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Control of Dodder in Alfalfa Seed Crops

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CONTROL OF DODDER IN ALFALFA SEED CROPS

by

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INTRODUCTION

Dodder (Cuscuta spp.) is a parasitic weed which attacks alfalfa, clovers, lespedeza, and many other species of plants. This pest is especially troublesome when these crops are grown to produce seed.

Control of dodder should increase the financial income of a seed producer in several ways. First, control should make it possible for a producer to raise seed of high quality which will command a better price; second, it should enable the producer to increase yields; and last, it should eliminate much of the cost of harvesting and cleaning his product.

Where dodder is present in seed, the grower loses money because of the reduced quality of the seed. Most states have regulations which make it impossible to certify seed from dodder-infested fields. Thus, if dodder is present, a certified seed producer is forced to sell his seed as uncertified at a lower price. In the south San Joaquin region of California in 1951 (13), 86 per cent of the seed lots were rejected for certification because of dodder. This exemplifies losses occurring in other parts of the West. Some states have seed laws which require a producer to mow the crop for hay before any dodder seed matures, and others prohibit the movement of contaminated seed across state lines. These laws, if enforced, would almost eliminate the seed business from the West under present conditions. In addition, consumers of Western seed are refusing to buy dodder-infested seed; therefore, this pest prevents many growers from finding a ready market for their product.

Dodder greatly reduces alfalfa seed yields and, under extreme conditions, may prevent the production of alfalfa seed entirely. A report by Stitt (25) on dodder control in lespedeza shows that lespedeza seed yields were 212 pounds per acre where dodder was present as compared to 712 pounds per acre where dodder was controlled. This represents an increase in seed yield of 500 pounds per acre just by controlling dodder. Yield reductions such as these mean the difference between profit or loss on a seed crop.

At present, mechanization has almost taken over seed harvesting. Many farmers like to combine seed directly from the stump to save hand labor; however, large patches of dodder often will plug a combine, making it necessary to stop operations and clean the machine. Seed losses also occur where dodder seed must be removed from the seed crop. It was reported by Harvey (13) that in recleaning clover seed to remove dodder, 8 per cent of the clover seed was lost. This loss, added to the cost of cleaning, provides another illustration of the value of dodder control.

REVIEW OF LITERATURE

The genus Cuscuta (29) is world wide in its distribution, but the largest number of species are found in the Americas, where they extend from southern Canada on the north to Chile and Argentina on the south. In the Old World, dodder extends from the 60th parallel north in Europe and Asia to the Cape Regions of south Africa. Dodder is found also on the islands in the Indian and Pacific Oceans. From 150 to 175 species of Cuscuta have been found in the United States.

Dodder has long been recognized as a serious problem in legume seed production. During the early 1900's, Idaho (23), Utah, and other Western states recognized the danger of this pest. It is believed by some alfalfa workers in Utah that dodder, along with lygus bugs, was responsible for forcing many Utah alfalfa seed producers out of business during the late 1920's and early 1930's. MaCrae (18) sums up his attitude toward dodder in this statement, "Dodder is not just another weed. It is a menace to important farm crops and to the whole farm economy."

Many species of dodder have been found in Utah alfalfa seed fields. Identification of species is difficult, even for the trained taxonomist; therefore, the only classification that will be used in this paper will be into the general groups of small- and large-seeded dodder. These groups appear to react similarly to the herbicides used.

Dodder seeds germinate in the soil (12, 22) and produce a yellowish shoot resembling a bent toothpick, except that it is much more slender. A dodder shoot rotates until it comes in contact with a congenial

host plant. It then twines around the plant and develops wart-like suckers known as haustoria, which penetrate the host tissues. Haustorial hypha (15) contact the phloem cells of the host plant and apparently receive nourishment from those cells by diffusion. Zylem elements of the dodder intermingle directly with those of the host plant and seem to unite with them. Once this contact is made, dodder receives all of its nourishment from the host plant and loses all contact with the soil.

After dodder is attached to the host plant, it makes rapid growth. Stitt (26) reported that a single dodder seedling may form a foliage growth two feet in diameter two weeks after attachment and up to twenty feet in diameter before growth is stopped by maturity. As dodder growth continues, the alfalfa host plant is killed back to the crown and, as new alfalfa shoots develop, they are immediately attacked.

Dodder shoots (12, 20) are tough, curling, threadlike, leafless stems. A close examination of these stems reveals minute scales, the rudiments of leaves. These stems usually are yellowish or orange in color, but sometimes they are tinged with purple or red and occasionally are almost white. Tiny flowers that may be white, pink, or yellowish in color occur from early June until frost. It is reported by Stitt (26) that blossoms were found 21 days after germination and matured seed 38 days after germination. Gray to reddish brown seeds are produced in great abundance from early July until frost, a single plant being able to produce over 3,000 seeds. Seeds of dodder have a rough, pitted seed coat which may vary in shape from a sphere to a quarter sphere, depending upon the number of seeds per capsule. This variation in number of seeds per capsule causes from one to three flat faces to be formed on the dodder seed. Dodder seed is easily distinguished from alfalfa seed, since the

latter has a smooth, waxy seed coat and is shaped like a kidney.

Growth habits of dodder which make its control difficult

Dodder has the following habits of growth which make control by chemical or mechanical means difficult:

(1) As reported by Goss (11) and others, dodder seed will remain viable in the soil for five or more years. Once seed is introduced to the soil, it continues to germinate for many years.

(2) Dodder develops no functional root. Unlike other plants, dodder does not absorb nutrient materials from the soil to make its early growth; therefore, most chemicals used as pre-emergence herbicides have no effect on dodder seedlings.

(3) Dodder seedlings lose all contact with the soil soon after germination.

(4) Dodder seed may germinate any time between March and September when moisture is available.

(5) Treatments which kill dodder after it becomes attached to the alfalfa plant will also kill the alfalfa top growth.

Present status of dodder control

A review of literature has shown that little research work has been reported on dodder control. Several accounts of research work were found in which such chemicals as NaOH (10), H_2SO_4 (6), and more recently 2,4-D (1, 4) have been used for spot-treating dodder in flax, lespedeza, and alfalfa. Conclusions of these reports have been that the NaOH and H_2SO_4 are hard to work with and are only partially effective, and that the 2,4-D, while effective, kills the host plant as well as the dodder. Another report by Timmons and Lee (27) indicates that aromatic oils or dinitro-fortified oil-water emulsions can be used effectively in con-

trolling scattered patches of dodder in alfalfa seed fields. No reports have been found of work on controlling general infestations of dodder.

During the past 40 years, many writers have been giving specific recommendations for controlling dodder. Dewey (3), MaCrae (17, 18), and others (12, 13, 22, 23) state that dodder patches can be controlled by cutting the vegetation by hand and destroying the cuttings by drying them and burning them in the field or removing them in sacks. In this day of high labor costs, such means of control are not economical. It has also been recommended that, for dense stands of dodder, the field should be mowed for hay or plowed up before any dodder seed is formed. While this latter method may be practical where forage is produced, it is impractical for a seed producer to adopt such drastic methods of control.

MATERIALS AND METHODS

Exploratory experiments

In view of the lack of information on effective and economical methods of controlling general infestations of dodder, it was decided that exploratory experiments should be conducted. An experiment in the spring of 1951 compared several of the pre-emergence herbicides such as 2,4-D, CMU, sodium TCA, and others. Results of this experiment showed these herbicides, even though tested at rates several times as high as would be needed to control other annual weeds, had no apparent effect on dodder.

Another experiment started in June 1951 compared an aromatic weed oil, a furnace oil, and a dinitro-fortified furnace oil-water emulsion on control of dodder, applied as a stubble treatment following the removal of the first crop for hay. In this test, the aromatic and furnace oils gave good control of dodder. Alfalfa on these plots was mowed for hay by mistake; hence, it was not possible to obtain data on seed yield.

In 1952, an extensive experiment was started at Hyde Park, Utah, to compare different rates and volumes of aromatic weed oils, dinitro-fortified furnace oil-water emulsions, and burning of plots with a weed burner; however, extreme drought during the spring and summer of 1952 prevented growth of alfalfa and dodder.

Another experiment conducted in 1952 in Duchesne County, Utah, compared an aromatic weed oil and several dinitro-fortified furnace oil and dinitro-fortified aromatic oil-water emulsions. Results of this experiment showed,

as did the 1951 stubble treatment, that these materials greatly reduced the dodder infestation. In the 1951 and 1952 tests, about 70 per cent of the dodder was controlled by the best treatments. Alfalfa seed yields from the 1952 experiment were more than doubled where dodder control was good.

Greenhouse study

During the winter of 1952-53, an experiment was conducted in the greenhouse to test the effect of some of the new herbicides on germinating dodder seed. In this experiment, seeds of large-seeded dodder were soaked for 20 minutes in a Gooch crucible (9) containing concentrated H_2SO_4 to destroy the impermeable seed coat. After the seeds were soaked for the required interval in the acid, the crucible was transferred and placed for a moment in a 10 per cent solution of bicarbonate of soda. The seeds were then rinsed with tap water, again immersed in the bicarbonate solution until all the acid was neutralized, and then thoroughly washed with water.

After this acid treatment, the seeds were planted in dry soil. Two hundred seeds were planted in rows in each greenhouse flat. Chemical treatments were made immediately following planting.

In making the spray applications, an area 8 1/4 feet long and 4 1/8 feet wide was marked off. Flats were then placed one at a time in the center of this 1/8-square rod area, and the entire area was sprayed uniformly with a knapsack sprayer fitted with a 4-nozzle boom. One hundred gallons of spray per acre were applied. Each treatment was replicated 3 times.

The chemicals used in this test were CIPC (isopropyl N-(3-chlorophenyl) carbamate) at rates of 3, 6, and 9 pounds per acre, SES (sodium salt of

2,4-dichlorophenoxyethyl sulphate) at 5, 7, and 9 pounds per acre, CMU (3-(p-chlorophenyl)-1,1-dimethylurea) at 3 pounds per acre, TCA (sodium trichloroacetate) at 8 pounds per acre and Endothal (disodium 3,6-endoxo-hexahydrophthalate) at 4 pounds per acre. As soon as the chemicals had been applied, all flats were sprinkled with a uniform amount of water to wet the soil to a depth of 3 inches, so that the chemical would be leached down to the seed zone. Flats were then kept moist during the remainder of the test to insure close contact between chemical and dodder seeds.

As soon as the dodder seedlings began to appear, records were made periodically of the number of seedlings which had emerged. A toothpick was placed beside each shoot that was counted, so that the same shoot would not be recorded more than once. Counts were continued during a period of 22 days until no additional shoots emerged.

Pre-emergence investigations

In 1953, an experiment on dodder control was conducted at the Greenville Agronomy Farm at North Logan. This experiment was designed to test under field conditions the chemicals which had shown promising results in the greenhouse test. Soil on the Greenville farm is classified as a Millville loam and is fairly high in organic matter. This soil, being of calcareous origin, has a pH of about 8.6. The experiment was conducted on second-year Ranger alfalfa. The field had been seeded with both large- and small-seeded dodder in the spring and again in the fall of 1952. Approximately 20 pounds of the dodder seed were planted. This planting was done to assure a good stand of dodder for experimental work in 1953.

Treatments compared were CIPC at rates of 3, 6, and 9 pounds per acre and SES at rates of 5, 7, and 9 pounds per acre. Applications were made

at two different dates, the first on April 1, at which time the alfalfa was just starting to grow, and the second on May 6. On this latter date, it was necessary to clip and remove the alfalfa growth from the plots, so that the chemical could be applied directly to the soil. All treatments were replicated 6 times, and the plots were 1/2 rod wide by 1 rod long. A randomized complete block design was used. Blocks were laid out so that there were 3 rows of plots with 2 complete blocks side by side in each row. Alleyways 1/2 rod wide separated each row of plots. All plot borders were sprayed as needed during the summer with an aromatic weed oil to provide a band about 1 foot wide where all vegetation was killed. This strip, free of vegetation, was to prevent spreading of the dodder from plot to plot.

Spray applications were made on these plots with a knapsack sprayer equipped with a 4-nozzle boom. This boom sprayed a strip 4 1/8 feet wide, and the plot was completely covered by making two passes through the plot. This sprayer was equipped so that a constant pressure of 30 pounds per square inch could be maintained, assuring a uniform application. Before each chemical was applied, the sprayer was calibrated and the time necessary to deliver the required quantity of spray was computed. By using a stop watch, it was possible to apply the required amount of spray uniformly over the entire plot. Eighty gallons of liquid per acre were used on all plots in making the applications.

Dodder patches on the plots were counted four times during the season. Counts were made at six points around the plot by standing in the oil-sprayed borders of the plots and counting all dodder patches that could be reached by the right hand from that point. Counts were made in this manner to prevent tramping the alfalfa in the plots, since seed yields were to be taken at harvest time.

When the crop was harvested, a strip 3 feet wide and 10 feet long was cut from each plot and bagged for use in determining yield of seed. These bagged samples were dried, and a crude separation was made in a small sample thresher. Seed, seed pods, and leaves were found in one fraction and stems and rough chaff in the other. It became necessary, therefore, to devise a procedure for cleaning and separating the alfalfa and dodder.

The steps used to clean and separate the two seeds were as follows:

(1) The threshed material was run through a clover huller to remove the alfalfa seed from the pods.

(2) The material was then run over a clipper, which removed most of the seed pods, leaves, and light chaff present.

(3) The small dodder was removed from the alfalfa by use of a series of small screens.

(4) Chaff and other impurities were then removed from the alfalfa seed by means of a Bates aspirator.

(5) The alfalfa seed was then run over a dodder mill to remove any large-seeded dodder or other weed seed that were present. Since very few plots actually had large dodder seed present, no determinations of this seed were made.

Stubble tests

Exploratory work conducted at the Utah Experiment Station in 1951 and 1952 indicated that stubble treatments showed some promise in reducing dodder infestations. Two experiments were conducted in 1953, comparing 26 stubble treatments. One of these tests was conducted at the Greenville farm at North Logan on the field seeded to dodder in 1952. The other experiment was conducted at Fielding, Utah.

The experimental plan and the methods of procedure used in these two experiments were similar to the test already explained under the heading of pre-emergence treatments. Treatments in the Greenville test were replicated 6 times, while those in the Fielding test were replicated 4 times.

EXPERIMENTAL RESULTS

Greenhouse study

It is shown in table 1 that two of the chemicals tested, CIPC and SES, had a definite effect on the emergence of the dodder shoots. Chemicals affected the seeds in different ways. CIPC increased the number of seeds which emergec 56 to 184 per cent as compared to the untreated check. In addition, it caused an abnormal growth of the seedlings. At the two heavier rates, SES tended to reduce the number of seeds emerging. The other chemicals tested showed no significant effect on the emergence of dodder seeds.

A normal dodder seedling develops a slender, thread-like shoot 3 to 5 inches long, which twines around and parasitizes the host plant. It will be noted on figure 1 that the dodder shoot which developed when the soil was treated with CIPC never attained a length of more than .5 to 1 inch and was much thickened and rigid. Since it is necessary for the dodder seedling to make close contact with a host plant to parasitize it, this abnormal growth made it impossible for these plants to contact and parasitize other plants. Freed (8), Ivens and Blackman (14), Martin and Miles (19), and others who have studied the action of the carbamates on plant cells state that this action inhibits mitosis and narcotizes the cell. This interference with the process of mitosis, which arises from either inhibition or disorganization of the spindle development, causes abnormal growth of the cells that are affected. According to the observations of other research workers, the stunted, thickened seedlings

Table 1. Number of dodder seedlings emerging following soil treatments with chemicals

Kind of Chemical[1]/	Average number of seedlings emerging[2]/			
	None	Low	Medium	High
CIPC (isopropyl N-(3-chlorophenyl carbamate)	25	45	39	71
SES (sodium salt 2,4-dichlorophenoxy-ethyl sulphate)	25	36	14	4
CMU (3-p-(chlorophenyl)-1,1-dimethyl urea)	25	-	-	16
TCA (sodium trichloroacetate)	25	-	-	17
Endothal (3,6-endoxohexahydro-phthalate)	25	-	-	23

1/ Rates of application in pounds per acre were as follows: CIPC--3, 6, and 9; SES--5, 7, and 9; CMU--3; TCA--8; Endothal--4. All chemicals applied in 100 gallons of water per acre.

2/ 200 large-seeded dodder seeds planted in each flat. Number given is average number of seedlings emerging in 3 flats.

Figure 1. Comparison of normal dodder shoots and shoots from soil treated with CIPC

Shoots at left untreated; shoots at right from soil treated with 6 pounds of CIPC per acre

that developed showed common symptoms of CIPC injury.

No explanation has been found for the increased germination caused by CIPC. Chloride of lime sometimes is used to break the dormancy of other types of seed. Since there is chlorine present in the CIPC molecule, it is possible that in the breakdown of CIPC chlorine is produced, which may act on the dormant dodder seed in much the same manner as the chlorine in the chloride of lime.

SES in its commercial form has no biological activity; however, under certain soil conditions it is hydrolyzed (2) to 2,4-dichlorophenoxy ethanol and sodium bisulphite. Biological tests with 2,4-dichlorophenoxy ethanol have shown that very low concentrations of this chemical are highly toxic to germinating seedlings. It is possible that conditions were favorable for this conversion in the greenhouse test.

Pre-emergence investigations

Dodder control by CIPC was excellent in the 1953 experiment. As is shown in table 2, no small dodder seed was produced on any of the plots treated April 1 with CIPC. Only 3 patches of large-seeded dodder were found on the 18 plots thus treated, when counts were made August 26, and these patches developed so late in the season that no dodder seed was produced. Alfalfa seed yields were increased 124 to 163 pounds per acre over those of the untreated check.

Where CIPC treatments were made on May 6, some dodder became established late in the season and produced seed. Dodder seed yield on the CIPC plots treated in May ranged from 4 to 92 pounds per acre, while dodder seed yield on the untreated check was 1051 pounds per acre. Alfalfa seed yields ranged from 347 to 380 pounds per acre on these plots as compared to 153 on the untreated check. A statistical analysis of the data (table 3) showed that both the increase in alfalfa seed yield and the

Table 2. Number of dodder patches and yield of alfalfa and dodder seed,[1] as related to chemical soil treatment

Chemical[2]	Rate in lbs. per acre	Ave. no. of dodder patches per plot[3] by date				Yield of seed in pounds per acre	
		6-8-53	7-8-53	7-28-53	8-26-53	Alfalfa	Dodder
Chemical treatments made April 1, 1953 Alfalfa just beginning to grow							
CIPC	3	0	0	0		324	0
CIPC	6	0	0	0	Tr	353	0
CIPC	9	0	0	0	Tr	363	0
SES	5	5	10	10	10	207	735
SES	7	4	9	9	10	210	840
SES	9	7	9	10	10	244	725
Untreated check		3	7	9	10	200	371
Chemical treatments made May 6, 1953. Alfalfa clipped and removed from plots so that chemical could be applied directly to the soil							
CIPC	3	0	2	2	3	368	92
CIPC	6	0	0	1	1	380	13
CIPC	9	0	0	0	Tr	347	4
SES	5	7	10	10	10	138	1063
SES	7	6	10	10	10	135	1146
SES	9	6	10	10	10	142	1069
Untreated check		8	10	10	10	153	1051

1/ Average of 6 replications
2/ All chemicals applied in 80 gals. of water per acre
3/ Where the number of dodder patches exceeded 10 per plot, it became impossible to differentiate individual patches. Thus, 10 patches per plot constitutes a complete infestation

Table 3. Analysis of variance of alfalfa and dodder seed yields

Source of variation	D. F.	Yield alfalfa seed lbs./acre m. sq.	Yield dodder seed lbs./acre m. sq.
Blocks	5	18,935	86,803
Check vs treated	1	84,999**	582,148**
Chemical	1	559,506**	14,875,791**
CIPC rates	2	212	7,042
SES rates	2	1,600	38,213
Date within CIPC	1	1,503	11,811
Date within SES	1	60,516**	943,347**
CIPC rates x date	2	3,907	7,042
SES rates x date	2	927	1,196
Rate of chem. within dates	4	2,417	4,119
Among checks	11	615	126,294*
Remainder	55	8,372	62,046
Total	83		

** Significant at 1 per cent level
* Significant at 5 per cent level

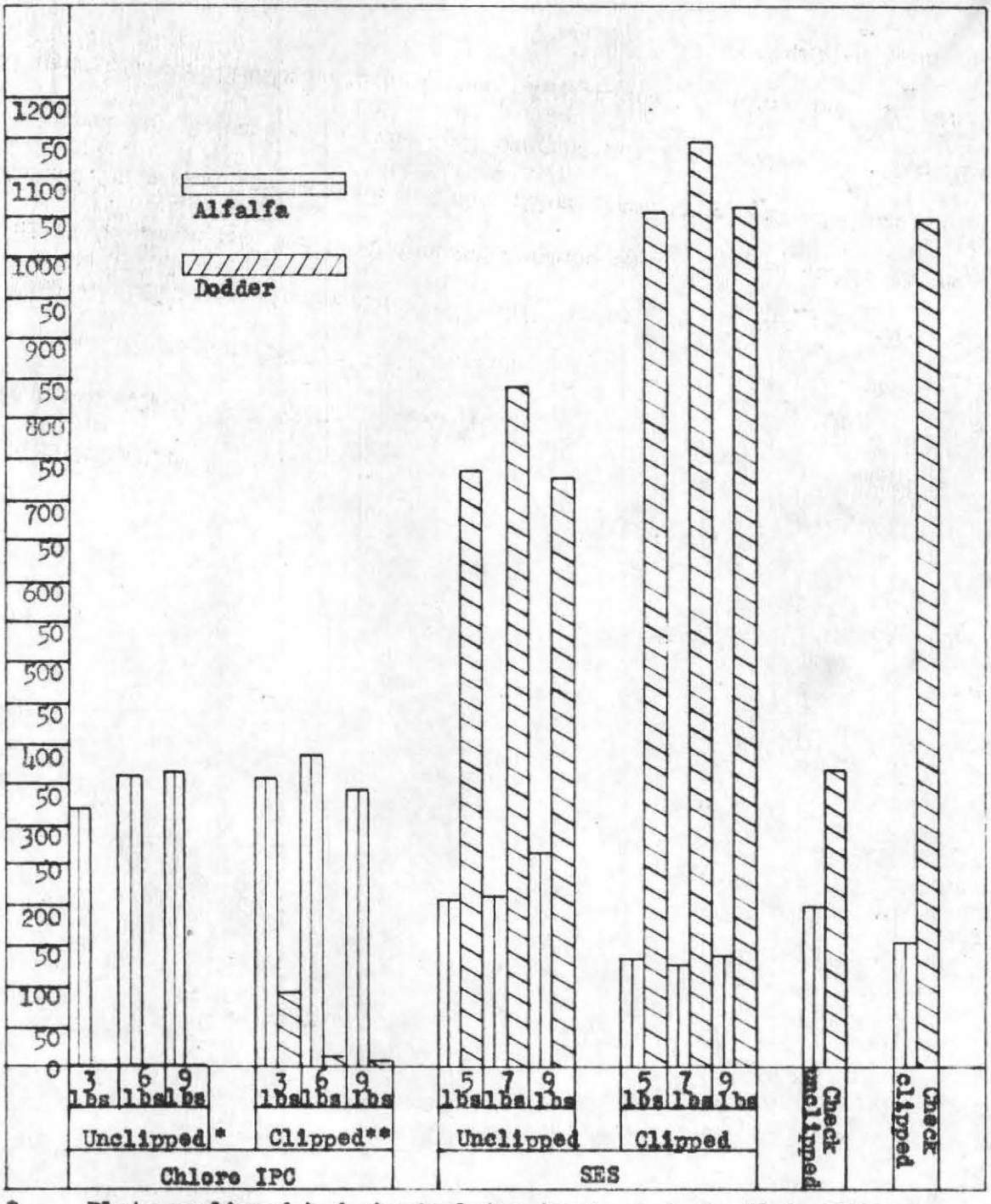
reduction in dodder seed yield by CIPC were highly significant. There was no significant difference for rates or dates of applying CIPC.

Unlike the data obtained in the greenhouse tests, SES showed no effect on dodder on either date under field conditions. On the contrary, it is noted that the amount of dodder seed produced was higher on the plots treated with SES than it was on the untreated check. SES did cause a temporary curling of some alfalfa leaves and reduced the density of the alfalfa foliage. This damage may have been advantageous to the development of the dodder.

Figure 2 gives a graphical presentation of the data presented in table 2.

Figure 3 shows an inverse correlation of -.75 between alfalfa and dodder seed yields. This correlation shows the seriousness of the competition between the alfalfa and dodder and the reduction in yields when an alfalfa seed field becomes infested with dodder.

Temperature, moisture, soil texture, and pH (5) are factors which must be considered in evaluating the results of this experiment. Several workers (7, 16, 24) have pointed out the conditions which influence the effectiveness of CIPC. This chemical has a relatively long period of toxicity in the soil when temperatures remain below 75° F., but toxicity is lost rapidly when temperatures rise much above this point. For good results with CIPC, it appears necessary that sufficient precipitation be received to carry the chemical into the surface soil and that the soil remain moist to make close contact between CIPC and the seed. CIPC is lost rapidly from very heavy soils but has an extended period of toxicity in soils of medium or light texture that have a good supply of organic matter. The period of toxicity is much longer on alkaline soils than it is on acid soils.



* Plots unclipped had chemical treatments made April 1, 1953

** Plots clipped had alfalfa clipped and removed before chemicals were applied May 6, 1953

Figure 2. Acre yields in pounds of alfalfa and dodder seed as related to various chemical soil treatments

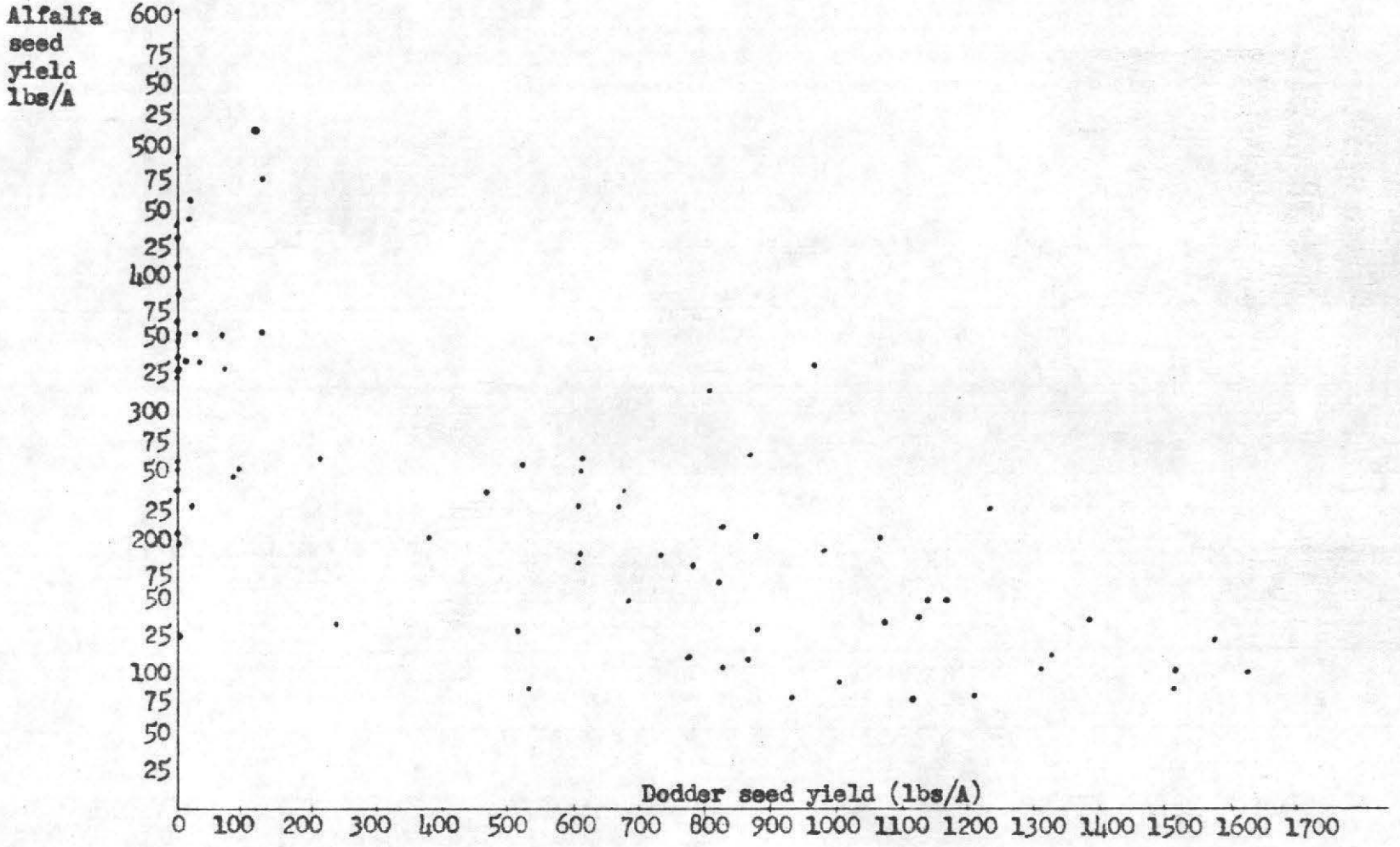


Figure 3. Correlation between the yield of alfalfa and dodder seed

Temperature and moisture conditions were very favorable following the pre-emergence treatments, especially those made in April (table 4). Dodder shoots which emerged on the CIPC plots showed the characteristic stunted and thickened abnormalities observed in the greenhouse test; therefore, it is believed that the CIPC treatment gave excellent results, not by killing the dodder shoots but by preventing the normal development of the shoot.

It is not clearly understood why dodder control was better where treatments were made in April than in May. Some of the following reasons may explain the differences in the April and May results:

(1) In the greenhouse test, germination was increased by CIPC. In the field, where these treatments were made early, all of the dodder seed at the soil surface may have been stimulated to germinate, so that none was left in the surface soil after the CIPC was lost from the soil.

(2) Where CIPC was applied in April, temperature and moisture conditions were favorable for a longer period of toxicity than following the May applications.

(3) By having the chemical present in the seed zone for a longer period of time, more of it may have been absorbed by the seed, thus causing abnormal effects on germination of the seed.

It is reported by Vlitos (28), Carroll (2), Pass (21), and others that SES is not an active herbicide in its commercial form. It is dependent upon soil pH or soil micro-organisms to make it toxic to seedlings. These workers report that SES has been shown to be converted to an active herbicidal compound in sterile soils of low pH. Non-sterile soils of acidic or neutral character also are able to convert the compound to its active form. In highly alkaline soils, either sterile or non-sterile, this chemical conversion does not occur.

Table 4. Temperature and precipitation data following pre-emergence applications made April 1 and May 6

Date	April		May		June	
	Max. temp.	PPT	Max. temp.	PPT	Max. temp.	PPT
1	57		47		74	
2	49		53		64	.27
3	58		53		66	
4	57		63		81	
5	55	Tr	71		69	.31
6	49	.02	75		67	.04
7	37	.39	73		67	.63
8	40		58		66	.03
9	40	.27	42	.12	79	
10	39	Tr	44	.13	83	
11	40	Tr	55		85	
12	38	.15	56		85	
13	48		61		81	
14	48	.09	67		79	
15	52		65	.02	73	
16	62		68		86	
17	61	.40	68		85	
18	53	.27	65	.12	85	
19	61		63	.45	85	
20	71		56	.60	74	
21	75		58		79	
22	74		60		84	
23	73	.01	60	.05	85	
24	65		54	.79	85	
25	69		60		74	
26	75		69		71	
27	70		72		77	
28	63	.32	73	.03	86	
29	52		65	.52	88	
30	48	.22	65		90	
31			75			
Mean	55		62		78	
Total		2.14		2.83		1.28

Findings of these workers would fully explain the failure of SES under the conditions of this experiment. Since the pH at the Greenville farm is about 8.6, the chemical probably was never converted to an active form.

Favorable results obtained in the greenhouse test with SES can be explained by the fact that a mountain soil, very high in organic matter, was used. Such soils often have a pH of 7 or even below, which would have activated the SES, thus giving more favorable results than were noted under field conditions.

Stubble tests

Results in both of the 1953 experiments with stubble treatments were rather disappointing. As shown in tables 5 and 6, several of the treatments showed excellent initial kills of the dodder present on the plots, but as the season advanced, the dodder began to show up, presumably from germinating seed. By the end of the growing season, all treatments with the exception of stubble burning had so much dodder present that they were considered unsatisfactory. There was much variability present in these experiments. On the experiment at the Greenville farm, the dodder stand was very spotted. Counts of the number of dodder patches present on the untreated checks showed that the number ranged from 0 to 10 patches per plot. Variability at the Fielding test was caused by differences in soil conditions. Alfalfa growth on the Fielding plots varied in height from 6 inches to 2 feet. These differences showed up in the alfalfa and dodder seed yield. Because of this large variability and the poor results obtained, no statistical analysis was made of these data.

Even though the variability within blocks in the stubble experiments was high, several trends were apparent. Aromatic weed oil at rates of

Table 5. Effect of treatments made to the alfalfa stubble following the removal of the first crop of hay--Fielding, Utah--averages of 4 replications

Chemical and rate of application per acre	No. of dodder patches per plot			Yield of seed in pounds per acre	
	6-30 1/	7-27 2/	8-14 2/	Alfalfa	Dodder
Richfield Weedkiller A 40 gals	.2	3.0	3.0	244	38
Richfield Weedkiller A 80 gals	0.0	1.5	2.2	289	22
Richfield Weedkiller A 120 gals	0.0	1.2	1.5	178	40
Richfield Weedkiller A 8 gals + Contax 3 pts + 111 gals water + Trem 618 (2% of oil)	.2	4.0	4.7	224	169
Richfield Weedkiller A 14 gals + Contax 3 pts + 106 gals water + Trem 618 (2% of oil)	0.0	2.2	3.0	252	31
Richfield Weedkiller A 20 gals + Contax 3 pts + 100 gals water + Trem 618 (2% of oil)	1.0	3.7	4.5	211	128
Fuel oil 20 gals + Dow General 2 pts + 100 gals water + Trem 618 (2% of oil)	1.2	2.2	2.7	193	111
Fuel oil 20 gals + Dow General 3 pts + 100 gals water + Trem 618 (2% of oil)	3.0	6.2	9.2	286	175
Fuel oil 20 gals + Dow General 4 pts + 100 gals water + Trem 618 (2% of oil)	.7	4.0	4.7	235	239
Fuel oil 20 gals + Sinox General 2 pts + 100 gals water + Trem 618 (2% of oil)	0.0	3.5	4.7	223	147
Fuel oil 20 gals + Sinox General 3 pts + 100 gals water + Trem 618 (2% of oil)	.2	3.5	4.5	217	77
Fuel oil 20 gals + Sinox General 4 pts + 100 gals water + Trem 618 (2% of oil)	1.5	2.0	2.5	249	82
Fuel oil 20 gals + Contax 2 pts + 100 gals water + Trem 618 (2% of oil)	2.2	9.0	10.2	244	178
Fuel oil 20 gals + Contax 3 pts + 100 gals water + Trem 618 (2% of oil)	1.2	4.5	6.0	272	143
Fuel oil 20 gals + Contax 4 pts + 100 gals water + Trem 618 (2% of oil)	1.5	5.7	7.0	233	123

1/ Counts made 6-30 represent the number of dodder patches in 3 meter quadrats per plot
2/ Counts made 7-27 and 8-14 were made at six points around plot as explained under methods and materials

Table 5. (Continued)

Chemical and rate of application per acre	No. of dodder patches per plot			Yield of seed in pounds per acre	
	6-30[1]	7-27[2]	8-14[2]	Alfalfa	Dodder
Wasco Herbicide conc-water emulsion 1-5 mixture--120 gals	1.7	4.0	4.7	185	130
Wasco Herbicide conc-water emulsion 1-10 mixture--120 gals	1.5	3.5	3.2	234	59
Wasco Herbicide conc-water emulsion 1-15 mixture--120 gals	.7	4.0	4.2	296	87
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 3 lbs--120 gals	0.0	3.5	4.5	220	181
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 6 lbs--120 gals	0.0	1.7	3.7	294	66
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 9 lbs--120 gals	0.0	.7	2.0	243	36
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC .5 lbs--120 gals	3.0	5.0	6.5	156	318
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 1 lb--120 gals	.7	2.5	4.2	333	80
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 2 lbs--120 gals	.2	2.2	2.5	217	36
Stubble burned with weed burner	0.0	0.0	0.0	198	0
Stubble burned with weed burner, then 3 lbs Chloro IPC applied in 60 gals of water per acre	0.0	0.0	0.0	184	0
Untreated check[3]	2.2	5.2	6.5	270	211

1/ Counts made 6-30 represent the number of dodder patches in 3 meter quadrats per plot
2/ Counts made 7-27 and 8-14 were made at six points around plot as explained under methods and materials
3/ Check is average of 16 plots

Table 6. Effect of treatments made to the alfalfa stubble following the removal of the first hay crop--Greenville farm, North Logan, Utah

Chemical and rate of application per acre	No. of dodder patches per plot	
	7-10	8-13
Richfield Weedkiller A 40 gals	.50	.83
Richfield Weedkiller A 80 gals	.16	.66
Richfield Weedkiller A 120 gals	0.00	.16
Richfield Weedkiller A 8 gals + Contax 3 pts + 111 gals water + Trem 618 (2% of oil)	.33	.50
Richfield Weedkiller A 14 gals + Contax 3 pts + 106 gals water + Trem 618 (2% of oil)	.33	1.00
Richfield Weedkiller A 20 gals + Contax 3 pts + 100 gals water + Trem 618 (2% of oil)	.16	.66
Fuel oil 20 gals + Dow General 2 pts + 100 gals water + Trem 618 (2% of oil)	.83	1.33
Fuel oil 20 gals + Dow General 3 pts + 100 gals water + Trem 618 (2% of oil)	.66	1.00
Fuel oil 20 gals + Dow General 4 pts + 100 gals water + Trem 618 (2% of oil)	.50	1.33
Fuel oil 20 gals + Sinox General 2 pts + 100 gals water + Trem 618 (2% of oil)	.83	.33
Fuel oil 20 gals + Sinox General 3 pts + 100 gals water + Trem 618 (2% of oil)	.16	.16
Fuel oil 20 gals + Sinox General 4 pts + 100 gals water + Trem 618 (2% of oil)	.16	1.50
Fuel oil 20 gals + Contax 2 pts + 100 gals water + Trem 618 (2% of oil)	1.33	1.83
Fuel oil 20 gals + Contax 3 pts + 100 gals water + Trem 618 (2% of oil)	.16	.66
Fuel oil 20 gals + Contax 4 pts + 100 gals water + Trem 618 (2% of oil)	.50	1.33
Wasco Herbicide conc-water emulsion 1-5 mixture--120 gals	.50	1.33
Wasco Herbicide conc-water emulsion 1-10 mixture--120 gals	.66	1.16

Table 6. (Continued)

Chemical and rate of application per acre	No. of dodder patches per plot	
	7-10	8-13
Wasco Herbicide conc-water emulsion 1-15 mixture--120 gals	.83	2.00
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 3 lbs--120 gals	0.00	.66
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 6 lbs--120 gals	0.00	.66
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 9 lbs--120 gals	0.00	0.00
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC .5 lbs--120 gals	1.00	2.00
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 1 lb--120 gals	0.00	.16
Wasco Herbicide conc-water emulsion 1-10 mixture + Chloro IPC 2 lbs--120 gals	.16	.33
Stubble burned with weed burner	.16	.33
Stubble burned with weed burner, then 3 lbs Chloro IPC applied in 60 gals of water	0.00	0.00
Untreated check[1/]	3.24	4.40

1/ Check is average of 16 plots

80 and 120 gallons per acre, the herbicide concentrate-water emulsion followed by CIPC at rates of 3, 6, and 9 pounds per acre, and stubble burning gave 100 per cent kill of all dodder attached to the alfalfa at the time the treatments were made, as determined by plant counts made June 30 in the experiment at Fielding and July 10 in the experiment on the Greenville farm. The other stubble treatments were much less effective on the Greenville farm and showed no significant effects for either chemical or rate of application at Fielding.

As the season advanced, these same trends seemed to follow; however, dodder did develop on all plots except those that were burned. Even though these treatments reduced the number of dodder patches considerably, the infestation became heavy enough that it was felt control was not satisfactory.

The cost of the contact herbicides is high, ranging from $7.00 to $22.00 or more per acre. In view of this high cost of materials and the unsatisfactory results obtained, it is believed that the only treatment really promising in the tests was the stubble burning. It is observed in table 5 that the alfalfa seed yield was 27 per cent less on burned plots than on the untreated check. Since the variation within plots was so great, it is not known whether this reduction was caused by the treatment, but it is believed that stubble burning was effective in controlling dodder and warrants further testing.

The question may be raised at this point as to why CIPC was so effective in the experiment previously reported but not nearly so effective in the stubble treatments. It is believed that the high temperatures and

the lack of effective precipitation following the applications caused the CIPC to disintegrate very rapidly and thus be lost from the soil. The dodder seeds could then germinate without being affected by the chemical.

SUMMARY

In a greenhouse study, CIPC increased the germination of dodder seeds 56 to 184 per cent. In addition, it caused abnormal growth of the shoots which developed. This abnormality was expressed in the form of severe stunting and thickening of the shoots which developed. Under greenhouse conditions, this interference with cell division prevented the dodder from contacting and parasitizing host plants.

SES at heavy rates tended to inhibit the germination of dodder seeds in greenhouse tests. As the rate of application increased, the percentage of germination decreased.

In field pre-emergence investigations, CIPC gave excellent control of dodder at 3, 6, and 9 pounds per acre. The treatments made April 1 showed slightly better control than those made May 6; however, these differences were not statistically significant.

CIPC increased alfalfa seed yield for all rates at both dates of application. Yields of alfalfa seed were significantly higher than seed yields on the untreated check.

SES showed no effect on dodder seed germination under field conditions. This probably was due to the high soil pH, which prevented activation of this chemical.

Despite the high degree of variability present in the 1953 stubble tests, it is felt that the data on the number of dodder patches present is sufficiently reliable to show that none of the chemical treatments tested were satisfactory for controlling dodder.

Where the stubble was burned with a weed burner, dodder control was excellent. Even though the alfalfa seed yield was reduced by this treatment, it is felt that this method of control warrants further testing.

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