.

Now these non-ionic forms, of which there are many on the market now help in the penetration of 2,4-D and that type of material through the cuticle in getting into the plant so that you can get better results with translocation. I am hoping that some of the poly-ethylene-glycol types where we have, as I mentioned yesterday, a balance between water and oil solubility will help to open up the cuticle and get materials in. Dr. Leonard is trying quite a few of these materials and he has very definite evidence that under certain conditions, particularly where it is difficult to get the materials in, that there is a decided advantage. In the early work we used to standardize on 1/10% as enough to reduce the surface tension down to a place where we got good spreading. We have, I think, fairly definite evidence, that you can go on up to at least 5/10% and still get increased effectiveness due to the fact that you are getting increased penetration in addition to wetting as a result of the use of these materials.

HARVEY: Lowell, do you or Virg have anything you would like to add on that?

LOWELL: Nothing as far as I am concerned. This agrees with what I have observed.

HARVEY: Virg doesnot have any more to add to that one. This one we will probably have to give to Jess Hodgson - the question is - "How potent are these water herbicides on fish life?"

HODGSON: I assume that the aromatic solvent type aquatic herbicides seem to be very potent on fish - evidently the difficulty there being in the breathing apparatus and we note that they will try to get out of the concentration as it moves down the stream, but if they do not get out of it they will soon be laying on their belly floating down the stream - it doeskill then alright.

HARVEY: The question was asked about livestock poisoning from these solvent treatments.

HODGSON: We do not have any data on that. However, with the concentrations that we are using, the animal would have to drink a tremendous amount of that water to get a very small amount of the material. Also, being oil-like, it is obnoxious to the animals' taste and generally they will leave it alone and not bother it. I believe there has been some work on Benachlor, which is a somewhat similar material and as I recall the results the lethal dose was such that they would have to consume much more of the treated water than was possible to get a lethal dose. That is about the best information which I have, perhaps someone in the audience has more, I don't know.

HARVEY: While we are on these aromatic solvents, are there some other questions, for Jess or Gene Oborn, or some of the other boys?

VOICE: Effect on the crops?

HARVEY: Jess I know has been working on the effect of these aromatic solvents on crops.

HODGSON: We have been testing them in irrigation waters on crops for about 3 years and we have run concentrations on up as high as 2400 parts per million which is around 5 times the recommended dosage and we have not gotten any appreciable reduction in our yields. There has been occasion such as a flood irrigation on spring wheat where we did have some reduction at 2200 parts per million; however, when you consider that most of our recommendations for treatments are in the range of 400 to 800 or maybe as high as 1200 in some cases have not had any damage to crops such as potatoes, corn, beans and grains. Some of the other fellows have been running tests as well. Fred Arle and Vic Bruns ran some early work in the lab. Fred you ran it on cotton and maize and one other thing there, do you have any comments to make?

FRED ARLE: We ran it on cotton, maize and alfalfa. Yields were not effected. This summer we found a very, very slight reduction in yield which did not amount to anything. In grain sorghums we did get a definite reduction at 1600 parts per million. We irrigated using the solvent in our irrigation water for three irrigations to bring the crop to maturity. All of the damage occurred in that first irrigation which destroyed about a third of the plants and reduced the yield correspondingly.

HODGSON: Now speaking of these concentrations, perhaps that is confusing. In my tests at least, these concentrations were held for 30 minute periods - now 400 parts means roughly, a little less than 6 gallons of material per cubic foot per second flow of water. That material was applied during the 30 minute period, you see. Each time you double your concentration up to 800 to 1200 and so on, you can see that you are getting into a pretty high rate of application, much higher than the recommended rate for water weed treatment.

HARVEY: Thanks Jess - our time is running short and we will have to roll along. The next two questions are somewhat different, but they concern the same crop and that is "Weeds in alfalfa".

One of them is how to control dodder that grows on morning glory in second cutting of alfalfa, and the second one is how to eliminate rye from an alfalfa field without cutting the hay early? This is from Lovelock, Nevada - Is that rye grass or tame rye?

F. BATCHELDER: Tame Rye-

HARVEY: Yes, Crop rye. Orvid Lee, I believe is here and could give us some information from the work he and Timmons have been doing.

Lee: Well, the only one I know anything about is dodder; so far the work that has been done at Logan has been more exploratory work, so we do not really have too much on it. However, the only thing we have tried so far that gave any degree of control at all, was straight aromatic weed oil - 120 gallons per acre applied after the first cutting of alfalfa. This has been an exploratory experiment so we do not know just what range can be used - probably 60, or 40, or 80 gallons. Work will be carried on next summer and maybe we will have more results by then.

HARVEY: Thanks Orvid. We have used aromatic oils in California for dodder control and either a straight oil or an oil-water emulsion, or an oil, dinitro, water emulsion - are the common things we use for control there. Down where we are, we do not have tame rye as a problem but I think we would handle it with an oil emulsion spray just about the time the alfalfa was breaking out of dormancy in the spring. An average dosage might be 50 gallons of oil, 70 or 80 gallons of water and perhaps a quart of D.N. General per acre. Now you may have to vary the oil, or you may have to vary the D.N. a little bit to fit your conditions. We sometimes in the spring start with 35 to 40 gallons of oil and by the time we are through spraying are up to 60 gallons of oil because the grass gets bigger and the grass gets tougher and it gets a little harder to get. I think IPC is another possibility. Virg, how good is IPC on rye? Virg says IPC handles rye plenty well and we have been using IPC in alfalfa for some of the other grasses.

VIRG: You might add that before your rye gets out of hand you will have to use some oil with the IPC.

HARVEY: Virg says before the rye gets out of hand and is getting bigger, you may have to use some oil with the IPC to get a top burn on the grass and then let the IPC kill the roots.

Now there is a question here about use of oil on Halogeton in Idaho that I think I will refer to Lambert Erickson.

ERICKSON: The question is why haven't oils - he specifies some particular oils here - he says Richfield A and Pentox, too - why have they not been tried in Idaho. There are several reasons why we have not gone into the oil on a large scale basis. The work that Morton reported already involves about 500 plots and there is very definitely a limitation as to what any one man can do. That is one of the very good reasons why we have not gone extensively into oils. However, we have had oils out there in small quantities in some tests. One reason why we have not gone heavily into oils is the fact that in the stands of Halogeton there is frequently some grass. We want to maintain all the possible sensitivity that we can get in order to get that grass to come along back,

we don't want to leave the spaces wide open. We have to get something there to fill them again and for that reason we don't use a general contact killer- one that would take everything out. We want to revegetate that ground and I think that it is one of the things on a large scale we want to be careful of. However, on a small scale basis on small infestations there may be a place for oils.

HARVEY: It's approaching 12:00 o'clock but we can stand another question or two from the floor.

VOICE: Special agents on Russian Knapweed?

ERICKSON: I will tell you of the battle we have been conducting for the last five years. This area was once a solid mass of weed and completely out of production - it had been that way for approximately twenty years when we took it over. We started in on 4# per acre of various material and after testing out a series of 2,4-D compounds we finally settled on the Amine form because we were getting just a little better effect with the Amine than with the other materials that we had in the test and that included quite a complete roll of Esters available at that time. That was in '47 and then we plowed the same and planted it to a pasture mixture. Since that time it has been in pasture with a good stand of grass. We have been in there every year since with 4# of 2,4-D Amine. The grass stand is holding up and we have reduced the Knapweed stand a total of 97%. There is still Knapweed in there - you don't notice it as you drive along, but as you out to get the count you see the Knapweed in there. This year we have changed the plan- we are plowing it up and putting it into wheat. We anticipate a tremendous growth of Russian Knapweed seedlings, because of the tremendous number of seeds that there must be in that soil. We anticipate carrying on a selective wheat program, for possibly two years, then possibly switch into another crop and then come back to grasses again so that by following a combination system, we manage to get a consistent reduction in the Knapweed stand and also provide a piece of ground with some income on yield.

VOICE: One question for Lambert. What stage of growth was the Knapweed in when you made your sprays.

ERICKSON: Always in the bud stage. Early bud stage, in fact, and we incidentally learned a lot of interesting things. We started out with this treatment in June and after two years of these treatments of 4#, we made a treatment in June and the count was way down. We thought we were really going to town on this thing and about the first of August, H.Y. Meacham, the County Weed Supervisor, wrote me and said that we had missed the boat on this thing because there was a lot more regrowth than there was at the time we treated it in June. In that particular year we had two treatments of 3# each and since that time we have varied the treatment to get the type of treatment we were seeking.

HARVEY: I would like to put just a little bit of our information on some of the drier areas of California. We are finding out that LV esters are looking a lot better than any of the other materials at the moment, on small dry land Knapweed and there are spots in California

that are quite dry normally. We have tried all sorts of mixtures and have had very erratic results on Russian Knapweed. We think moisture is a big factor. We are getting better control where we have adequate soil moisture than on dry ditch banks. Where we can irrigate, keep soil moisture up, keep the weeds alive and healthy and growing vigorously, we seem to be doing very well with it. LV Esters are looking promising and also one of the emulsifiable acid formulations has shown good results in preliminary tests. I think our problem there is one that Dr. Crafts mentioned under dry conditions our Knapweed hardens off very rapidly and we just do not seem to be getting material into it. Knapweed is susceptible because I have seen kills up to very near 100% with one application, so it can be done. Our problem is to find a mixture or combination or formulation that will get into the plant and do the job more consistently than we have in the past.

REPORT OF THE EXECUTIVE COMMITTEE

WESTERN WEED CONTROL CONFERENCE

March 19, 1951

A meeting of the executive committee of the Western Weed Control Conference was held on the evening of March 19 at Boise, Idaho, with the vice president acting as chairman due to the absence of the president. Those in attendance were: C.I. Seeley, Chet Otis, F.L. Timmons, E.D. Whitman and Walter S. Ball.

The first order of business was the meeting to be held in Reno and it was suggested that the meeting be held the last week in January or the first week in February and that Mr. Lee Burge inform the committee as to the dates that he can arrange and that the meeting start on Monday and that the first day be given to the research session. It was further decided that Tuesday forenoon be a business meeting and registration and that the regular meeting start Tuesday noon and continue until Thursday morning.

It was moved that a committee be appointed by the chairman to act as a program committee and this was seconded and carried. The committee appointed was Robbins, Ball, Otis Timmons and Burge. It was agreed by the four last named members of the committee that a meeting could be held possibly in May in either Sacramento or Reno, inasmuch as Mr. Timmons would be in that area at that time.

Under the Report of the Association of Weed Control Conferences Mr. Ball reported on the publication "Weeds" which had not been presented to the Western Weed Control Conference due to the fact that this organization had not held its annual meeting. Attached is information relative to the new national publication.

The executive committee suggested certain amendments -- Under "Purpose" that the wording of this paragraph be changed to "Weeds will publish articles of interest to technical workers, teachers, regulatory and county officials, farmers and ranchers, and others desiring information on weeds and their control".

Under "Organization and Publication" it was recommended that under "I" that we have technical which would include research; under "II" Applied Weed Control and "III" Education and regulation, followed, of course, by a bibliography, news and notes. On the receipt of the subscriber it was suggested that his occupation be secured along with his name and address in order that we may have an index of the people purchasing the magazine.

It was moved and seconded that the publication of "WEEDS" be approved as amended. This was carried.

It was necessary that the executive committee suggest an associate editor for the Western region and Dr. W.W. Robbins was named, with Bill Harvey, as alternate in case that Dr. Robbins did not care to take this responsibility.

The next topic for discussion was that of a national meeting. A great deal of time was spent discussing this topic inasmuch as the Southern and Northeastern groups had agreed on a national meeting while the North Central had discussed but not acted upon it and the Western Conference, of course, has not had a meeting to act upon it. Following the discussion it was suggested that a national meeting be held only in case that it be rotated among the regions and that it be programmed by the Association of Weed Control Conferences in cooperation with the host conference and that the meetings be held every other year.

There followed a discussion concerning a representative to the other regional conferences. It was moved and seconded that no delegate be sent to regional conferences. Another subject taken up by the Association of Weed Control Conferences was the secretary of the Association would need funds for stationary, stamps and other incidentals relative to his secretarial work and it was recommended that each conference send \$100. It was moved, seconded and carried that the secretary of the Western Weed Control Conference be instructed to send \$100 to the secretary of the Association of Weed Control Conferences.

Closing the meeting a rather lengthy discussion was held relative to registration fees and charges for the research report. It was agreed that we comply with the constitution and charge \$3 for registration plus the cost of the research report which will have to be determined after the report is compiled.

The committee meeting then adjourned but on March 20th at 5 o'clock it was again called into session to take action upon a resolution presented by the research committee. The resolution in part read as follows: "That the research section pass a resolution to activate Halogeton control under WII RMA Project and that the executive committee take action." The executive committee considered this resolution from various points. They considered the action taken on Halogeton by the Western Weed Control Conference for the past 5 or 6 years and that at the present time ample information has been submitted to Washington and other public agencies relative to this weed and that the Washington officials are in the position to consider such action. It was further felt that there would possibly be some criticism in a resolution such as this emanating from a research committee. It was thought that it should possibly originate from the coordinating committee.

It had been suggested at the business meeting of the research committee that the chairman of the executive committee appoint the nominations

and resolutions committees. Mr. Seely submitted the following names for the nominating committee: Del Tingey, Chairman; Bill Harvey and George Harston; Resolutions Committee: Lin Harris, Chairman, Robert Warden and J. N. Robertson.

REPORT OF THE COORDINATING COMMITTEE

Boise, Idaho
March 20, 1951

The Coordinating Committee of the Western Weed Control Conference met in Boise, Idaho on March 20, 1951 with the following in attendance:

Lee Burge, Chairman
V.L. Cox, Member
Ray Whiting, Member
George B. Harston, Member
R.L. Warden, Member
Virgil Moss, Invited Guest
Speed Agee, Invited Guest
Dr. Tisdale, Invited Guest

The Committee discussed several items, considered to be of interest and importance to the Conference as a whole, and make the following recommendations.

1. That all possible efforts be made by states, financially able to do so, to set up a project under W-11, to include research on all weeds effecting the public lands; especially, Halogeton glomeratus.
2. The matter of a research publication was discussed. No further recommendation was made, other than the action taken by the Research Section in their regular meeting, March 20, 1951.
3. The uniform survey method proposed by the Inter-Departmental Committee in Washington was discussed and has the approval of this Committee as a basis of determining weed infestations. This report was submitted by a sub-committee, headed by Lee Popham, Bureau of Entomology and Plant Quarantine. We recommend that all weed men make themselves familiar with this proposal as early as possible.
4. Enabling legislation, permitting the Federal Government to cooperate with the proper state departments in chemical control, surveys, research and seeding programs was discussed and approved as presented in HR 1933 (S.1041). This legislation provides that the Federal Government shall make it a policy to develop surveys, research, and control measures on public lands for the control of Halogeton and other poisonous weeds, irregardless of ownership of land. Under the provisions of the legislation proper state agencies authorized by state law must enter into cooperative agreements with the Federal Government in order to obtain such financial benefits.
5. We recommend to the Executive Committee that the research section of the Conference be given a place in the regular program and that such meetings be open to the public. We further recommend that there shall be no "closed sessions" within the Western Weed Control Conference.

6. We recommend that the Executive Committee propose to the Western Congressmen that the sum of five million dollars (\$5,000,000.00) be appropriated by the Congress to carry out the provisions of HR 1933.

REPORT OF THE EXECUTIVE COMMITTEE

February 5, 1952

The executive committee met on February 5, 1952 to take up matters relative to the meeting. It was necessary to okey the bills for the re-search report which were as follows:

Utah State College	\$357.65
Herald-Journal Printing Co. for covers	<u>42.43</u>
	400.08

This was approved.

The next order of business was to appoint a delegate for the Association of Regional Weed Control Conferences and Ball was selected with the incoming president as alternate. The meeting place of the next conference was discussed but inasmuch as no invitation had been submitted to the executive committee this matter had to be postponed until later in the meeting.

The matter of the selection of State delegates was discussed and after a rather lengthy discussion it was decided that Chet Otis should present the ideas of the executive committee at the regular business session.

BUSINESS MEETING

The business meeting was called to order by Vice-president Seely who asked for the Treasurer's report which was read by Secretary Ball. Following the reading of the treasurer's report, which was approved, the president asked for the executive committee's report. The executive committee report was read and the following action was taken prior to the approval of the report:

Mr. Burge made a motion, which was seconded and carried, that the next meeting be set for either March or April.

The next matter of business put before the group was a motion by Anderson, seconded by Warden, that the constitution be changed to hold annual meetings. The president asked for the rise of hands and the motion was lost.

At this time a delegate from Arizona, Mr. Howard P. Cords, formally invited the Western Weed Control Conference to meet in the State of Arizona at its next meeting. It was moved by Mr. Fultz and seconded by Whitman that the next meeting be held in Arizona; the motion carried.

It was then moved that the executive report be approved as read following the general discussion. This was carried.

Chet Otis then discussed the matter of selection of state delegates setting forth the ideas that the state delegates should be chosen at each regular meeting of the Western Weed Control Conference by the state delegates in attendance and that they serve for a period of a term the same as the regular officers of the conference. (See recommendation of the Executive Board)

Mr. Seely then called upon the coordinating committee. (See report of coordinating committee).

The resolutions committee was then called upon and the resolutions submitted by Chairman Lin Harris were adopted. (See Resolution)

The nominations committee was then called upon. Chairman Tingey reported the committee selections as follows: President: Ball and Seely, Vice-president: Anderson and Warden; Secretary: Warren and Rasmussen.

The president asked if there were further nominations and Bill Harvey was nominated from the floor. Following the selection of officers they were:

President: Seely
Vice-President: Warren
Secretary-Treasurer: Bill Harvey

The meeting then adjourned

Recommendation of the Executive Board

Following is presented at request of W.W.C.C. Executive Board as a recommendation from it to the Conference.

The Conference has official state delegates. Their duties are to:

1. Be the liaison between Conference officers or executive board and conference members within the delegate's states.
2. Promote Conference activities within the various states.
3. Be responsible for preparation of state reports to the Conference.

In order to distribute the work load more equitably and establish a more workable election procedure the following amendment to the W.W.C.C. Constitution is proposed:

Paragraph 4 of Article IV, having to do with official state delegates, shall be changed to read as follows:

"Official state delegates shall be elected from among the voting membership of each state concerned by the voting members of that particular state. The delegates shall be elected at each meeting of the Conference and shall serve the same term served by the elected Conference officers. Alternate delegates shall also be elected in the same manner. It shall be the duty of the alternate delegate to fill out the delegate's unexpired term in the event the delegate vacates his office. It shall be the responsibility of the Conference president and/or executive board to provide for delegate elections at each Conference meeting".

RESOLUTIONS

Resolution No. 1

WHEREAS the success of the 13th Western Weed Control Conference at Reno, Nevada, Feb. 5, 6 & 7, 1952 has been in large measure due to the efforts and facilities furnished by the following organizations.

NOW, THEREFORE be it resolved that the Western Weed Control Conference assembled at Reno, Nevada, Feb. 5, 6 & 7, 1952 express its appreciation to:

Nevada State Department of Agriculture
University of Nevada
Reno Chamber of Commerce
Mapes Hotel

Resolution No. 2

WHEREAS research is the basis of weed control and
WHEREAS reports of research projects are important to members of this conference.

NOW, THEREFORE be it resolved that the 13th Western Weed Control Conference meeting in Reno, Nevada, Feb. 5, 6 & 7, 1952 Commend the Research Committee for the preparation of the Research Progress Report.

BE IT FURTHER resolved that this Conference commend F. L. Timmons and V. F. Bruns for the leadership of the Research Committee in organizing the committee to make the report possible. The Conference also extends its appreciation to F. L. Timmons for his work in preparing and distributing his News Letter.

ARIZONA

Arle, H. Fred
 Cords, Howard P.
 Irvine, Milt
 Norris, Lloyd E.
 Pearse, C. Kenneth

Div. of Weed Investigations, U.S.D.A., Phoenix
 Agronomy Dept., Univ. of Arizona, Tucson
 Dow Chemical Co., Phoenix
 General Chemical Division, Mesa
 U.S. Forest Service, Tucson

CALIFORNIA

Bahme, R.B.
 Ball, Carroll D., Jr.
 Ball, Walter
 Baranek, Paul
 Beck, Ralph R.
 Bernard, Gould E.
 Branstetter, Chas. H. Jr.
 Bronson, Art
 Calhoun, Wendell
 Christian, Jim
 Cook, F.E.
 Coulston, John
 Crafts, A.S.
 Daniel, Orin
 Dean, D.W.
 Drescher, Paul
 Ferris, Curt
 Fisher, R.A.
 Fix, Ernest E.
 Graves, C.E.
 Hall, Vernon
 Harang, Edward A.
 Hanson, W.J.
 Hardman, Newton
 Harrigan, P.V.
 Harvey, William A.
 Heckathorn, E.S.
 Henriques, A.R.
 Hinchman, Roger
 Hoagland, Alan R.
 Holloway, J.K.
 Holmes, G.R.
 Holzwarth, Charles W.
 Howard, Jim
 Hughes, William J.
 Hurst, J.C.
 Jones, Luther G.
 Klatt, W.L.
 Leonard, Oliver
 Lewton, Ted
 Littooy, Ed.
 Logan, John C.
 Long, Jack
 Lunsford, C.F.
 Mackenzie, Chas.
 Mahney, John
 Mazzetti, Dr. Paolo
 Meyer, George A.
 Miller, C.E.

E.I. DuPont Co., Sacramento
 Food Machinery and Chem. Corp, North Sacramento
 State Dept. of Agriculture, Sacramento
 A.E.S., P.O. Bldg, Madera
 American Cyanamid Co., Oakland
 Carbide & Carbon Chemicals Co., San Francisco
 Branstetter Flying Service, Sacramento
 Richfield Oil Corporation, Los Angeles 17
 Western Agric. Econ. Research Council, Berkeley
 Dow Chemical Company, Fresno
 Stauffer Chemical Company, Riverside
 Coastal Chemical Company, Oxnard
 University of California, Davis
 Sutter Orchard Supply, Yuba City
 U.S.D.A., San Francisco
 American Chemical Paint Company, San Jose
 Geigy Company, Fresno
 California Spray Chemical Company, Richmond
 Agricultural Commission Lassen County, Susanville
 E.I. DuPont De Nemours & Company, San Francisco
 Chipman Chemical Company, Inc., Palo Alto
 Spraying Systems Company, San Francisco
 Agricultural Research, Dow Chemical Co., Seal Beach
 Stauffer Chemical Company, Mountain View
 Glenn County, Memorial Bldg., Willow,
 Botany Div., University of California, Davis
 United Chemical Co., Richmond
 General Chemical Division, Sacramento
 Pacific Coast Borax Company, San Francisco
 American Cyanamid Company, Modesto
 U.S.D.A. and University of California, Albany
 B & H Equipment Company, Mt. View
 Food Machinery Company, San Jose
 California Spray Chemical, Yuba City
 Shell Agric. Laboratories, Modesto
 Hurst Industries, Inc., San Jose
 Agronomy Dept., University of California, Davis
 Pacific Coast Borax Co., Los Angeles
 Botany Division, University of California, Davis
 155 Montgomery St., San Francisco
 2598 Taylor Street, San Francisco
 Pacoast Chemical Co., Fair Oaks
 Shell Chemical Corporation, Sacramento
 Agricultural Chemical Division, Grace & Co., S.F.
 Mackenzie Chem. Corporation., 29th & R., Sacramento
 Standard Agricultural Chem., Sacramento
 Stauffer Chemical Company, San Francisco
 Chipman Chemical Company, Fresno
 Colloidal Products Corporation, San Francisco

Miner, L.H.
Nail, Jack R.
Nielsen, Walter R.
Offord, H. R.
Onstott, Ken
Otis, Chet
Ragsdale, W.E.
Raynor, R.N.
Rooke, Lloyd
Schuler, Ed
Scott, Roger
Scull, Charles H.
Sharp, P.E.
Strege E.A.
Strew, Stanley
Suggett, R.E.
Swezey, A.W.
Swingle, M.C.
Taylor, Cliff
Taylor, L.F.
Thurmond, Chas. D.
Tierney, George M.
Trimble, Jim P.
Trombley, C.F.
Turner, Jim
Underhill, Bob
Westgate, W.A.
Whelan, Bob
White, Loring
Wilbrand

Niagra Chemical Company, Richmond
E.I. DuPont De Nemours & Co., Piedmont
Triangle Company, 320 West Mkt., Salinas
U.S.D.A., Forestry Bldg., Berkeley
Rt. 1, Eddy's Air Service, Yuba City
Dow Chemical Company, San Francisco
Ragsdale Chemicals, Sacramento
The Dow Chemical Company, San Francisco
American Cyanamid Company, Los Angeles
Monsanto Chemical Company, San Francisco
Geigy Company, 10 E. Walnut St., Yakima
California Spray-Chemical Corp., Sacramento
Columbia-Southern Chem. Corp., Bartlett,
Stauffer Chemical Company, San Francisco
Chipman Chemical Company, Palo Alto
United Chemical Company, Sacramento
Dow Chemical Company, Seal Beach
DuPont Company, San Jose
Assoc. Seed Growers, Milpitas
DuPont Company, San Jose
Monsanto Chemical Company, Santa Clara
Modoc Company, Dept. of Agric., Alturas
U.S.D.A., Box 1339, Brawley
Monsanto Chemical Company, San Francisco
Atlas Powder Company, Los Angeles 13
Dow Chemical Company, San Francisco
Standard Agricultural Chemicals, Sacramento
Agronomist Sierra Ordinance Depot, Herlong
Department of Agriculture, Alturas
305 39th Way, Sacramento

COLORADO

Bardwell, C.M.
Blouch, Roger
Doran, Clyde W.
Fults, Jess
Harrison, R.J.
Hosticka, Harold E.
Maletice, John T.
Osborn, Eugene
Rogers, D.E.
Thatcher, Clayton
Thornton, Bruce J.

National Aluminate Corp., Denver
Botany Dept., Colorado A&M College, Fort Collins
Rocky Mt. Forest & Range Exp. Sta., Delta
Botany Dept., Colo. A&M College, Fort Collins
National Aluminate Corp., Denver
U.S. Bureau of Reclamation, Denver
Bureau of Reclamation, Denver
U.S.D.A. B.P.I.S.A.E., Denver Federal Center
2905 Chase St., Denver 14
Food Machinery and Chemical Corp., Fort Collins
Dept. of Agric., Colo. A&M, Fort Collins

DELAWARE

Burgoyne, D.L.

E.I. DuPont Company, 25 B Lancaster Ct., Wilmington

IDAHO

Atwood, H.F.
Boyle, W. Dean
Corn, Clyde L.
Cox, V.
Edwards, H.M.
Erickson, Lambert
Galloway, W.H.
Gault, H.S.
Hall, Delane

Lincoln County Weed Control, Shoshone
Bureau of Reclamation, Boise
Bonneville Co. Weed Control, Idaho Falls,
Ada County Weed Control, Meridian
Agric. Extension Service, Donnelly
University of Idaho, Moscow
Food Machinery & Chemical Corp., Boise
County Weed Supervisor, Twin Falls, Idaho
Power Co. Weed Supervisor, American Falls

Hansen, A.C.
Herring, Donald E.
Hodgson, Jess
Huey, D.L.
Jensen, Frank
Jensen, Wilfred L.
Johannesen, E.J.
Kautz, Don
King, John W.
Knox, Roy
Leise, Wm. K. Jr.
McCollum, J.D.
Mason, W.L.
Mecham, H.M.
Moffett, Rex C.
Morton, Howard
Moss, Irvin
Roylance, Howard B.
Seely, C.I.
Squires, Walter
Strand, T.P.
Sutton, Cecil
Whitman, E.W.
Whornham, George
Wilcox, F.O.

A.C. Hansen Company, Rexburg
Pres. Idaho Nox Weed Assoc., Moscow
Bureau of Plant Inc., Dept of Agric. Meridian
Gooding Co. Weed Control, Gooding
Ada County Weed Control, Boise
Madison County, Route 1, Rexburg
Ext. Service, Court House, Emmett
801 W. 2nd St., Weiser,
Rt. 8, Boise
Rt. 1, Emmett
Van Waters & Rogers Inc., Boise
Simplot Soil Builders, Box 110 Twin Falls
Nexperce Co. Weed Control, Lewiston
Jerome Co. Weed Control, Jerome
Stauffer Chem. Company, Idaho Falls
Univ. of Idaho, Moscow
Power County Commissioner, Rockland
Univ. of Idaho, Ext. Serv., Boise
University of Idaho, Moscow
Weed Control, Idaho Clear Water County, Orofino
Spray Chemical Corp., Caldwell
County Commissioner, Ola, Idaho
State Representative, Univ. of Idaho, Boise
154 7th St., Idaho Falls,
Freemont Co., Weed Supervisor, St. Anthony

MARYLAND

Lovvorn, Roy
Minarick, C.E.

Plant Industry Station, Beltsville
Camp Detrick, Frederick,

MISSOURI

Roos, Elizabeth
Stahler, L.M.
Taylor, George V.
Wangerin, R.R.

Monsanto Chemical Co., KXOK Bldg., St. Louis
U.S.D.A., Columbia
Spencer Chemical Co., Kansas City 6
Monsanto Chemical Co., St. Louis 4

MONTANA

Butler, C.C.
Cable, A.R.
Clem, B.L.
Hunt, C.R.
Myrick, D.C.
Warden, R.L.

Bureau of Teclamation, Region 6, Billings
H-C-L Equipment, Billings
Montana Flour Mills, Co., Great Falls
DuPont Company, Corvallis
Bureau of Agric., Economics, Mont. St. Col., Bozeman
Montana State College, Dept. of Agric., Bozeman

NEVADA

Albright, Archie
Bowser, Ernest W.
Bradley, Harry H.
Burge, Lee M.
Burma, George
Cook, Clyde Jr.
Copple, R.F.
Cox, Raymond C.
Creel, Cecil
Crowl, John

County Ext. Agent, P.O.Ex. 1789, Reno
Bureau of Reclamation, Boulder City
Assistant County Agent, Fallon
State Dept. of Agric., Reno
Nevada Indian Agency, Stewart
Indian Service, Owyhee
Bureau of Land Management, Reno
Nev. Ext. Office, Ninden,
University of Nevada, Reno
Bureau of Land Management, Carson City,

Dangberg, J.B.
Dye, W.B.
Funk, Ezra
Gardella, Louie
Hansen, D.
Kromberg, Marty
McCaslin, Harold
Peavy, John
Roberts, W. Lynn
Robertson, Joseph
Varnun, Jack J.
Whitbeck, C.
York, Charles R.

Minden, Nevada
Univ. of Nevada Expt. Station, Reno
P.O. Box 191, Elko, Nevada
County Ext. Agent, P. O. Box 32, Yerington
734½ W. Seventh, Reno
Kromberg Dusting and Spraying, Reno
Aircraft Service, 1694 Watt St., Reno
Bureau of Land Management, Ely
Roberts Aircraft Service, 1694 Watt St., Reno
University of Nevada, Plant Industry, Reno
Sunset Nursery Co., Box 2002, Reno
Wellington, Nevada
County Extension Agent, Fallon

NEW JERSEY

Alexander, C.C.
Brunton, J.G.

Geigy Company Inc., Bayonne,
Kolker Chemical Works, Newark

OHIO

Fosse, Richard

Monsanto Chemical Company, Dayton

OKLAHOMA

Welch, James

American Chemical Paint Co., Clinton

OREGON

Bates, Gene
Conaway, Norman C.
Craig, William F.
Eichmann, R.D.
Fitzpatrick, Al
Francies, Merrit
Freed, V.
Hansen, Lee R.
Harris, Lin
Hitchcock, O.B.
Miller, Roy
Pullen, Eddie
Robinson, Dave
Starker, Chuck
Sturges, Lee
Warren, Rex

Van Water's & Rogers, Portland
Willamett Weed Chemical Co., Eugene
Willamett Weed Chemical & Fertilizer, Eugene
Stauffer Chemical Co., North Portland
Pacific Supply Corp., Portland
Stauffer Chemical Co., North Portland
Official Rep., Oregon State College, Corvallis
Pacific Coast Borax Co., Portland
Chipman Chemical Co., Portland
U.S. Industrial Chemical, Portland
Foot of Southwest Carruthers, Portland
Van Water's and Rogers, Portland
Miller Products Company, Portland
Pacific Supply Corp., Res. Div., Portland
Stauffer Chemical Co., North Portland
Oregon State College, Corvallis

PENNSYLVANIA

Newton, W.F.
Turner, M.B.

Columbia Southern Chem. Corp., Pittsburg
American Chemical Paint Co., Ambler

TEXAS

Condron, Carl
Fisher, C.E.
Koogler, John G.

California Spray Corp., Uvalde,
Tex. Agric. Exp. Sta., Spur
Region 5, Bur. of Reclamation, Amarillo

UTAH

Anderson Bryant
Blanchard, T.L.
Davis, Wynn L.
Gore, H.W.
Hirst, W. Harold

Dept. of Agric., St. Rep., Bountiful
Dept. of Agric., Cache Co., Logan
State Dept. of Agric., Brigham City
State Dept. of Agric., Richfield
Bureau of Reclamation, Salt Lake City

Holmes, F.A.
Lee, W.O.
Markham, Ben
Robinson, Blaine
Smith, Elmer
Stark, A.
Thatcher, La Van
Tingey, D.C.
Whiting, Ray
Zupko, John

I.E. DuPont Co., Brigham
464 E. 5th, Logan
Bureau of Land Management, Salt Lake City
Weed Supervisor Millard County, Hinckley
The Denver Fire Clay Company, Salt Lake City
Wasatch Chemical Company, Salt Lake City
Wasatch Chemical Company, Salt Lake City
U.S. Agric. College Research Group, Logan
State Representative Dept. of Agric., Ogden
Duchesne County, Roosevelt

VIRGINIA

Flory, Evan L.

U.S. Indian Service, Arlington

WASHINGTON

Allen, Paul
Ash, Al
Bonn, Art
Bruns, V.F.
Fowler, Roy D.
Rasmussen, L.W.
Suggs, Delbert D.
Smith, Louis
Vogel, M.A.
Watke, Phil

Geigy Company, Yakima
Pennsylvania Salt Manufacturing Co., Tacoma
Van Water's and Rogers Co., Seattle
U.S.D.A., Irrig. Exp. Sta., Prosser
Stauffer Chemical Co., Oakesdale,
State College, Pullman
Bureau of Reclamation, Ephrata
Van Waters & Rogers, Spokane
Stauffer Chemical Company, Yakima
American Chemical Paint Co., Spokane

WASHINGTON D.C.

Balcom, Robert B.
Pierson, Riley

Bureau of Reclamation, Washington D.C.
Bureau of Land Management, Washington D.C.

WYOMING

Bohmont, Dale W.
Kissinger, Neland A.

University of Wyoming, Laramie
C/O Agronomy Dept., Univ. of Wyoming, Laramie

HAWAII

Chillingworth
Griswold, B.E.
Hance, Francis E.

American Factors Ltd., Hilo,
American Factors Ltd., Honolulu
Hawaiian Sugar Planters Assoc., Honolulu

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American Cyanamid Co.	Pennsylvania Salt
California Spray-Chemical Corp.	Pittsburgh Agric. Chem. Co.
Chipman Chemical Co.	Richfield Oil Corporation
Colloidal Products Corp.	Shell Oil Company
E.I. duPont de Nemours & Co., Inc.	Standard Agricultural Chem., Inc.
Hurst Industries, Inc.	Stauffer Chemical Company
Miller Products Co.	The Dow Chemical Company
Monsanto Chemical Co.	United Chemical Company
Niagara Chemical Division	W.R. Grace & Company