THE EFFECT OF SOME CHEMICAL WEED KILLERS ON CERTAIN WEEDY GRASSES

by

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TABLE OF CONTENTS

INTRODUCTION

A definite need exists for a chemical method of controlling weedy grasses. This need is perhaps best shown by the prevalence of weedy bromegrass species in smooth brome meadows and pastures in Kansas and other states. Seed production and the carrying capacity of smooth brome pastures are greatly reduced by the presence of weedy bromes. The effect of the presence of these weeds, even in small quantities, is to render smooth seed practically unsalable for planting. Brome seed containing more than 200 weedy brome seeds per pound cannot be certified in Kansas.

The project reported upon consisted mainly of a study of the effect of several chemicals and rates of application on Japanese brome or chess, Bromus japonicus Thunb. Gates (15, 16) lists this grass as one of the 20 most noxious weeds in Kansas. He further describes it as a winter annual which has spread with amazing rapidity in the past 20 years, appearing almost native in many places.

Other weedy grasses included in certain of the treatments were: yellow foxtail, Setaria lutescens Weigel; crabgrass, Digitaria sanguinalis (L); goatgrass, Aegilops cylindrica Host.; nimble will, Muhlenbergia schreberi Gmel; stinkgrass, Eragrostis cilianensis (All.), and goosegrass, Eleusine indica (L). Tests also were conducted to observe the effect of certain of the chemicals and rates employed upon smooth bromegrass, Bromus inermis Leyss., a cool season perennial cultivated grass.

The chemical 2,4-Dichlorophenoxyacetic acid and several of its derivatives have been widely publicized and used as effective herbicides during recent years. However, this chemical does not offer the best control of all weeds, especially weedy grasses.

Various new chemicals and new uses for several old chemicals have been proposed as solutions to the weedy grass problem. Nine chemicals in all were used in this project. These were: Sodium trichloroacetate, isopropyl n-phenyl carbamate, phenyl mercuric acetate, pentachlorophenol, dinitro-ortho-secondary amyl phenol, sodium isopropyl xanthate, maleic hydrazide, alpha hydroxy beta trichloroethyl sulfonic acid, and Carbide and Carbon Co. E.H. #2. (The active ingredients of the last named herbicide are unknown to the writer). Brand names, formulations, and other pertinent data concerning the above listed compounds will be given in later paragraphs.

The field and greenhouse experiments described herein were designed (1) to compare the nine chemicals as to herbicidal value on grasses, (2) to determine conditions during fall or early spring for the most effective applications and (3) to observe the results of varying the concentrations and total amounts of several of the chemicals at each application date.

REVIEW OF LITERATURE

Chemical weed control methods have progressed rapidly in the past 50 years. As previously mentioned, the discovery and use of 2,4-D has given great impetus to the use of chemicals for weed control within the last decade. However, it was pointed out that the discovery of this chemical has not ended the search for chemicals which are specific in their herbicidal effect upon grasses. Chemicals, rates, and formulations discussed in the following paragraphs have been used in the search for effective weedy grass herbicides.

It was reported from England by Templeman and Sextion (34) that isopropylphenylcarbamate[1] in concentration which stopped seedling growth of cereals did not affect the growth of several broadleaved plants. In heavier concentrations, IPC arrested the growth of established cereal plants where they were in flower, and, once arrested, little or no growth resulted. Ennis (14) reported that IPC applied to the soil at the rate of seven pounds per acre immediately after planting prevented emergence of oats, barley, wheat, rye, orchard grass, timothy, ryegrass, and red top. Corn, rice, sudangrass, millet and sorghum were less affected but most failed to develop beyond the plumule leaf stage. Fifteen of 39 broadleaved species showed some reaction to IPC.

According to Allard et al. (1) and Allard (2), IPC appears to be a more effective herbicide on several of the cereals than some of the halogenated phenoxyacetic acids. They also observed that soil applications appeared more promising than foliage sprays and that the use of IPC as a weedy grass herbicide is

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[1]Throughout the remainder of this thesis, isopropyl n-phenyl carbamate shall be referred to as IPC.

indicated. In greenhouse tests at Davis, California, IPC applied to nine species of weedy grasses grown in pots in the greenhouse resulted in killing Bromus mollis, Hordeum murinum, Poa annua, and Phalaris minor at rates of five pounds per acre. Papsalum dilatum was severely stunted by the 10 pound per acre rate. Echinochloa crusgalli, Sorghum halepense, Poa pratensis, and Panicum capillare were unaffected or only slightly stunted by the 10 pound per acre rate.

Shaw and Willard (27) report that two pounds of IPC per acre in 100 gallons of water applied to soil planted to red clover permitted a good stand of clover and almost completely prevented the establishment of foxtail and crabgrass. Lachman (19) stated that both 5 and 10 pound rates in greenhouse and field studies prevented growth of several grasses, specifically domestic ryegrass. Spinach and beets emerged normally after pre-emergence treatments at these rates. Shaw and Willard (28) found that IPC applied at 20 pounds per acre in 100 gallons of water as a pre-emergence spray on corn and soybeans gave good to perfect control of green foxtail, Setaria viridis, and crabgrass, Digitaria sanguinalis. Corn, however, was killed or severely injured by this rate. These workers suggest the possible use of lower rates of IPC on legume pre-emergence for the control of weedy annual grasses.

IPC cannot be used to control established stands of such perennial grasses as Johnson grass, Bermuda grass, and quack grass according to McCall (21). He also stated that results from the use of IPC have been varied and it is difficult to predict the place IPC will occupy in weed control work.

McCall (21), in describing results from the use of trichloroacetic acid[1] and its ammonium[2] and sodium salts,[3] stated that there is a widespread interest in the possibilities they offer as weed control agents. Ryker (24) described ATA as a contact non-selective herbicide when applied to foliage. When applied on the soil surface, it inhibits seedling growth of monocotyledonous plants more than dicotyledonous plants. On grass the killing action, especially on underground parts, is slow, requiring two or three months under some conditions. ATA is more effective under moist than dry conditions. It is readily soluble in water, a characteristic not possessed by IPC. The above statements regarding ATA may also be applied in general to TCA and STA.

Since the period of toxicity resulting from use of the trichloroacetates is relatively short (two or three months at most), they are classed as temporary soil sterilants. Robbins, Crafts, and Raynor (23) define temporary soil sterilization as a period of one year or less during which the soil remains sterile as the result of a particular treatment.

Barrons (3) reporting on physiological studies of TCA as a herbicide stated that plots of quack grass and bluegrass receiving

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[1]Herafter referred to as TCA.

[2]Hereafter referred to as ATA.

[3]Hereafter referred to as STA.

equal sprays, with one immediately washed with water, showed equal effect on grasses after three weeks. Thus root absorption is shown to be an important avenue of entry.

Satisfactory control of foxtails (Setaria spp.) was reported by Derscheid, Stahler, and Kratochvil (et al. (12) when 6, 12, and 24 pounds of ATA per acre were applied as pre-emergence sprays to flax. They also reported that flax stands were reduced by these rates. Leonard and Harris (2) found that STA and ATA at 10 to 20 pounds per acre showed promise of being useful for controlling Bermuda grass, Johnson grass and other weeds in cotton when applied as pre-emergent sprays.

Shafer (25) applied foliage sprays of ATA at 10, 20, and 40 pounds per acre on crabgrass, Digitaria sanguinalis, green foxtail, Setaria viridis, barnyard grass, Echinochloa crusgalli, and panic grass, Panicum scribnerianum. He reported kills of 90 to 95 per cent from the 40 pound rate six weeks after treatment and 75 per cent kill from the 10 and 20 pound rates. Shaw and Willard (27, 28) found that 2, 4, 8, and 16 pounds of STA and ATA applied in five gallons of water per acre, while preventing growth of red clover at all rates, prevented establishment of crabgrass and foxtail at the 4 pound rates, with even the 2 pound rate showing considerable effect. They also reported that STA and ATA gave excellent control of green foxtail and crabgrass when applied at 20, 40, and 80 pounds per acre as pre-emergence sprays to corn and soybeans. However, corn and soybeans were also affected by the lowest rate (20 pounds) used. These investigators suggested the possibility of using TCA legumes pre-emergence for control of weedy annual grasses.

Carlson and Moulton (7) found STA at rates of 30 pounds per acre effective in controlling quackgrass and Kentucky bluegrass in raspberry plantings. Smith, Meadow, and Marshall (31) reported that 20 pounds of STA in 100 gallons of water resulted in significant reduction of weedy grasses below the untreated when pre-emergence sprays were applied to potatoes. Davidson and Coulter (11) controlled annual bluegrass, Poa annua, in blueberry plantings with 19 pounds of STA per acre. Quackgrass was controlled in asparagus at 62 pounds of the acid equivalent.

Hanson (17) reported from Hawaii that 40 and 60 pounds of ATA or STA per acre have shown considerable promise for the control of Bermuda grass grown in pots when used in repeated treatments. Warren (35), using ATA at 5 and 10 pounds, acid equivalent, per acre in pre-emergence experiments with lima beans, reported excellent control of witchgrass, Panicum capillare, and foxtail, Setaria spp., although no beans were produced on any plots receiving ATA. Zahnley (36) reported control of annual grasses, using ATA at rates of 3/8 and 1/2 pound per 100 square feet.

McCall and Zahnley (22) recommended dosages ranging from 20 to 60 pounds for control of annual grasses. They stated that application can be made to the foliage or to the soil just before the grass seed sprouts. As a rule, 50 to 100 gallons of solution per acre are used. These investigators stated that 1/4 to 1/2 pound of trichloroacetate per square rod has satisfactorily controlled chess, crabgrass, and foxtail. Lighter rates (1/6 to 1/8 pound per square rod) used as pre-emergence treatments have killed the germinating seed of many annual grasses. Considerably higher rates are recommended for controlling established stands of perennial noxious grasses. Four factors are listed as affecting the herbicidal efficiency of the trichloroacetates, namely: (1) Character of the root system, (2) Soil conditions, (3) Time of application, and (4) Plant species.

Engel and Wolf (13) using several organic mercuries, including phenyl mercuric acetate[1] at several rates, reported crabgrass control ranging from 68 to 98 per cent. These results, however, were secured by several applications in most cases. These workers concluded that the phenyl mercury compounds are quite similar in their ability to control crabgrass.

Pentachlorophenol[2] is a compound formerly used as a wood preservative and now used both for that purpose and as a herbicide. The sodium salt of pentachlorophenol, bearing the trade name Santobrite, has been used in Hawaii for some years as a herbicide. In reporting on its use there, Sherwood (29) stated that soil applications of 15 to 35 pounds of Santobrite per acre, made immediately after cane or pineapple are planted, prevent all weed growth from 30 to 90 days.

Barrons (4) reporting on the phenolic herbicides, stated

[1]Commonly referred to as PMA.
[2]Commonly referred to as PCP.

that PCP, both as the parent compound in emulsifiable oils and as the water soluble sodium salt, have been used for contact spraying and residual soil treatment. He also stated that oil solutions and emulsions containing PCP may be classified as general contact herbicides.[1]

In commenting upon the progress in herbicidal applications of PCP, Sherwood (3) stated that oil is essential in any formulation designed for killing the top growth of emerged grasses as well as broadleaved plants. Hence, the PCP acts as an oil fortifier, since the oil, too, is herbicidal in nature. In fact, Crafts (8) wrote concerning the herbicidal properties of certain of the oils that the use of oil fractions to control weedy grasses in certain broadleaved crops (beet , mangel, and composites of the lettuce type) warrants trial since oils seem particularly toxic to grasses.

Shafer (25) found PCP at one part to seven in oil gave 90 to 95 per cent kill of several annual grasses when applied at 40 gallons of solution per acre. These results were an average of three replications. He found 40 gallons of solution per acre too light when contact herbicides of the PCP type were used. When sodium pentachlorophenate was used at 20 pounds per acre in 100 gallons of water, Smith, Meadows, and Marshall (31) reported almost complete control of grasses and broadleaved weeds in potatoes sprayed prior to emergence. According to Leonard and

[1]Contact herbicides are those which are applied to foliage, killing all tissue with which they come in contact.

Harris (20) sodium pentachlorophenate at 20 to 40 pounds per acre gave excellent control of weeds in some tests but injured cotton in others when applied in pre-emergence sprays.

Dinitro-ortho secondary amyl phenol, better known as Sinox General, is one of several of the dinitro phenols used as herbicides. Robbins, Crafts, and Raynor (23) described the chemical composition and uses of Sinox in considerable detail. These authors stated that sodium dinitro-ortho cresylate, closely related to Sinox General, is extremely toxic and high selective. Barrons (4) wrote that the dinitro phenolic compounds are about four times as toxic as the pentachlorophenols pound for pound. He also stated that in California, winter annual grasses in alfalfa have been controlled by dormant season contact spraying.

According to Danielson (10) true winter annual grasses were controlled during winter and spring in asparagus when one pint of Sinox General to 100 gallons of Stoddard's solvent, Kerosene, or Diesel fuel, was applied before emergence of the crop.

It was reported by Swanson, Helgeson, and Stahler (33) in a summary of weed control investigations at Fargo, North Dakota, and East Grand Forks, Minnesota, in sugar beets, that good weed control was received using 1, 2, and 4 pounds of Sinox General per acre at one of the locations given and originally good control at the other location, but weeds grew in later at Fargo.

Shafer, Klingman, Furrer, and Viehmeyer (26) stated that successful use of contact weed killers, such as Sinox General and PCP, depends upon complete coverage of all the vegetation, which requires 100 gallons per acre or above. These workers suggested that for best results on annual bromes, sprays should be made on the seedlings which germinate in the fall or early spring. One quart of Sinox General added to 15 gallons of Diesel or heating fuel with this mixture emulsified in 85 gallons of water, is recommended as a contact herbicide for annual grasses.

A review of the literature concerning sodium isopropyl xanthate[1] as a weed killer indicates that it is not outstanding as a grass herbicide. Baumgartner (5) stated that SIX provides effective weed control at concentrations of from 0.5 to 1.0 per cent and from 15 to 20 pounds per acre, depending on the size and age of the plants. He also reported that SIX is most effective against plants of the primary stages of succession. However, Hanson (17) reported that rates of SIX at 40 pounds per acre did not kill more than 50 per cent of Bermuda grass plants in pots after two treatments.

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[1]Sodium isopropyl xanthate shall be referred to as SIX throughout the remainder of this Thesis.

PRECIPITATION FROM OCTOBER 1, 1948, TO JUNE 1, 1949, AT MANHATTAN, KANSAS

Day	Inches							
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1								1.36
2		.37		.09				
3		.18		.34	.04		.10	
4				.71	.03			
5		.07	.13					.04
6	.45	.13						
7	.65							.06
8								.78
9		Trace	.07			.03		
10				.43		Trace	.91	.01
11				.66			.04	
12				.05		Trace		
13					.69	.05		
14					.03		.16	
15			.02	.25	.01	.05	.11	.01
16	Trace			.17				.02
17								.87
18			.01			.02		
19				.22				.30
20		.03	Trace		.01		.05	
21		Trace				.02		1.16
22				Trace		.50	.07	.04
23				1.12		.05		
24			.24	.04	.07			.01
25			.04	.09				
26				.05		1.04		Trace
27				.25	.11	Trace	.01	
28		.30		.12				
29	.03		.02					.88
30	.52					.24		
31								
Total	1.65	1.08	.53	4.59	.99	2.00	1.45	5.55

MATERIALS AND METHODS

Four field tests were conducted during the fall of 1948 and spring of 1949 to determine the effect of a single treatment with various chemicals on chess, smooth brome, and mixed stands of smooth brome and chess. Greenhouse tests were conducted on several grasses in addition to the above named.

Fall Field Tests

The problem of evaluating the effectiveness of weed control resulting from the use of chemicals was encountered in this project. A method employing seedling counts previous to the initial applications was considered. However, it was found that a more rapid method of sampling was necessary due to the time and labor that would be involved in counting seedlings on the 160 field plots treated during the course of this project.

Such a method was suggested by Hanson (17) in reporting on weed control experiments in Hawaii. He pointed out that there has long been need for an adequate system of evaluating the results of weed control tests without the laborious task of counting individual plants. A grading system worked out in cooperation with H. A. Alexander and Peter Kim was described in that report. This index system of grading is based on visual estimate of percentage reduction in weed population on treated as compared with untreated plots. The system also can take into account reduced vigor of remaining plants to evaluate results where actual stand is counted. It has the further advantage of classifying differences on a broad percentage basis, thus making estimates quick and fairly accurate.

The index system is as follows:

Index	Percentage reduction of weeds in stand and vigor
1	Less than 50 per cent
2	50 to 70 per cent
3	70 to 85 per cent
4	85 to 95 per cent
5	95 to 100 per cent

This system of grading recognizes the fact that the lower percentages of reduction are of little consequence in practical weed control. Therefore, close differences are measured only at the higher percentages. A chemical must result in 95 to 100 per cent control to be given a top rating.

The above system was adopted in place of actual seedling counts and was used in the field tests reported upon in this thesis.

It was intended that the initial phase of this project would consist of chemical treatments on mixed stands of smooth brome and chess during the fall of 1948. However, low rainfall during the early fall months resulted in low germination and reduced growth of chess, which rendered difficult the determination of chess infestations in smooth brome. It also was realized that separate treatment of chess and smooth brome areas would offer opportunity for study of effects of chemicals used on each species. Consequently, separate areas of each were treated during the fall. Subsequent heavy precipitation during the early spring of 1949 permitted a field test on mixed stands of smooth brome and chess.

The first of two fall field tests was conducted on a weedy area that was thoroughly, though not uniformly, infested with chess. Plots 5 by 10 feet were laid out in randomized block design, with a check provided in each block. The plots were mapped and the percentage density of chess as compared to the check plots was estimated prior to treatment in each plot. Application equipment consisted of a three-gallon hand-operated knapsack sprayer. A fan type nozzle with a small orifice was used in applying all of the chemicals except IPC. A wettable powder of IPC was used in all of the field tests and caused clogging of the small orifice of the fan type nozzle with the result that a cone type nozzle with a larger orifice had to be used for spraying this chemical. Chemicals used and rates per acre with each of the treatment results, are shown in Table 1.

Applications were made October 24, 1948. The soil was dry and the atmospheric temperature was 63° F. at the time of the treatment. The soil was a silt loam with pH 7. No measurable precipitation had occurred for 17 days prior to the date of treatment. Rainfall amounting to 0.56 of an inch fell six days after the treatments, with a total of 1.3 inches falling in the three weeks following the applications. The index system of evaluating results was used, with readings at three dates: November 13, 1948, March 25, and June 8, 1949.

The second fall field test was conducted in a smooth brome meadow. Plots were clipped at a height of 3 to 4 inches and the dead foliage was removed before the chemicals were applied to the brome which was nearly dormant at that time. The same rates were used as in the preceding test although they were not replicated in this test. Chemicals were applied November 24, 1949. The soil was dry and the atmospheric temperature was 45° F. November precipitation prior to treatments was 0.75 of an inch. Four days following the applications, 0.30 of an inch of precipitation occurred as snow. A total of 0.77 inch of precipitation fell as rain and snow in the month following the treatments. Chemicals, rates, and results of this test appear in Table 2. Readings shown in the table were taken May 6, and June 6, 1949.

Spring Field Tests

The first of two spring field tests was conducted in a chess-infected smooth brome meadow. Relative density of each species was estimated and recorded for each plot prior to treatment. Both brome and chess were growing actively at the time of treatment. Chess was 1 to 4 inches tall, and brome 1 to 6 inches.

Plots were replicated three times in randomized block design. One check was provided in each of three blocks. Plots were 5 by 10 feet. Chemicals, carriers, and rates used were the same as in the fall tests except that Reade Z[1] was added and TAT C-Lect was omitted in this test. Chemicals were applied April 5. Soil was moist at the time of application and the atmospheric temperature was 53°F. Soil was a silt loam with a pH 7. Five days after the chemicals were applied, 0.91 inch of rain fell. A total of 1.35 inches of rain fell in the three weeks following the applications. An estimate of the control of chess and reduction of brome due to treatment was made June 13. Results of this test appear in Table 3.

A final field test was carried out in an area in which chess predominated as the principal weed. Downy brome, Bromus tectorum L., was also present in several of the plots. The plants were 6 to 14 inches high and some heading was observed in the downy brome areas. Plots were replicated three times in randomized blocks with a check plot in each block. Each plot was mapped and the per cent density of chess as compared to the check plots was estimated.

All chemicals in this final field test were applied May 13, with the exception of Chlorosol-A, which was applied May 20. Within 6 hours after the last chemical was applied, 1.6 inches of rain fell. Consequently, Chlorosol-A may have been leached from the plants and soil before it had opportunity to act. Four days after the May 13 applications, 0.90 inch of precipitation fell. A total of 2.39 inches occurred during the remainder of

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[1]Active ingredients: sodium isopropyl xanthate, sodium pentachlorophenate, and sodium glycophenoxide, not less than 57 per cent.

the month of May. Index readings were taken May 28, 1949, and June 28. Results of this test are given in Table 4.

Foliage Treatments in the Greenhouse

Several concentrations of chemicals were compared as to their herbicidal properties when applied to the foliage of various grass species growing in the greenhouse. Maleic hydrazide[1] was added to the list of chemicals previously used. Hoffman and Schoene (18) described this chemical as a growth inhibitor with a pronounced, but temporary effect on plant growth, with little visible effect on the plants. Chemicals were sprayed on the foliage to the point of run-off with a DeVilbiss No. 15 atomizer at a pressure of 20 pounds per square inch. Precautions were taken to prevent the chemicals from reaching the soil by inverting the pots at the time of spraying and rotating them slowly while the sprays were applied. Care was taken when the pots later were watered that the chemicals were not washed from the plants and into the soil. Water was applied daily in small amounts directly to the soil. It was believed that the amounts of chemicals which reached the soil were negligible. The average greenhouse temperature was 75° F. and the average relative humidity was 70 per cent.

One laboratory test consisted of a comparison of foliage sprays applied to the point of run-off on smooth brome and chess plants. Smooth brome rhizomes were transplanted to unglazed

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[1] 1,2-dihydropyridazine-3, 6-dione.

6 inch pots from out-of-doors on January 14. Chess plants were transplanted from out-of-doors to the same pots one month later. Plants were then allowed to grow until the brome was 6 to 12 inches tall and chess 4 to 6 inches. Foliage sprays were applied on March 14 as described in the preceding paragraph. Six pots were treated alike with each concentration of each chemical. Six pots were untreated in this test and served as checks in estimating foliage damage to treated plants. All pots were moved periodically from one position to another on the greenhouse bench to minimize border effects. Foliage injury was read April 10. Chemicals, concentrations, and foliage injury are shown in Table 5.

A second test was conducted comparing the effect of foliage sprays applied to the point of run-off on several species of young grass plants. Grasses treated were: yellow foxtail, crabgrass, goatgrass, nimble will, smooth brome, stinkgrass, and goosegrass. Seeds were planted March 24 and seedlings were treated April 22, when 1 to 4 inches high. Treatments were not replicated within a species. One check pot was provided in each species. Chemicals used, concentrations, and foliage injury are given in Table 6.

Soil Treatments in the Greenhouse

A greenhouse test was conducted during the late spring of 1949 comparing the effects of several chemicals on germinating seeds of chess, crabgrass, and yellow foxtail. Seeds of each grass were planted one-half inch deep in silt loam soil. Unglazed 4-inch pots were used and 50 seeds were planted in each pot. Each treatment was replicated three times with two check pots provided for each species. The soil was moistened immediately after treatment and chemicals were applied in aqueous solution and water insoluble chemicals were applied in sand which had passed through a 60-mesh screen. Pots were shaded and moistened twice daily to induce maximum germination. An experimental chemical, Carbide and Carbon Experimental Herbicide No. 2, was used in this test though not used in previous field or greenhouse tests. Chemical constituents of this herbicide were not known to the writer. Toxicity readings were taken 10 days after the chemicals were applied to the soil. Seedlings that had developed beyond the plumule leaf stage were counted as living, all others regarded as killed. Chemical rates, and results of this test appear in Tables 7 to 12 inclusive.

EXPERIMENTAL RESULTS

Results of Field Tests

The effects of several chemicals applied on chess, smooth brome, and mixed stands of smooth brome and chess were observed in four field tests during the fall of 1948 and the spring of 1949. Estimated reduction in stands of chess and smooth brome due to chemical treatment is shown in Tables 1 to 4 inclusive. Rates of all chemicals are based on acid equivalent or active ingredients unless otherwise specified. While some of the treatments were effective in controlling chess, it is apparent that they also were detrimental to smooth brome.

It should be noted that a given rate of application of a chemical does not give the same degree of control in every case. According to Robbins, Crafts, and Raynor (23) the interplay of several factors determines the percentage of the weed population that will be killed in selective weed control. Three of these factors are: (1) The size and age of the weeds present, (2) Weather conditions at and immediately after spraying, and (3) The relation between concentration and volume of spray applied to a given area. Crafts (9) also stated that selective soil sterilization depends on profound differences between the crop and weed in susceptibility, root location, or some other factor.

Table 1 shows STA at 15 pounds per acre and IPC at 20 and 30 pounds per acre to be the most effective of the fall treatments in controlling chess. Since neither of these chemicals caused severe foliage injury at the rates used, it appears that their main toxic action results from their presence in the soil and absorption by the grass roots and germinating seeds. As shown in Plate I, several dicotyledoncus species were conspicuous in the spring on plots treated with STA and IPC during the fall. Principal species present were: Lactuca serriola L., Melilotus officinalis (L) Lam., Teucrium canadense L., Convolvulus arvensis L., and Erigeron canadensis L. Triodia flava (L) and Carex vulpinoidea Mixch. were not noticeably injured by any of the chemicals used.

Table 1. Results of fall application of several chemicals on chess.

Chemical	Rate per acre	Carrier#	Control index## 11/3/ 1948	3/25/ 1949	6/8/ 1949
STA	5.0 lbs	100 gal water	1	2	2
STA	10.0 lbs	100 gal water	2	4	4
STA	15.0 lbs	100 gal water	3	5	5
IPC	10.0 lbs	100 gal water	1	3	3
IPC	20.0 lbs	100 gal water	2	5	5
IPC	30.0 lbs	100 gal water	3	5	5
PMA[1]	6.8 gal	100 gal water	1	1	1
PMA	20.4 gal	100 gal water	1	1	1
PMA	30.0 gal	100 gal water	2	2	1
PCP	1.0 qt	10 gal diesel fuel 90 gal water	2	1	1
PCP	2.0 qts	20 gal diesel fuel 80 gal water	2	1	1
PCP	3.0 qts	30 gal diesel fuel 70 gal water	3	1	1
Sinox General[2]	1.5 qts	20 gal diesel fuel 80 gal water	3	1	1
Sinox General	2.0 qts	25 gal diesel fuel 75 gal water	3	2	1
Sinox General	1.5 qts	100 gal diesel fuel	3	3	2
Untreated	----	----	--	--	--

Note: All chemicals applied October 24, 1948.

[1] Two per cent phenyl mercuric acetate

[2] Seventy-five per cent dinitro-ortho secondary amyl phenol

\# Volume application was 100 gallon per acre on all plots

\## Control index — Per cent reduction of weed in stand and vigor

Control index	Per cent reduction of weed in stand and vigor
1	Less than 50 per cent
2	50 to 70 per cent
3	70 to 85 per cent
4	85 to 95 per cent
5	95 to 100 per cent

Estimated on three successive dates

Each index number represents an average of three replications.

EXPLANATION OF PLATE I

Fig. 1. Effect of fall application of isopropylphenylcarbamate on chess. Plot on left (1) treated October 24, 1948, at rate of 20 pounds per acre. Note absence of chess. Plot on right (2) untreated. Photographed May 30, 1949.

Fig. 2. Effect of fall application of sodium trichloroacetate on chess. Plot on left (3) treated October 24, 1948, at rate of 15 pounds per acre. Plot on right (4) untreated. Photographed May 30, 1949.

Fig. 1

Fig. 2

Table 2. Effects of fall application of several chemicals on brome.

Chemical	Rate per acre	Carrier*	Estimated per cent reduction due to treatments** 5/6/49	6/6/49
STA	5.0 lbs	100 gal water	50	30
STA	10.0 lbs	100 gal water	60	40
STA	15.0 lbs	100 gal water	70	50
IPC	10.0 lbs	100 gal water	70	30
IPC	20.0 lbs	100 gal water	90	70
IPC	30.0 lbs	100 gal water	95	80
PMA[1]	6.8 gal	93 gal water	0	0
PMA	20.4 gal	80 gal water	0	0
PMA	30.0 gal	70 gal water	20	0
PCP	1.0 qt	10 gal diesel fuel 90 gal water	20	0
PCP	2.0 qts	20 gal diesel fuel 80 gal water	30	0
PCP	3.0 qts	30 gal diesel fuel 70 gal water	40	20
Sinox General[2]	1.5 qts	20 gal diesel fuel 80 gal water	30	0
Sinox General	2.0 qts	25 gal diesel fuel 75 gal water	40	20
Sinox General	1.5 qts	100 gal diesel fuel	50	30
Untreated	----	----	--	--

Note: Chemicals applied November 24, 1948.

[1]Two per cent phenyl mercuric acetate

[2]Seventy-five per cent dinitro-ortho secondary amyl phenol

*Volume application was 100 gallons per acre on all plots

**As compared to untreated check plots.

led by either of these chemicals at any of the dosages used.

The 5 and 10 pound per acre rates of STA did not completely control chess. The 15 pound per acre rate controlled chess, but definitely injured the brome. All rates of STA caused leaves on some brome plants to fail to unroll properly and formative effects to appear in the inflorescences. This injury increased with increasing dosage rates. Definite reduction in stand and inhibition in growth of brome was observed in plots receiving the 15 pound per acre rate of STA.

IPC did not completely control chess at the lowest rate used. Rates of 20 and 30 pounds per acre of IPC effectively controlled chess in brome. However, brome definitely was injured at the same rates which controlled chess. All rates of IPC inhibited the development of shoots and inflorescences of brome, with the inhibition most apparent in those plots of brome receiving the 30 pound per acre rate of IPC. Brome treated with IPC also appeared dark green in color and many leaves were thickened on brome plants receiving the higher rates of IPC.

Results of late spring chemical treatments on chess are recorded in Table 4. The relatively poor control of chess by IPC and STA in this test may have been due in part to the more advanced stage of development of the plants. Heavy rainfall following application might have leached certain of the chemicals from the plants and the soil. Also, complete coverage may have been prevented by the very dense foliage growth. Dicotyledonous plants, when partially freed from competition offered by the

Table 3. Effects of spring application of several chemicals on mixed stands of brome and chess.

Chemical	Rate per acre	Carrier*	Control index** determined 6/13/49	
			Chess	Brome
STA	5.0 lbs	100 gal water	3	1
STA	10.0 lbs	100 gal water	4	2
STA	15.0 lbs	100 gal water	5	3
IPC	10.0 lbs	100 gal water	4	2
IPC	20.0 lbs	100 gal water	5	2
IPC	30.0 lbs	100 gal water	5	3
SIX[1]	15.0 lbs	100 gal water	1	1
SIX	30.0 lbs	100 gal water	1	1
SIX	60.0 lbs	100 gal water	1	1
PCP	1.0 qt	10 gal diesel fuel 90 gal water	1	1
PCP	2.0 qts	20 gal diesel fuel 80 gal water	1	1
PCP	3.0 qts	30 gal diesel fuel 70 gal water	2	1
Sinox General[2]	1.5 qts	20 gal diesel fuel 80 gal water	1	1
Sinox General	2.0 qts	25 gal diesel fuel 75 gal water	2	1
Sinox General	1.5 qts	100 gal diesel fuel	3	2
Untreated	----	----	--	--

Note: All chemicals applied April 4, 1949.

1 Sodium isopropyl xanthate

2 Seventy-five per cent dinitro-ortho secondary amyl phenol

* Volume of application was 100 gallons per acre on all plots

** Control index — Per cent reduction in stand and vigor

Control index	Per cent reduction in stand and vigor
1	Less than 50 per cent
2	50 to 70 per cent
3	70 to 85 per cent
4	85 to 95 per cent
5	95 to 100 per cent

Each index number represents an average of three replications.

Table 4. Results of spring application of several chemicals on chess.

Chemical	Rate per acre	Carrier*	Control index** 5/28/49	Control index** 6/30/49
STA	5 lbs	150 gal water	1	1
STA	10 lbs	150 gal water	2	2
STA	15 lbs	150 gal water	3	2
STA	20 lbs	150 gal water	4	4
IPC	10 lbs	150 gal water	3	3
IPC	20 lbs	150 gal water	4	4
SIX	30 lbs	150 gal water	1	1
Chlorosol-A[1]	5 lbs	150 gal water	1	1
Chlorosol-A	10 lbs	150 gal water	1	1
Chlorosol-A	20 lbs	150 gal water	1	1
PMA	30 gal	130 gal water	3	2
PCP	2 qts	20 gal diesel fuel 80 gal water	2	2
Sinox General	2 qts	25 gal diesel fuel 75 gal water	4	3
Untreated	----	----	--	--

Note: Chlorosol-A applied May 20; all others applied May 13.

1 Alpha hydroxy beta trichloroethyl sulfonic acid

* Volume application was 150 gallons per acre on all plots

** Index system explained in Table 3

Each number represents an average of three replications with readings on two successive dates.

Table 5. Greenhouse comparisons of several chemicals sprayed to point of run-off on brome and chess plants.

Chemical	Concentration per cent	Diluent	Estimated per cent foliage injury*	
			Brome	Chess
STA	0.6	Water	40	30
STA	1.2	Water	70	70
STA	1.8	Water	80	80
IPC	1.2	Water	10	10
IPC	2.4	Water	20	20
IPC	3.6	Water	40	60
PMA	0.14	Water	10	20
PMA	0.42	Water	80	90
PMA	0.70	Water	90	95
Maleic hydrazide	0.2	Water	10	10
PCP	0.25	10% diesel fuel 90% water	80	60
PCP	0.50	20% diesel fuel 80% water	90	90
PCP	0.75	30% diesel fuel 70% water	100	100
Sinox General	0.37	20% diesel fuel 80% water	100	100
Sinox General	0.50	25% diesel fuel 75% water	100	100
Sinox General	0.37	100% diesel fuel	100	100
Untreated	--	----	--	--

Note: Plants treated March 13. Injury estimated April 10.

* Each estimate is an average of six pots treated alike as compared to untreated pots.

chess, made rapid growth on plots treated with IPC and TCA.

Results of Greenhouse Treatments

The results of several chemicals sprayed to the point of run-off on brome and chess plants in the greenhouse are shown in Table 5. Comparative effects of several chemicals sprayed to the point of run-off on seedlings of seven grass species appear in Table 6. The relative effects of four chemicals on germinating seeds of chess, crabgrass, and yellow foxtail are listed in Tables 7 to 12, inclusive.

Table 6. Greenhouse comparisons of several chemicals sprayed to point of run-off on seven species of grasses.[1]

Chemical	Concentration per cent	Diluent	Estimated per cent reduction in stand and vigor* A	B	C	D	E	F	G
STA	1.2	Water	70	40	60	20	50	60	70
STA	1.8	Water	80	50	80	95	80	70	80
IPC	1.2	Water	10	20	20	10	40	30	10
IPC	2.4	Water	10	20	40	10	50	30	20
Maleic hydrazide	0.2	Water	40	20	20	30	10	40	20
PCP	0.5	20% diesel fuel 80% water	100	100	100	100	100	100	100
Sinox General	0.5	25% diesel fuel 75% water	100	100	100	100	100	100	100
Check	--	----	--	--	--	--	--	--	--

Note: Chemicals applied April 17. Injury read May 8.

[1] Grass species designated by letters in Table 6 as follows:

A. Setaria lutescens
B. Aegilops cylindrica
C. Muhlenbergia schreberi
D. Eragrostis cilianensis
E. Bromus inermis
F. Digitaria sanguinalis
G. Eleusine indica

* As compared to untreated pot.

The above data indicate only the <u>contact effect</u> of the chemicals used and not the eventual systemic effects. This is particularly true of STA at the greater concentration and maleic hydrazide. Both of these chemicals definitely inhibited heading and reduced the size of the inflorescences of the grasses in addition to their initial necrotic effect.

Table 5 shows that PCP and Sinox General in diesel fuel were the most toxic of several chemicals used as contact sprays on the foliage of chess and smooth brome. PMA at the higher concentrations caused severe necrosis of old leaves and chlorosis of new leaves of both species. STA resulted in marked necrosis of all foliage and some stunting of plants at the highest concentration. All concentrations of STA caused new leaves to fail to unroll properly and heads to be distorted. This type of injury increased with increasing concentrations of STA. IPC did not cause severe foliage injury at any of the concentrations used although considerable injury resulted on leaves receiving the highest concentration. Definite inhibition of growth in both brome and chess resulted from all dosages of IPC. Maleic hydrazide caused slight necrosis and slight stunting of both species.

Results of several chemicals applied as foliage sprays on seedlings of various grass species are shown in Table 6. Species varied in their response to each chemical and concentration. However, all seedlings of all species were killed by PCP and Sinox General in diesel fuel. In general, the injuries resulting from the chemicals were similar to those described in the preceding test. Goatgrass appeared to be one of the most resistant grasses to the sprays used. Stinkgrass was not injured severely by any chemicals except the heavier concentrations of STA and the above mentioned PCP and Sinox General in diesel fuel. The symptomatic responses attributed to STA in the preceding test also were observed on all species in this test. Neither of the concentrations of IPC produced severe foliage injury in this test, although considerable necrosis of brome leaves resulted from the heavier rate of IPC. Yellow foxtail and crabgrass, two species that often show some anthocyanin coloration, responded to maleic hydrazide with pronounced anthocyanin development throughout the plants. Other species also showed slight anthocyanin development when treated with maleic hydrazide. Growth of all grass species was inhibited by maleic hydrazide, with yellow foxtail and crabgrass being most affected. Both of these species have wider leaf blades than any of the other species tested. Maleic hydrazide caused dwarfed heads to appear on stunted plants of these two grasses about one month after normal heading occurred in the untreated plants. This chemical also caused slight necrosis to all grass seedlings.

The results of two rates of each of four chemicals applied to germinating seeds of crabgrass and yellow foxtail are shown in Tables 7 to 12 inclusive. Results for chess, which also was included in this experiment, are not shown as all seeds of this grass were killed by the four chemicals at all rates used.

Transformations of the data on crabgrass and yellow foxtail were necessary for tests of significance. The counts of seedlings killed were first converted to percentages. As the numbers of seedlings killed were all less than 100, a transformation was made. The one used converted percentages into angles as shown in Tables 7 to 10.

The differential responses observed among the three grasses may have been due to morphological differences in the seed of the different species. Laboratory germination tests on these grasses also showed marked differences in germination rates. Chess germinated very rapidly, crabgrass more slowly, and yellow foxtail very slowly. Germination percentages in the seed laboratory tests were: chess, 93 per cent; crabgrass, 40 per cent; and yellow foxtail, 51 per cent. Germination percentages in the soil of the check pots were: chess, 94 per cent; crabgrass, 68 per cent; and yellow foxtail, 70 per cent. The poorer control of crabgrass and yellow foxtail may have been due in some cases to the leaching of the chemicals from the seed zone. Consequently, the chemicals may not have been present in lethal concentrations when the seeds germinated. This is particularly true of the water soluble chemicals used.

Table 7. Summary of chemical tests and per cent kill of germinating crabgrass seed.

Chemical treatment	Seeds planted (y)[1]	Seedling counts (n)[2]	Per cent kill	Av. (1-Z)	Arcsine[3] (1-Z)[4]
10# STA/acre	50	4	88		69.7
"	"	7	79		62.7
"	"	10	71	79	57.4
15# STA/acre	"	4	88		69.7
"	"	5	85		67.2
"	"	10	71	81	57.4
20# IPC/acre	"	14	59		50.1
"	"	7	79		62.7
"	"	4	88	72	69.7
30# IPC/acre	"	2	94		75.8
"	"	4	88		69.7
"	"	0	100	94	90.0
10# Chrosol-A/acre	"	20	41		39.8
"	"	17	50		45.0
"	"	8	77	56	61.3
20# Chrosol-A/acre	"	7	79		62.7
"	"	2	94		75.8
"	"	1	97	90	80.0
10# Carbide and Carbon	"	2	94		75.8
Exp. Herb. #2/acre	"	0	100		90.0
"	"	5	85	93	67.2
20# "	"	0	100		
"	"	0	100		
"	"	0	100	100	
Check	"	33	--	--	--
Check	"	35	--	--	--

1 Number of seeds planted per pot.

2 Number of seedlings living past the plumule leaf stage after treatment.

3 Taken from Table 16.8, Statistical Methods, 4th Edition, Snedecor, G. W., 1946.

4 $1-Z = 1 - \frac{n}{.68(y)}$ where .68 is the ratio of the average (n) to the average (y) for check pots.

Table 8. Analysis of variance of angles for Table 7.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	20	3267.76	163.38
Between treatments	6	2013.16	336.63*
Within treatments	14	1244.60	88.9

* Significant

The analysis of variance of the angles shows that the chemicals differed in their toxicity to germinating crabgrass seed. Carbide and Carbon Experimental Herbicide #2 at 10 pounds per acre was almost as effective as the 30 pound per acre rate of IPC. Chlorosol-A at 20 pounds per acre was almost as effective as the two chemicals just mentioned. STA at 10 and 15 pounds, and IPC at 20 pounds per acre were of somewhat similar toxicity. Chlorosol-A at 10 pounds per acre was least effective of the chemicals and rates used, and was significantly less toxic than four of the seven treatments. Carbide and Carbon Experimental Herbicide #2 at the 20 pound per acre rate killed all germinating seeds of crabgrass, consequently, results from it were not used in the analysis of variance.

Table 9. Array of treatment means of Table 7. (In arcsines)*

Chemical treatment on crabgrass	Mean angle
30# IPC per acre	78.5
10# Carbide and Carbon E. H. #2 per acre	77.7
20# Chlorosol-A per acre	72.8
15# STA per acre	64.8
10# STA per acre	63.3
20# IPC per acre	60.8
10# Chlorosol-A per acre	48.7

* LSD between angles = 16.5

Table 10. Summary of chemical tests and per cent kill of germinating yellow foxtail seed.

Chemical treatment	Seeds planted (y)[1]	Seedling counts (n)[2]	Per cent kill	Av. (1-Z)	Arcsine[3] (1-Z)[4]
10# STA/acre	50	0	100		90.0
"	"	9	74		59.3
"	"	12	66	80	54.3
15# STA/acre	"	4	89		70.6
"	"	2	94		75.8
"	"	6	83	89	65.6
20# IPC/acre	"	9	74		59.3
"	"	7	80		60.0
"	"	10	71	75	57.4
30# IPC/acre	"	4	89		70.6
"	"	6	83		65.6
"	"	8	77	83	61.3
10# Chlorosol-A/acre	"	13	63		52.5
"	"	13	63		52.5
"	"	15	57	61	49.0
20# Chlorosol-A/acre	"	4	89		70.6
"	"	8	77		61.3
"	"	10	71	82	57.4
10# Carbide and Carbon	"	0	100		90.0
E.H. #2/acre	"	0	100		90.0
"	"	3	91		72.5
20# "	"	0	100	97	
"	"	0	100		
"	"	0	100	100	
Check	"	37	--	--	--
Check	"	33	--	--	--

1 Number of seeds planted per pot.

2 Number of seedlings living past the plumule leaf stage after treatment.

3 Taken from Table 16.7, Statistical Methods, 4th Edition, Snedecor, G. W., 1946.

4 $1\text{-}Z = 1 - \frac{n}{.70(y)}$ where .70 is the ratio of the average (n) to the average (y) for check pots.

Table 11. Analyses of variance of angles for Table 10.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	20	3038.35	151.92
Between treatments	6	1886.74	314.46*
Within treatments	14	1150.61	82.19

* Significant

The analyses of variance of the angles of Table 10 show that treatments differed with respect to their toxicity to germinating seeds of yellow foxtail. The 20 pound per acre rate of Carbide and Carbon Experimental Herbicide #2 killed all germinating seeds of yellow foxtail, and results from it were not used in the analyses of variance. IPC at 30 pounds and Carbide and Carbon #2 at 10 pounds per acre appeared almost equal in effect. STA at 10 and 15 pounds and IPC at 20 pounds per acre were similar in effect. Chlorosol-A at 10 pounds per acre was least effective of the treatments and was significantly less effective than the two top treatments as shown in Table 12.

Table 12. Array of treatment means of Table 10. (In arcsines)*

Treatment	Mean angle
10# Carbide and Carbon E. H. #2/acre	84.1
15# STA per acre	71.7
10# STA per acre	67.9
30# IPC per acre	65.8
20# Chlorosol-A per acre	62.4
20# IPC per acre	58.9
10# Chlorosol-A per acre	51.3

* LSD between angles = 15.8

SUMMARY AND CONCLUSIONS

The control of weedy grasses remains a problem in spite of increased knowledge concerning cultural practices and notable advances in the field of chemical weed control. The presence of weedy brome species in smooth brome pastures and meadows constitutes a special problem in weed control. Selective grass herbicides which will solve this problem have not yet been developed. However, certain chemicals known at present do cause marked effect upon grasses. Several such chemicals were used in tests composing the project reported upon.

Nine chemicals were compared as to their herbicidal value when used on certain weedy grasses. Smooth brome, a cultivated grass, also was included in certain of the tests. Chess was the principal weedy grass studied. Chemicals used in the field and greenhouse tests consisted of the following: STA, IPC, PMA, PCP, SIX, Sinox General, and three experimental chemicals not yet used commercially: Maleic hydrazide, Chlorosol-A, and Carbide and Carbon Experimental Herbicide #2.

A portion of this project consisted of a study to determine the conditions during fall or spring for the most effective applications of chemicals to control chess. Four field tests, two in the fall and two in the spring, were conducted to study the time for most effective application. The tests also were designed to observe the results of varying the concentrations and rates of several of the chemicals at each application date.

From the studies and observations made on the effects of some chemical weed-killers on certain weedy grasses, it may be concluded that:

1. STA and IPC will control chess.

2. Concurrent severe injury resulted to brome when chess in brome was controlled by the use of STA and IPC in this experiment.

3. Fall or early spring applications of STA at 15 pounds and IPC at 20 to 30 pounds per acre in 100 gallons of water were more effective than late spring applications in controlling chess.

4. Contact non-selective sprays of the phenolic type are not effective as a single fall treatment for controlling chess when temperature and moisture are favorable for germination at any time following treatment.

5. IPC and STA act principally through the soil in killing chess.

6. Carbide and Carbon Experimental Herbicide #2 was most toxic of several compounds tested on germinating seeds of three species of grasses. Results obtained in this study indicate the desirability of further testing of this chemical.

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LITERATURE CITED

(1) Allard, R. W., W. B. Ennis, H. R. DeRose, and R. J. Weaver. The action of isopropylphenylcarbamate upon plants. Botan. Gaz. 107: 589-596. 1946.

(2) Allard, R. W. Effect of certain growth regulating compounds upon grasses. Report of Division of Agronomy, University of California. Minutes, Ninth Annual Western Weed Control Conference. p. 46-47. (Mimeographed). 1947.

(3) Barrons, K. C. Field studies on the physiology of TCA as an herbicide for the control of quackgrass and bluegrass. Report of Dow Chemical Co., Fifth Annual North Central Weed Control Conference Research Report. Abstract VII-15. (Mineographed). 1948.

(4) Barrons, K. C. The phenolic herbicides. Dow Chemical Co. Proc., Northeastern States Weed Control Conference. p. 219-224. (Mimeographed). 1949.

(5) Baumgartner, L. L. Sodium isopropylxanthate; a new herbicide and vine-killer. Report of B. F. Goodrich Co. Proc., Fourth Annual North Central Weed Control Conference. p. 50. (Mimeographed). 1947.

(6) Baumgartner, L. L., and B. Wolfe. Sodium isopropylxanthate as a new selective herbicide. Report of B. F. Goodrich Co. and Seabrook Farms Co., Supplement to Proc., Northeastern Weed Control Conference. p. 30-39. (Mimeographed). 1949.

(7) Carlson, R. F., and J. E. Moulton. Control of grasses in raspberries by fall, spring and summer applications of sodium trichloroacetate. Report of Mich. Agr. Expt. Sta., Supplement to Proc., Northeastern Weed Control Conference. p. 24-26. 1949.

(8) Crafts, A. S. Selectivity of herbicides. Plant Phys. 21: 345-361. 1946.

(9) Crafts, A. S. A theory of herbicidal action. Science 108: 85-86. 1948.

(10) Danielson, L. L.
A progress report on chemical weed control in vegetable crops. Va. Truck Expt. Sta., Norfolk, Va. Proc., Northeastern States Weed Control Conference. p. 54. (Mimeographed). 1949.

(11) Davidson, J. H., and L. L. Coulter.
Trichloroacetic acid; sodium salt, for the control of annual bluegrass (Poa annua) and quack-grass (Agropyron repens) growing in certain horticultural crops. Report of Dow Chemical Co. Fifth Annual North Central Weed Control Conference Research Report. Abstract V-24. (Mimeographed). 1948.

(12) Derscheid, Lyle A., L. M. Stahler, and D. E. Kratochvil.
Effects of 2,4-D, TCA, IPC and contact dinitro on the yields and test weight of flax when applied as pre-emergence sprays. Report of S. Dak. Agr. Expt. Sta. and Div. of Cereal Crops and Diseases, BPISAE, U.S.D.A. Fifth Annual North Central Weed Control Conference Research Report. Abstract IV-38. (Mimeographed). 1948.

(13) Engel, R. E., and D. E. Wolf.
Chemicals for crabgrass control. Report of New Jersey Agr. Expt. Sta. and Div. of Cereal Crops and Diseases, BPISAE, U.S.D.A. Proc., Northeastern States Weed Control Conference. p. 159-163. (Mimeographed). 1949.

(14) Ennis, W. B., Jr.
Plant responses to isopropylphenylcarbamate. Report of Chemical Corps of the Army, Camp Detrick, Frederick, Maryland. Proc., Fourth Annual North Central Weed Control Conference. p. 54-58. (Mimeographed). 1947.

(15) Gates, F. C.
Grasses in Kansas. Rept. of the Kansas State Board of Agr. Vol. LV 220-A. p. 80-88. 1937.

(16) Gates, F. C.
Weeds in Kansas. Rept. of the Kansas State Board of Agr. Vol. LX. 243. p. 93. 1941.

(17) Hanson, N. S.
Weed control experiments and practices in sugar cane production. The Hawaiian Planter's Record 52(2): 113-154. 1948.

(18) Hoffman, O. L., and D. L. Schoene.
Maleic hydrazide, a unique growth regulant. Naugatuck Chem. Div. of U. S. Rubber Co. (Mimeographed leaflet) March, 1949.

(19) Lachman, W. H.
Some studies using IPC as a selective herbicide. Amer. Soc. Hort. Sci. Proc. 51: 541-544. 1948.

(20) Leonard, O. A., and V. C. Harris.
Pre-emergence weed control in cotton. Crops and Soils 1 (June-July, 1949) 18-19, 30.

(21) McCall, G. L.
Report of results from use of IPC and TCA. Kansas Agr. Expt. Sta. Proc. Fifth Annual North Central Weed Control Conference. p. 175-176. 1949.

(22) McCall, G. L., and J. W. Zahnley.
Control of noxious perennial grasses with the trichloroacetates. Kansas Agr. Expt. Sta. Circ. 255. 1949.

(23) Robbins, W. W., A. S. Crafts, and R. N. Raynor.
Weed Control. New York: McGraw-Hill. 543 p. 1942.

(24) Ryker, T. C.
Ammonium trichloroacetate. Report of E. I. DuPont de Nemours Company. Proc. Fourth Annual North Central Weed Control Conference. p. 58-59. (Mimeographed). 1947.

(25) Shafer, N. E.
Effect of four contact herbicides on several species of annual weedy grasses (Digitaria sanguinalis (L) Scop., Setaria viridis (L) Beauv., Echinochloa crusgalli (L) Beauv., and Panicum scribnerianum Nash.) Report of Agronomy Dept., Nebr. Agr. Expt. Sta. Fifth Annual North Central Weed Control Conference Research Report. Abstract VII-32. (Mimeographed). 1948.

(26) Shafer, N. E., D. L. Klingman, J. D. Furrer, and G. Viehmeyer. Weed Control in Nebraska. Nebr. Agr. Expt. Sta. Ext. Circ. 179. 1949.

(27) Shaw, W. C., and C. J. Willard.
Effect of IPC and TCA, pre-emergence, on red clover, Columbus, Ohio. Report of Ohio Agr. Expt. Sta. Fifth Annual North Central Weed Control Conference. Abstract VII-11. (Mimeographed). 1948.

(28) Shaw, W. C., and C. J. Willard.
The effect of new chemicals on corn and soybeans when applied as pre-emergence sprays. Report of Ohio Agr. Expt. Sta. Fifth Annual North Central Weed Control Conference Research Report. Abstract VII-13. (Mimeographed). 1948.

(29) Sherwood, L. V.
Sodium pentachlorophenate and pentachlorophenol as new herbicides. Report of Monsanto Chemical Company. Proc. Fourth Annual North Central Weed Control Conference. p. 52-54. (Mimeographed). 1947.

(30) Sherwood, L. V.
Progress in the herbicidal applications of pentachlorophenol. Report of Mansanto Chemical Co. Proc., Northeastern States Weed Control Conference. p. 196-200. (Mimeographed). 1949.

(31) Smith, O., M. W. Meadows, and E. R. Marshall.
Control of weeds in potatoes by pre-emergency sprays. Report of Cornell University. Proc. Northeastern Weed Control Conference. p. 107. (Mimeographed). 1949.

(32) Stahler, L. M., and L. A. Derscheid.
Effect of herbicidal oils, oils fortified with PCP and sodium PCP in water spray on weeds in flax and yield and test weight of flax. Report of S. Dak. Agr. Expt. Sta. and Div. of Cereal Crops and Diseases. BPISAE, U.S.D.A. Fifth Annual North Central Weed Control Conference Research Report. Abstract III-47. (Mimeographed). 1948.

(33) Swanson, C. R., E. A. Helgeson, and L. M. Stahler.
Summary of weed control investigations in sugar beets at Fargo, N. Dak. and East Grand Forks, Minn., conducted during the summer, 1948. Pre-emergence treatments. Report of Div. of Cereal Crops and Diseases, BPISAE, U.S.D.A. and N. D. Agr. Expt. Sta. Fifth Annual North Central Weed Control Conference Research Report Abstract V-42. (Mimeographed). 1948.

(34) Templeman, W. G., and W. A. Sexton.
Effect of some arylcarbamic esters and related compounds upon cereals and other plant species. Nature (London) 156: 630. 1945.

(35) Warren, G. F.
Effect of several pre-emergence treatments on weed control and the growth and yield of lima beans. Report of Dept. of Hort., Univ. of Wis., Fifth Annual North Central Weed Control Conference Research Report. Abstract V-4. (Mimeographed). 1948.

(36) Zahnley, J. W.
The effect of ammonium trichloroacetate on quack grass, Johnson grass, Bermuda grass, _Muhlenbergia mexicana_, _Tripsacum dactyloides_, and annual grasses. Report of Department of Agronomy, Kansas Agr. Expt. Sta. Fourth Annual North Central Weed Control Conference Research Report. Abstract pp. 285-286. (Mimeographed). 1947.