THE EFFECT OF 1,2,4,5-TETRACHLOROBENZENE
ON THE GERMINATION, AND SEEDLING VIGOR
OF BARLEY, OATS, AND WHEAT

by

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INTRODUCTION

Barley, oats, and wheat have been established as important crops in the irrigated areas of Southern Arizona. Wild oats, Avena fatua L. is one of the most serious weeds in small grains in this area, especially in the Salt River Valley. It has been estimated that every small grain field in the Salt River Valley contains from 1 to 75% wild oats (33).

Wild oats is responsible for tremendous losses to farmers, not only in reducing the yield and quality of the grain crop, but also in costing the farmer additional expense in extra tillage practices and handling costs (39). Records show that wild oats infestations can reduce cereal crop yields as much as 50% (12).

Research workers of the Dow Chemical Company (17, 26) have discovered that 1,2,4,5-tetrachlorobenzene (TCB) kills wild oats seed and offers a means of economically eradicating field infestations of wild oats.

REVIEW OF LITERATURE

Cultural Control of Wild Oats

Success in the application of cultural practices for the control of wild oats depends very largely on a knowledge of the botanical characteristics of the plant. Lindsay (19) states that an examination made on 3,500 panicles of wild oats from seven selected areas in Western Canada showed that most of the plants could be placed into the Avena fatua L. group and that these specimens could be grouped into four varieties: Pilossissima, Glabrata, Intermedia, and Vilis. All of these varieties appear to possess similar "dormancy" characteristics.

Wood (39) and Brenchley (4) stated that seed dormancy, early maturity, and seed shattering are the most important characteristics of wild oats that render it a difficult weed to control. The most generally accepted explanation of dormancy in wild oats is one given by Atwood (3). He concluded that dormancy, or delayed germination, is associated with respiration. In dormant seeds when water is restricted, the normal processes associated with germination do not take place.

Breaking seed dormancy of wild oats is one of the keys to the control of wild oats. Helgeson and Green (15) found that gibberellic acid appears to show promise in

breaking the dormancy of wild oats seeds. Fifty ppm. resulted in from 86 to 88% germination. Johnson (16) found that dormancy was broken by drying newly matured wild oats seeds at 21° C. for 90 days.

The findings of Johnson have been supported by Brown (7) who found that the breaking of dormancy is hastened by subjecting the seeds to continuous dry, warm condition. Stoa and others (36) reported that to shorten the dormancy period and bring about germination of the shattered seeds as soon as possible, it would seem better to leave such seeds on the surface until at least the early fall, and perhaps through the winter. Free circulation of air, variation in temperatures, and alternate wetting and drying tend to shorten the dormancy period.

Early autumn cultivation to encourage germination is generally recommended, with emphasis on the need for this to be shallow (7, 20, 21, 31). Shallow ploughing is generally specified with the explanation that the seed needs to be lightly covered with soil so as to encourage germination.

While autumn cultivation is recommended for countries which have a long enough growing season, it is not recommended in Canada and Sweden. In Canada the value of spring cultivation with delayed seeding of small grains is recommended (5, 7, 22, 23). As an example, Brown (7) gave the following results of trials in Manitoba, Canada, which show the reduction in wild oats infesting barley sown at dif-

ferent dates.

Barley sown 8-5-1952 contained 28.5 wild oat plants per square yard. Barley sown 11-6-1952 contained 4.4 wild oat plants per square yard.

Molberg and Leggett (27) reported that there may be a reduction in yield as a result of delayed sowing of the crop, however, this may be justified on the basis of the need for controlling wild oats.

Chemical Control of Wild Oats

It is the intention here to review the general lines along which the selective chemical control of wild oats has been proceeding. This has involved the testing of sodium 2, 2-dichloropropionate (sodium salt of dalapon), malic hydrazide (MH), iso-propyl-n-phenyl carbamate (IPC), iso-propyl-N-(3-chlorophenyl) (CIPC), trichloroacetic acid (TCA), 1 chloro-N-N-diallyl acetamide (CDAA), and, more recently, 1,2,4,5-tetrachlorobenzene (TCB).

In 1954 Anderson and Helegeson (2) reported that Dalapon at rates as low as 4 and 6 pounds per acre effectively controlled vegetative production in wild oats when applied at the early tillering and fully tillered stages of growth. No serious reduction in the yield of Selkirk spring wheat, Ramsey durum wheat, and Marine flax was found at the rates of 2 to 6 pounds of Dalapon per acre (1). Selleck and Alex (34) found that 16 pounds of Dalapon per acre will render wild oats sterile and 3 to 6 pounds per acre will de-

lay heading of wild oats.

MH was tested by Knowles (18) as a pre-heading (short-blade stage) application at 1 pound per acre in barley and wheat that had already headed. Almost complete sterility of the wild oats followed, with minor or only moderate sterility in the barley and wheat. This technique showed promise in spite of the practical difficulty of applying the material, but has been dropped primarily because the relationship between the time of heading of the crop and weed is not sufficiently regular.

Work with IPC, CIPC, and TCA has been reported from many sources. Wiese and Dunham (38) found that selective control of wild oats sown with a drill in silt loam soil was possible with pre-planting applications of IPC and CIPC as low as 2.5 pounds per acre in sugar beets, soybeans, field peas, and sunflower. It was impossible in corn, flax, wheat, barley and oats because of injury to the crop. Fall treatments of IPC and CIPC for selective control of wild oats in the spring were not successful in those treatments not toxic to cultivated oats (37). Wild oats were eliminated only on treatments where IPC and CIPC were very toxic to cultivated oats sown in the spring.

It was found by Friesen (14), in Manitoba, that the application of 10 pounds of CIPC per acre in the fall gave better control of wild oats than IPC at 5 and 10 pounds per acre. CIPC had a slightly longer residual toxicity than IPC.

Ebell (11) reported that CIPC and IPC applied to the soil at the rate of 20 pounds per acre significantly reduced the weight of wild oats. At the rate of 10 pounds per acre only CIPC resulted in significant plant weight reduction of wild oats.

It appears that IPC and CIPC may be useful in reducing the wild oats seed population in the soil after more of the factors affecting the toxicity of the chemical in the soil are understood.

In trials in Alberta, Canada, TCA was most effective when applied in late autumn (11). The TCA remained in the soil during the winter and controlled early spring wild oat growth. A rate of 50 pounds per acre was required to give effective reduction of wild oats stands. At this rate of application, it was necessary to follow the treatment with summer fallow, due to the residual effect of the TCA on cereals. The same results were found by Friesen (14) at rates of 20 and 30 pounds per acre.

Dadd (9) reviewed an article by Pfeiffer stating that TCA was safe and efficient for general use on sugar beets at 7 to 8 pounds per acre worked thoroughly into the seed-bed 10 to 14 days before sowing.

The use of CDAA for selective control of wild oats in both liquid and granular forms has been reported by many investigators. Brown (6) reported that rates of 4 and 6 pounds CDAA per acre in both liquid and granular forms are

the best for wild oats control. McCurdy (25) recommended 4 pounds CDAA per acre in both liquid and granular forms, when flax and wheat were sown immediately after the chemical was incorporated into the soil. Duncan (10) found that 8 pounds of CDAA per acre greatly reduced the stand of flax.

Carder (8) concluded that the methods of incorporating CDAA into the soil did not influence its effectiveness. Molberg and Leggett (29) determined that the liquid formulation of CDAA was slightly better when incorporated into the soil, but the granular form was slightly better when not incorporated into the soil.

Chemical control investigations have so far been concerned mainly with the use of herbicides to kill the young wild oats seedlings. The use of MH to produce sterility was an exception. Recently research workers of the Dow Chemical Company have discovered that 1,2,4,5-Tetrachlorobenzene (TCB) kills dormant and non-dormant wild oats seeds lying on a cereal stubble.

TCB is a stable, white crystalline solid with a molecular weight of 215.9. It has needle-like crystals which melt at 138° C. and it boils at 246° C. at atmospheric pressure. It is almost insoluble in water, and only slightly soluble in alcohol, benzene, carbon disulfide, and many other organic solvents (17).

Josephs, et al., (17) stated that TCB will kill dormant and non-dormant wild oats seeds by vapor contact when

mixed in the soil at rates of 5 to 10 pounds per acre. The chemical is active in the vapor phase and diffuses to a limited extent through the soil. Minarik (26) reported that TCB at 5 to 15 pounds per acre is highly specific for dormant or germinating wild oats seeds. The dry herbicide which has been incorporated into the soil vaporizes, and the vapors penetrate the seed coat and kill the embryo. This vapor activity on dormant seeds appears to be specific for wild oats and small grains. Best results are obtained from application to cool soil. Warm soil treatments have been less successful because of the rapid loss of the vapor from the soil after incorporation.

Molberg and Leggett (30) recommended 10 pounds of TCB in dry form containing 50% active ingredient which gave 100% control of wild oats. McCurdy (24) and Molberg and Leggett (32) found that fall application of TCB was best from the standpoint of wild oats control and also crop yield. A rate of 10 pounds per acre gave the best wild oats control with the fall application, and 15 pounds per acre with spring application.

The methods of incorporating TCB into the soil were studied by Molberg and Leggett (28) who found that the one-way disk gave better results than the roto-tiller. One-way disking twice was more effective than one-way disking once. Packing after incorporation decreased the effectiveness of the chemical.

Soine and Dunham (35) pointed out that TCB disked one week before sowing flax was better for wild oats control than TCB disked three weeks before sowing flax. Flax yields were reduced at both dates but were not significantly less than the check. Friesen (13) found that 15, 20, and 30 pounds of TCB per acre significantly reduced the wild oats population. Severe lodging was noticed on barley, wheat, and flax planted one day after soil treatment. The crops were injured severely when planted two weeks after treatment.

The literature review indicates that the dormancy of wild oats seeds can be reduced by cultural methods. TCB is the only chemical compound suggested for the control of dormant and non-dormant wild oats seeds in the soil. Information on the residual effect of TCB on the germination and seedling vigor of barley, oats, and wheat in Arizona is needed.

The objectives of this study were to determine:

1. The effect of TCB on the germination and seedling vigor of barley, oats, and wheat.
2. The period after treating different types of soil with different rates of TCB that these small grains could be grown.
3. Methods of increasing the rate of TCB volatilization from the soil.

EXPERIMENTAL PROCEDURE

Six randomized block experiments were conducted in 1958 in the Agronomy greenhouse, University of Arizona at Tucson, Arizona, to determine the residual effect of TCB on the germination and seedling vigor of barley, oats, and wheat (figure 1).

In experiment I 36 tin cans, each 6 inches in diameter and 7 inches high, were used for greenhouse pots. Three holes were cut in the bottom of each can for drainage. The cans were filled with washed sand to a depth of five inches. Six TCB treatments: 0, 5, 15, 45, 135, and 405 pounds per acre were mixed into the upper two inches of sand in the cans. The following three varieties of grain crops were used: Arivat barley, Palestine oats, and Ramona 50 wheat. Five seeds of each variety were planted at a uniform depth of one inch in each can following the TCB treatment of the soil. The cans were watered as needed throughout the experiment. The plants were grown for 18 days and then harvested. The germination percentage, seedling height, root length, and seedling weight were measured to determine the residual effect of TCB on small grains (figure 2).

The pots were planted again with the same varieties of crops two days after the first harvest. Therefore, the second planting was made 20 days after the soil treatment.

The plants were allowed to grow for another 18 days. The plants were then harvested and the same measurements were made as for the first planting. A new planting and harvest was made every 20 days for a period of 200 days.

Experiments II, III, IV, and V were conducted to study the effect of TCB on the germination and seedling vigor of barley, oats, and wheat in different types of soil.

In experiment II, 24 tin cans of washed sand were used. Six TCB treatments: 0, 1.7, 5, 15, 45, and 135 pounds per acre were incorporated into the upper two inches of sand in the cans. A new planting and harvest was made every 25 days for a period of 150 days. The remainder of the experimental procedure was the same as for experiment I.

In experiments III, IV, and V sandy loam, clay loam and clay soils were used, respectively. A new planting and harvest was made every 25 days for a period of 125 days in experiments III and V, and for a period of 150 days in experiment IV. The remainder of the experimental procedure was the same as for experiment II.

Experiment VI was conducted using 24 cans of washed sand. Six TCB treatments were used to study methods of increasing the rate of TCB volatilization from the soil. Two treatments were as follows: 0 pounds per acre and 10 pounds per acre applied to the surface with no mixing within a 32 day period. Four TCB treatments of 10 pounds per acre were incorporated into the upper two inches of sand and all of

the sand in the cans was mixed as follows: 2 mixings at 16 days intervals, 3 mixings at 11 day intervals, 4 mixings at 8 day intervals, and 8 mixings at 4 day intervals. Barley, oats, and wheat were planted at a uniform depth of one inch in each can 32 days after soil treatment. The plants were grown for 18 days and then harvested. The same measurements were made as in experiment I. A new planting and harvest was made every 20 days for a period of 40 days.

EXPERIMENTAL RESULTS

Experiment I.

The average germination percentages for barley and oats grown in sandy soil treated with different rates of 1, 2,4,5-tetrachlorobenzene (TCB) are reported in table 1. No germination was obtained when barley and oats were planted one day after soil treatment. The germination of barley was 20% when planted 20 days after soil treatment with 5 pounds of TCB per acre. The germination of barley gradually increased with each increase in time following soil treatment until it germinated 93% when planted 180 days after soil treatment with 405 pounds of TCB per acre. Oats first germinated 83% when planted 60 days after soil treatment with 5 pounds of TCB per acre. The germination of oats also increased with each increase in time following soil treatment until they germinated 100% when planted 180 days after soil treatment with 405 pounds of TCB per acre.

Table 2 gives the average seedling heights for barley and oats grown in sandy soil treated with different rates of TCB per acre. The barley seedling height grew to 1 inch when planted 20 days after soil treatment with 5 pounds of TCB per acre. The barley seedling height gradually increased with each increase in time following soil treatment until it reached 9.5 inches when planted 180 days

Table 1.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average germination percent-ages of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment																			
	1		20		40		60		80		100		120		140		160		180	
	B*	**O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O
lbs	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
0	83	87	80	90	100	97	93	100	100	93	97	100	93	97	93	97	97	90	90	93
5	o	o	20	o	30	o	87	83	97	100	97	93	97	93	90	90	93	93	93	85
15	o	o	o	o	o	o	70	50	97	97	93	90	97	97	90	97	100	97	87	97
45	o	o	o	o	o	o	35	o	70	57	97	97	93	93	100	100	97	97	93	90
135	o	o	o	o	o	o	o	o	o	o	3	o	40	23	93	97	90	97	80	90
405	o	o	o	o	o	o	o	o	o	o	o	o	o	o	3	o	67	73	93	100

*B = Barley

**O = Oats

Table 2.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average seedling heights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment																			
	1		20		40		60		80		100		120		140		160		180	
	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	5.0	6.1	6.0	7.3	6.8	6.8	6.2	7.1	6.5	6.4	8.9	10.9	9.7	10.2	9.4	9.5	10.1	10.6	8.7	11.8
5	0	0	1.0	0	2.2	0	7.9	7.5	7.9	7.1	9.5	10.5	10.0	9.3	10.8	10.8	11.0	11.4	9.8	11.2
15	0	0	0	0	0	0	5.6	3.2	8.2	6.9	9.5	10.9	9.2	10.4	10.8	10.1	10.9	10.4	10.8	12.2
45	0	0	0	0	0	0	2.4	0	5.2	4.2	9.6	10.1	9.4	9.5	10.3	10.3	10.4	11.2	9.5	12.0
135	0	0	0	0	0	0	0	0	0	0	1.1	0	5.3	4.3	10.5	10.5	9.9	11.5	10.9	12.1
405	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	6.6	7.0	9.5	10.9

after soil treatment with 405 pounds of TCB per acre. Oat seedlings grew 7.5 inches high when planted 60 days after soil treatment with 5 pounds of TCB per acre. The oat seedling height gradually increased with each increase in time following soil treatment until it reached 10.9 inches when the crop was planted 180 days after soil treatment with 405 pounds of TCB per acre.

The average seedling root lengths for barley and oats grown in sandy soil treated with different rates of TCB per acre are given in table 3. The barley root length was 0.1 inch when planted 20 days after soil treatment with 5 pounds of TCB per acre. The barley root length gradually increased with each increase in time following soil treatment until it reached 3.5 inches when the crop was planted 180 days after soil treatment with 405 pounds of TCB per acre. Oat roots grew 3.3 inches long when planted 60 days after soil treatment with 5 pounds of TCB per acre. The oat root length increased with each increase in time following soil treatment until it reached 3.7 inches when oats were planted 180 days after soil treatment with 405 pounds of TCB per acre.

The same results were obtained for the seedling weights of barley and oats as those observed for germination percentages, seedling heights, and root lengths when the crops were planted at different intervals after soil treatment (appendix I).

Table 3.--The effect of different rates of 1,2,4,5-tetrachloro-
benzene applied to sandy soil on the average root
lengths 18 days after planting of barley and oats
planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment																			
	1		20		40		60		80		100		120		140		160		180	
	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	3.5	2.6	4.4	3.5	4.0	3.8	3.6	3.4	3.2	3.5	4.1	3.4	3.8	2.9	3.6	3.0	3.8	3.3	3.7	4.1
5	0	0	0.1	0	1.3	0	3.7	3.3	3.7	4.2	4.1	3.9	2.8	3.1	4.7	3.9	4.5	3.8	4.2	3.6
15	0	0	0	0	0	0	2.4	1.3	4.2	3.4	4.1	3.7	3.9	3.5	4.5	3.8	4.4	3.7	3.9	4.1
45	0	0	0	0	0	0	0.4	0	2.9	2.0	4.1	3.4	3.9	3.1	4.5	4.2	4.1	4.0	3.7	4.0
135	0	0	0	0	0	0	0	0	0	0	0.3	0	1.8	0.8	4.0	3.4	3.7	3.7	3.8	4.2
405	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	2.1	2.0	3.5	3.7

The effects of TCB on the germination, seedling height, root length, and seedling weight of wheat were similar to those for barley and oats (appendices II through V). Figure 3 shows the results from experiment I when barley, oats, and wheat were planted 80 days after soil treatment. The average germination percentage of the wheat seed used in experiment I was much lower than normally expected for high quality wheat.

In general, barley appeared to be more tolerant to different rates of TCB per acre than oats or wheat.

Experiment II.

The effect of different rates of TCB applied to sandy soil on the average germination percentages of barley and oats are given in table 4. No germination was obtained when barley and oats were planted one day after soil treatment. The germinations of barley and oats were 100 and 95%, respectively, when planted 25 days after soil treatment with 1.7 pounds of TCB per acre. With each increase in time following soil treatment with different rates of TCB per acre, the germination percentages of barley and oats gradually increased. The germinations of barley and oats were 100 and 95%, respectively, when planted 125 days after soil treatment with 135 pounds of TCB per acre.

Table 5 presents the data for the effect of different rates of TCB applied to sandy soil on the average seedling heights of barley and oats. The barley and oats

Table 4.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average germination percentages of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs	%	%	%	%	%	%	%	%	%	%	%	%
0	100	95	100	100	100	100	95	95	100	80	95	90
1.7	o	o	100	95	100	100	95	95	95	80	100	90
5	o	o	o	o	100	100	100	100	100	95	95	95
15	o	o	o	o	80	80	100	95	95	90	100	100
45	o	o	o	o	25	o	75	85	95	100	100	95
135	o	o	o	o	o	o	3	o	70	70	100	95

Table 5.--The effect of different rates of 1,2,4,5-tetrachloro-
benzene applied to sandy soil on the average seedling
heights 18 days after planting of barley and oats
planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	7.2	7.2	6.9	7.2	9.5	11.0	8.1	8.7	10.1	11.1	10.2	11.0
1.7	0	0	8.2	7.7	9.7	10.8	11.1	10.1	9.7	12.0	9.9	11.1
5	0	0	0	0	9.6	11.5	9.9	9.6	10.7	12.5	10.4	11.6
15	0	0	0	0	7.5	7.3	9.5	8.9	10.5	11.2	10.8	10.9
45	0	0	0	0	1.4	0	10.3	8.7	10.6	11.3	10.6	11.2
135	0	0	0	0	0	0	0.8	0	7.5	8.2	10.6	11.1

Figure 1. The arrangement of 1,2,4,5-tetrachlorobenzene (TCB) experiments in the greenhouse.

Figure 2. Recording the data for barley, oats, and wheat planted in sandy soil treated with TCB.

Figure 3. The effect of different rates of TCB applied to sandy soil on the germination and seedling vigor of barley, oats, and wheat planted 80 days after soil treatment: (1) 0 pounds per acre, (2) 5 pounds per acre, (3) 15 pounds per acre, (4) 45 pounds per acre, (5) 135 pounds per acre, (6) 405 pounds per acre.

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seedling heights were 8.2 and 7.7 inches, respectively, when planted 25 days after soil treatment with 1.7 pounds of TCB per acre. With each increase in time following soil treatment with different rates of TCB per acre, the barley and oats seedling heights gradually increased. The barley and oats seedling heights were 10.6 and 11.1 inches, respectively, when planted 125 days after soil treatment with 135 pounds of TCB per acre.

The effect of different rates of TCB applied to sandy soil on the average root lengths of barley and oats are reported in table 6. When barley and oats were planted 25 days after soil treatment with 1.7 pounds of TCB per acre, the root lengths grew to 3.5 inches. As the time following soil treatment was increased, the barley and oats root lengths increased until they reached 3.9 and 3.7 inches, respectively, when the crops were planted 125 days after soil treatment with 135 pounds of TCB per acre.

The effects of TCB on the seedling weights of barley and oats were the same as those for germination percentages, seedling heights, and root lengths when the crops were planted at different dates after soil treatment (appendix VI).

Similar results were found for the average germination percentages, seedling heights, root lengths, and seedling weights of wheat planted in sandy soil treated with different rates of TCB per acre (appendices VII and VIII).

Table 6.--The effect of different rates of 1,2,4,5-tetrachloro-
benzene applied to sandy soil on the average root
lengths 18 days after planting of barley and oats
planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	3.6	4.2	3.6	3.5	3.5	3.4	3.6	3.1	3.8	3.5	3.9	3.6
1.7	0	0	3.5	3.5	3.2	3.5	4.2	3.6	4.1	3.0	3.7	3.6
5	0	0	0	0	3.5	3.4	4.3	3.3	4.6	3.7	4.3	3.5
15	0	0	0	0	2.7	2.7	3.6	3.5	4.2	3.3	4.0	3.5
45	0	0	0	0	0.4	0	3.5	2.1	3.8	3.5	3.8	3.8
135	0	0	0	0	0	0	0.3	0	3.1	2.3	3.9	3.7

Barley was more tolerant to TCB treatments than oats or wheat.

Experiment III.

The average germination percentages for barley and oats grown in sandy loam soil treated with different rates of TCB per acre are given in table 7. No germination was observed when barley and oats were planted one day after soil treatment. The germination of barley started at 90, 65, and 35% when planted 25 days after soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. The germination percentage of barley gradually increased with each increase in time following soil treatment with different rates of TCB per acre until it reached 100% when planted 100 days after soil treatment with 135 pounds of TCB per acre. The germination percentages of oats were 90, 30, and 15% when planted 25 days after soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. Similar increases in the germination of oats were obtained as those obtained for barley with each increase in time following soil treatment with different rates of TCB per acre. The germination of oats was 95% when planted 100 days after soil treatment with 135 pounds of TCB per acre.

Table 8 presents the average seedling heights for barley and oats planted in sandy loam soil treated with different rates of TCB per acre. The barley seedling heights were 8.6, 4.1, and 2.8 inches when planted 25 days after soil

Table 7.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy loam soil on the average germination percentages of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs.	%	%	%	%	%	%	%	%	%	%
0	95	100	95	95	90	90	90	90	85	95
1.7	0	0	90	90	100	100	90	90	90	95
5	0	0	65	30	100	100	90	95	90	95
15	0	0	35	15	100	100	100	95	85	100
45	0	0	0	0	65	15	80	75	100	95
135	0	0	0	0	0	0	20	15	100	95

Table 8.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy loam soil on the average seedling heights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	5.9	5.8	8.4	8.4	9.8	8.9	8.4	9.6	9.1	9.7
1.7	0	0	8.6	8.5	10.4	9.4	11.4	9.6	9.8	11.1
5	0	0	4.1	3.1	9.1	9.7	9.2	8.2	11.1	11.0
15	0	0	2.8	1.9	9.2	9.0	9.8	8.6	9.7	11.0
45	0	0	0	0	4.6	1.1	8.5	7.4	9.7	10.8
135	0	0	0	0	0	0	3.1	2.7	9.2	9.0

treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. The oats seedling heights were 8.5, 3.1, and 1.9 inches when planted 25 days after soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. The barley and oats seedling heights gradually increased with each increase in time following soil treatment until they reached 9.2 and 9 inches, respectively, when planted 100 days after soil treatment with 135 pounds of TCB per acre.

The average root lengths for barley and oats planted in sandy loam soil treated with different rates of TCB per acre are reported in table 9. The barley root lengths were 2.4, 1.1, and 0.8 inches when planted 25 days after soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. The barley root lengths were increased with each increase in time after soil treatment with different rates of TCB per acre. The barley root length was 3.2 inches when planted 100 days after soil treatment with 135 pounds of TCB per acre. The oats root lengths were 2.4, 1.3, and 0.8 inches when planted 25 days after soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. Similar increases in root lengths of oats were obtained as were obtained for barley with each increase in time after soil treatment with different rates of TCB per acre. The oats root length was 2.8 inches when planted 100 days after soil treatment with 135 pounds of TCB per acre.

Similar results were obtained for the seedling

Table 9.--The effect of different rates of 1,2,4,5-tetrachloro-
benzene applied to sandy loam soil on the average root
lengths 18 days after planting of barley and oats
planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	3.2	2.9	2.4	2.3	2.6	2.4	2.6	2.0	2.8	2.3
1.7	0	0	2.4	2.4	2.4	2.4	3.5	2.4	3.3	3.0
5	0	0	1.1	1.3	2.5	2.3	3.6	2.3	3.6	3.0
15	0	0	0.8	0.8	2.8	2.4	3.3	2.6	2.9	2.7
45	0	0	0	0	1.7	0.2	2.7	2.0	3.0	2.5
135	0	0	0	0	0	0	1.7	1.3	3.2	2.8

weights of barley and oats as were noted for germination percentages, seedling heights, and root lengths when the crops were planted at different intervals after soil treatment (appendix IX).

The germinations, seedling heights, root lengths, and seedling weights of wheat were affected in a similar manner as was observed for barley and oats when the crop was planted in sandy loam soil treated with different rates of TCB per acre (appendices X and XI).

The results from experiments II and III indicated that the detrimental residual effects of TCB on the germination, seedling height, root length, and seedling weight of barley, oats, and wheat were less in sandy loam soil than in sandy soil.

Experiment IV.

The average germination percentages of barley and oats planted in clay loam soil at different intervals after soil treatment are given in table 10. No germination was obtained when barley and oats were planted one day after soil treatment with different rates of TCB per acre. The germinations of barley and oats ^{were} obtained 25 days after soil treatment with 1.7, 5, and 15 pounds of TCB per acre. With each increase in the rate of TCB per acre, the germination of barley and oats decreased. The germinations of barley and oats were 75 and 65%, respectively, when the crops were planted 25 days after soil treatment with 1.7 pounds of TCB

Table 10.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to clay loam soil on the average germination percentages of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	%	%	%	%	%	%	%	%	%	%	%	%
0	80	100	60	60	70	95	45	60	60	75	35	55
1.7	0	0	75	65	70	95	70	80	80	95	30	70
5	0	0	15	20	80	80	40	50	60	70	30	60
15	0	0	10	10	70	100	40	55	65	90	40	55
45	0	0	0	0	20	45	20	80	75	75	30	55
135	0	0	0	0	0	0	5	0	10	45	35	65

per acre. In general, with each increase in time following soil treatment with different rates of TCB per acre, the germinations of barley and oats increased. The germinations of barley and oats were 35 and 65%, respectively, when the crops were planted 125 days after soil treatment with 135 pounds of TCB per acre.

Table 11 gives the average seedling heights for barley and oats planted in clay loam soil at different intervals after soil treatment. The barley and oats seedling heights grew to 2.8 and 2.6 inches, respectively, when planted 25 days after soil treatment with 1.7 pounds of TCB per acre. The barley and oats seedling heights increased with each increase in time after soil treatment with different rates of TCB per acre. The barley and oats seedling heights reached 3.5 and 4.6 inches, respectively, when planted 125 days after soil treatment with 135 pounds of TCB per acre.

The average root lengths for barley and oats planted in clay loam soil at different intervals after soil treatment are reported in table 12. The barley and oats root lengths were 1.5 and 1.3 inches, respectively, when the crops were planted 25 days after soil treatment with 1.7 pounds of TCB per acre. With each increase in time following soil treatment with different rates of TCB per acre, the barley and oats root lengths increased until they reached 1.3 inches when the crops were planted 125 days after soil treat-

Table 11.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to clay loam soil on the average seedling heights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	3.6	5.3	2.8	3.1	8.0	7.6	3.4	5.3	6.7	7.8	3.4	5.1
1.7	0	0	2.8	2.6	6.9	7.0	5.4	6.7	8.4	8.6	4.0	5.4
5	0	0	0.9	0.5	6.9	7.3	3.3	3.9	6.4	9.4	3.8	5.1
15	0	0	0.6	0.4	3.4	4.7	2.2	3.4	5.8	6.6	3.3	4.8
45	0	0	0	0	1.3	1.0	2.1	2.1	6.1	5.7	3.3	4.6
135	0	0	0	0	0	0	0.3	0	0.7	3.2	3.5	4.6

Table 12.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to clay loam soil on the average root lengths 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	2.5	2.2	1.5	1.3	2.0	1.5	0.8	0.8	1.7	1.6	1.6	1.4
1.7	0	0	1.5	1.3	1.6	1.3	2.2	1.3	2.2	1.7	1.6	1.6
5	0	0	0.3	0.2	1.6	1.3	1.1	0.9	1.6	1.6	1.3	1.6
15	0	0	0.2	0.1	0.9	0.5	0.8	1.1	1.7	1.4	1.5	1.5
45	0	0	0	0	0.3	0.1	0.7	0.4	1.3	1.5	1.3	1.5
135	0	0	0	0	0	0	0.1	0	0.1	0.4	1.3	1.3

ment with 135 pounds of TCB per acre.

The effects of different rates of TCB per acre applied to clay loam soil on the seedling weights of barley and oats were similar to those for germination percentages, seedling heights, and root lengths (appendix XII).

Similar increases in the germination, seedling height, root length, and seedling weight of wheat were obtained when the crop was planted at different intervals after soil treatment (appendices XIII and XIV).

In general, the average germination percentages, seedling heights, root lengths, and seedling weights of barley, oats, and wheat seeds were much lower in experiment IV than those in experiments I, II, and III.

The effects of TCB treatments on the germination and seedling growth of barley, oats, and wheat were less in clay loam soil than those noted in sandy soil. The toxicity of TCB in clay loam soil was similar to that observed in sandy loam soil.

Experiment V.

The average germination percentages of barley and oats planted in clay soil at different intervals after soil treatment with different rates of TCB per acre are given in table 13. The germination of barley started at 90, 45, and 35% when planted one day after soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. In general, the germination of barley increased with an increase in time

Table 13.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to clay soil on the average germination percentages of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs.	%	%	%	%	%	%	%	%	%	%
0	85	90	95	95	90	95	75	90	80	100
1.7	90	80	85	100	100	100	75	100	90	95
5	45	25	100	95	100	100	85	100	95	95
15	35	30	90	80	95	100	80	100	100	100
45	0	0	35	25	90	95	75	100	90	100
135	0	0	0	0	55	20	75	95	90	100

interval after soil treatment. The germination of barley reached 75% when the time interval from soil treatment with 135 pounds of TCB per acre and planting was 75 days. The germination of oats was 80, 25, and 30% when the time interval from soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively, and planting was one day. The germination of oats increased until they reached 95% when the time interval between soil treatment with 135 pounds of TCB per acre and planting was 75 days.

Table 14 gives the average seedling heights for barley and oats planted in clay soil at different intervals after soil treatment with different rates of TCB per acre. The barley seedling heights were 6.4, 5.7, and 1.7 inches when the time between soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively, and planting was one day. The oats grew to 6.3, 2.2, and 1.3 inches when planted one day after soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively. The barley and oats seedling heights increased with an increase in time interval following soil treatment. The seedling heights of barley and oats grew 8.3 and 7.2 inches, respectively, when the crops were planted 75 days after soil treatment with 135 pounds of TCB per acre.

The average root lengths of barley and oats planted in clay soil at different intervals after soil treatment with different rates of TCB per acre are reported in table 15.

Table 14.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to clay soil on the average seeding heights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	6.0	6.1	9.5	9.6	10.0	11.1	8.8	7.6	7.0	9.8
1.7	6.4	6.3	9.2	9.4	10.6	11.1	9.3	9.5	10.4	11.4
5	5.7	2.2	10.1	8.9	11.1	10.5	9.4	8.9	10.5	11.1
15	1.7	1.3	7.6	6.7	11.1	10.6	8.3	9.0	10.5	12.0
45	0	0	2.6	1.9	10.1	10.6	8.3	7.4	10.3	12.4
135	0	0	0	0	5.6	2.9	8.3	7.2	9.2	10.6

Table 15.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to clay soil on the average root lengths 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	2.8	3.0	2.3	2.1	2.1	1.8	2.2	1.8	2.0	2.0
1.7	2.8	2.9	2.9	2.6	2.5	2.1	2.6	2.1	2.4	2.1
5	1.8	0.8	2.8	2.6	2.8	1.9	2.7	2.1	2.5	2.1
15	0.6	0.3	2.1	1.8	2.2	1.9	2.5	2.0	2.7	2.4
45	0	0	0.7	0.6	2.5	2.0	2.0	2.0	2.6	2.2
135	0	0	0	0	1.1	0.4	2.1	1.8	2.3	2.2

The root lengths of barley were 2.8, 1.8, and 0.6 inches when the time from soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively, and planting was one day. The oats root length grew 2.9, 0.8, and 0.3 inches when the time from soil treatment with 1.7, 5, and 15 pounds of TCB per acre, respectively, and planting was one day. With each increase in time after soil treatment with different rates of TCB per acre, the barley and oats root lengths increased. When barley and oats were planted 75 days after soil treatment with 135 pounds of TCB per acre, the seedling root lengths grew to 2.1 and 1.8 inches, respectively.

The same results were observed for the average seedling weights of barley and oats planted in clay soil at different intervals after soil treatment with different rates of TCB per acre (appendix XV).

The effects of different rates of TCB per acre on the germination, seedling height, root length, and seedling weight of wheat were similar to those for barley and oats (appendices XVI and XVII).

The residual effects of TCB on the germination and seedling vigor of barley, oats, and wheat were less pronounced in clay soil than those in sandy, sandy loam, and clay loam soils. Figures 4, 5, and 6 demonstrate the results obtained from experiments II, III, and V, respectively, when the interval from sandy, sandy loam, and clay soil treatment with TCB and planting was 25 days.

Figure 4. The effect of different rates of TCB applied to sandy soil on the germination and seedling vigor of barley, oats, and wheat planted 25 days after soil treatment: (1) 0 pounds per acre, (2) 1.7 pounds per acre, (3) 5 pounds per acre, (4) 15 pounds per acre, (5) 45 pounds per acre, (6) 135 pounds per acre.

Figure 5. The effect of different rates of TCB applied to sandy loam soil on the germination and seedling vigor of barley, oats, and wheat planted 25 days after soil treatment: (1) 0 pounds per acre, (2) 1.7 pounds per acre, (3) 5 pounds per acre, (4) 15 pounds per acre, (5) 45 pounds per acre, (6) 135 pounds per acre.

Figure 6. The effect of different rates of TCB applied to clay soil on the germination and seedling vigor of barley, oats, and wheat planted 25 days after soil treatment: (1) 0 pounds per acre, (2) 1.7 pounds per acre, (3) 5 pounds per acre, (4) 15 pounds per acre, (5) 45 pounds per acre, (6) 135 pounds per acre.

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5

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Experiment VI.

The average germination percentages, seedling heights, and root lengths for barley and oats planted in sandy soil treated with 10 pounds of TCB per acre and given different numbers of soil mixings are reported in table 16. The germination of barley was 90 to 100%; seedling height was 7.8 to 10.3 inches; and root length was 2.6 to 3.7 inches when the crop was planted 32 days after soil treatment with different numbers of soil mixings. The germination of oats was 80 to 95%, seedling height was 8.6 to 10.7 inches; and root length was 2.3 to 2.8 inches when the crop was planted 32 days after soil treatment with different numbers of soil mixings. The germination of barley was 90 to 100%; seedling height was 7.8 to 9.9 inches; and root length was 3.3 to 4.5 inches when the crop was planted 52 days after soil treatment with different numbers of soil mixings following TCB application. The germination of oats was 80 to 100%; seedling height was 10.5 to 11.9 inches; and root length was 2.7 to 3.3 inches when the crop was planted 52 days after soil treatment with different numbers of soil mixings following TCB application. No outstanding differences in germination, seedling height, and root length of barley and oats were observed for different numbers of soil mixings prior to planting the crops 32 and 52 days after soil treatment.

The same results were found for the seedling weight

Table 16.—The effect of different numbers of soil mixings following application of 10 pounds of 1,2,4,5-tetrachlorobenzene to sandy soil on the average germination percentages, seedling heights, and root lengths 18 days after planting of barley and oats planted at different intervals after soil treatment.

Number of Soil mixings	Days after soil treatment											
	32						52					
	Germination		Seedling Height		Root Length		Germination		Seedling Height		Root Length	
	B	O	B	O	B	O	B	O	B	O	B	O
no.	%	%	in.	in.	in.	in.	%	%	in.	in.	in.	in.
0	100	85	9.0	10.7	3.7	2.8	100	80	9.4	10.5	4.5	3.3
2	90	90	8.5	8.6	2.6	2.3	95	100	9.9	11.4	3.3	2.8
3	95	95	7.8	8.8	2.6	2.4	90	90	7.8	10.7	3.3	2.7
4	100	80	9.5	8.9	3.3	2.6	90	100	8.4	10.7	3.8	2.9
8	100	95	9.6	9.9	3.4	2.6	90	95	8.9	11.9	4.1	3.2
Check	100	85	10.3	10.6	3.4	2.6	90	80	9.6	11.2	3.9	3.0

of barley and oats for different numbers of soil mixings when the crops were planted in sandy soil 32 and 52 days after soil treatment (appendix XVIII).

The effects of different numbers of soil mixings following the application of 10 pounds of TCB per acre on the germination, seedling height, root length, and seedling weight of wheat planted 32 and 52 days after soil treatment are reported in appendix XIX. No germination was obtained when wheat was planted in sandy soil with 2 mixings 32 days after soil treatment. The germination, seedling height, root length, and seedling weight decreased when wheat was planted in sandy soil with 3 and 4 mixings 32 days after soil treatment. No outstanding differences in germination, seedling height, root length, and seedling weight of wheat were noted for 0 and 8 numbers of soil mixings prior to planting the crops 32 days after soil treatment. The effects of different numbers of soil mixings following the application of 10 pounds of TCB per acre on the germination, seedling height, root length, and seedling weight of wheat were similar to those observed for barley and oats when the crop was planted 52 days after soil treatment.

DISCUSSION

Experiments I through V were undertaken to study the effects of 1,2,4,5-tetrachlorobenzene (TCB) on small grains. No germination was obtained when barley, oats, and wheat were planted one day after sandy, sandy loam, and clay loam soils were treated with TCB. Minarik (26) stated that TCB incorporated into the soil vaporizes to a limited extent, and the vapors penetrate the crop seed coat and kill the embryo. Germination started one day after soil treatment with low rates of TCB application in clay soil. The germination, seedling height, root length, and seedling weight of barley, oats, and wheat grown in sandy, sandy loam, clay loam, and clay soils increased with each increase in time following soil treatment. This probably is due to the volatilization of TCB from the soil surface, since TCB is insoluble in water (7), and it is not decomposed in the soil by soil organisms (26). The higher rates of TCB per acre produced more injury to small grains than the lower rates. Since the surface areas of all soil treatments were equal, there should be about the same number of pore spaces in the surface soil of a given soil type for all TCB treatments. In general, the rate of TCB volatilization from the soil was proportional to the amount of TCB incorporated into the soil. There-

fore, the higher rates of TCB per acre required more time to volatilize than the lower rates. The injury to small grains did not occur at 75, 125, 100, and 125 days-intervals after soil treatment in clay, clay loam, sandy loam, and sandy soils, respectively. The toxicity of TCB in the clay soil was less than in clay loam, sandy loam, and sandy soils, and the toxicity of TCB in clay loam and sandy loam soils was less than in sandy soil. The differences in TCB toxicity in the foregoing soils may be due to differences in texture and surface area of the soils. The particle size in clay soil is much smaller than in clay loam, sandy loam, and sand. The smaller particle size in the clay soil provides a greater soil particle surface area which tends to adsorb more TCB and prevent its free movement in the soil. The differences in soil texture and surface area might be two possible explanations of why the toxicity of TCB in the clay soil was less than in clay loam, sandy loam, and sandy soils. For the foregoing reasons the residual effect of TCB in clay loam and sandy loam soils may be expected to be less than in sandy soil. The similarity of the toxicity of TCB in the clay loam and sandy loam soils was unexpected. This, together with the lower germination and seedling vigor of barley, oats, and wheat obtained in clay loam soil may have been due to the high concentration of soluble salts found in the clay loam soil (7,700 ppm). Barley showed more tolerance to TCB treatments than both oats and wheat in

sandy soil. This might be due to differences in the genetic make-up of these crops. The average germination percentage of the wheat seed used was much lower than that normally expected for high quality seed wheat. The low germination percentage was probably due to the use of paradichlorobenzene nuggets in the wheat storage for grain weevil control.

In experiment VI no outstanding differences in germination and seedling vigor of barley and oats were observed for different numbers of soil mixings prior to planting the crops 32 and 52 days after sandy soil treatment with 10 pounds of TCB per acre. One would expect additional soil mixing to encourage TCB volatilization. This was evidenced when wheat was planted 32 days after soil treatment with different numbers of soil mixings. As the number of soil mixings was increased the germination and seedling growth of wheat also were increased. Similar results might be found for barley and oats as those obtained for wheat if the period of soil mixing was less than 32 days. Wheat was more susceptible to 10 pounds of TCB per acre with different numbers of soil mixings within a 32 day period than both barley or oats. Ten pounds of TCB per acre applied to the surface of the sandy soil volatilized within a 32 day period, since it was in direct contact with the air. The differences in the effect of different numbers of soil mixings in increasing the rate of TCB volatilization were not evident when wheat was planted 52 days after soil treatment.

The foregoing experiments determined that TCB had detrimental effects on germination and seedling vigor of small grains in four soil types. Further experiments are needed to determine the effect of pre-planting application of TCB on the advanced stages of plant growth and grain production of small grains.

SUMMARY

Six experiments were conducted in 1958 in the Agronomy greenhouse, University of Arizona, to determine the residual effect of 1,2,4,5-tetrachlorobenzene (TCB) on the germination and seedling vigor of barley, oats, and wheat planted at different intervals after soil treatment.

In experiment I sandy soil was used. The germination and seedling growth of barley, oats, and wheat increased with an increase in time following soil treatment. The higher rates of TCB per acre produced more injury to small grains than the lower rates. Barley was more tolerant to TCB treatments than both oats and wheat.

In experiment II sandy soil also was used. The germination of barley, oats, and wheat started 25 days after soil treatment with 1.7 pounds of TCB per acre. The germination and seedling growth of small grains increased with an increase in time after soil treatment. No injury to small grains was obtained 125 days after soil treatment with 135 pounds of TCB per acre.

Experiment III was conducted using sandy loam soil. The germination of barley, oats, and wheat was started 25 days after soil treatment with 1.7, 5, and 15 pounds of TCB per acre. With each increase in time after soil treatment, the germination and seedling growth of small grains in-

creased. No injury was obtained when small grains were planted 100 days after soil treatment. The residual effects of TCB on small grains were less in sandy loam soil than in sandy soil.

In experiment IV clay loam soil was used. The germination and seedling growth of barley, oats, and wheat gradually increased with each increase in time following soil treatment until the injury did not occur when the crops were planted 125 days after soil treatment with 135 pounds of TCB per acre. The toxicity of TCB treatments on small grains was less in clay loam soil than in sandy soil. The toxicity of TCB in clay loam soil was similar to that observed in sandy loam soil.

In experiment V clay soil was used. The germination of barley, oats, and wheat started one day after soil treatment with 1.7, 5, and 15 pounds of TCB per acre. The germination and seedling growth of small grains increased until no injury was noted when the time interval between soil treatment with 135 pounds of TCB and planting was 75 days. The residual effects of TCB were less pronounced in clay soil than those in clay loam, sandy loam, and sandy soils.

Experiment VI was conducted using different numbers of soil mixings following the application of 10 pounds of TCB per acre to sandy soil. No outstanding differences in germination and seedling growth of barley and oats were obtained for different numbers of soil mixings within a 32 day

period. As the number of soil mixings was increased the germination and seedling growth of wheat were increased.

Appendix I.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average seedling weights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment																			
	1		20		40		60		80		100		120		140		160		180	
	* B	** O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms	gms
0	0.5	0.4	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4
5	0	0	0.1	0	0.4	0	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.5	0.4	0.5	0.4	0.4	0.4
15	0	0	0	0	0	0	0.6	0.4	0.6	0.5	0.4	0.5	0.4	0.4	0.5	0.3	0.5	0.3	0.4	0.4
45	0	0	0	0	0	0	0.2	0	0.4	0.3	0.6	0.5	0.5	0.4	0.5	0.4	0.5	0.4	0.4	0.5
135	0	0	0	0	0	0	0	0	0	0	0.1	0	0.3	0.1	0.5	0.4	0.5	0.4	0.5	0.5
405	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.3	0.3	0.4	0.4

* B = Barley

** O = Oats

Appendix III.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average seedling heights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1	20	40	60	80	100	120	140	160	180
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	7.4	10.3	8.4	7.0	6.4	5.5	7.1	4.7	8.8	9.4
5	0	0	1.4	6.4	6.6	5.5	6.2	7.7	9.9	11.2
15	0	0	0	1.5	6.7	5.5	6.0	4.6	6.8	13.5
45	0	0	0	0	0.8	5.6	5.7	7.1	7.9	12.8
135	0	0	0	0	0	0	0	6.9	8.1	12.2
405	0	0	0	0	0	0	0	0	3.5	9.4

Appendix IV.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average root lengths 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1	20	40	60	80	100	120	140	160	180
lbs.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0	2.8	5.5	5.0	3.9	3.4	3.5	2.7	1.5	2.9	4.0
5	0	0	0.6	3.7	4.6	3.5	2.5	2.8	4.0	4.8
15	0	0	0	0.6	3.4	3.3	2.3	2.9	2.7	5.3
45	0	0	0	0	0.5	3.3	2.5	3.5	3.0	4.9
135	0	0	0	0	0	0	0	2.5	2.6	4.0
405	0	0	0	0	0	0	0	0	1.2	3.8

Appendix V.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average seedling weights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1	20	40	60	80	100	120	140	160	180
lbs.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
0	0.4	0.5	0.4	0.4	0.2	0.2	0.2	0.1	0.2	0.3
5	0	0	0.2	0.5	0.3	0.2	0.2	0.2	0.2	0.3
15	0	0	0	0.1	0.4	0.2	0.2	0.2	0.2	0.4
45	0	0	0	0	0.1	0.2	0.2	0.2	0.2	0.4
135	0	0	0	0	0	0	0	0.2	0.2	0.4
405	0	0	0	0	0	0	0	0	0.1	0.3

Appendix VI.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average seedling weights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
0	0.6	0.6	0.5	0.6	0.5	0.4	0.4	0.3	0.5	0.5	0.5	0.5
1.7	0	0	0.6	0.6	0.5	0.4	0.6	0.4	0.6	0.6	0.5	0.5
5	0	0	0	0	0.6	0.4	0.6	0.4	0.6	0.6	0.5	0.5
15	0	0	0	0	0.5	0.4	0.5	0.4	0.6	0.5	0.5	0.5
45	0	0	0	0	0.1	0	0.6	0.3	0.6	0.5	0.5	0.5
135	0	0	0	0	0	0	0.1	0	0.4	0.4	0.5	0.5

Appendix VII.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average germination percentages and seedling heights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	Germ.*	S.**Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.
lbs.	%	in.	%	in.	%	in.	%	in.	%	in.	%	in.
0	80	8.1	30	5.0	50	6.8	25	6.6	25	11.5	30	10.9
1.7	0	0	40	5.7	85	8.7	25	9.1	30	13.7	35	10.5
5	0	0	0	0	50	6.8	30	9.3	25	11.3	30	9.6
15	0	0	0	0	35	4.2	25	7.1	40	13.7	40	8.6
45	0	0	0	0	0	0	0	0	30	11.6	40	10.9
135	0	0	0	0	0	0	0	0	10	4.4	40	10.8

* Germ. = Germination

** S.Ht. = Seedling Height

Appendix VIII.--The effect of different rates of 1,2,4,5-tetrachlorobenzene applied to sandy soil on the average root lengths and seedling weights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	* R.L.	** S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.
lbs.	in.	gms.	in.	gms.	in.	gms.	in.	gms.	in.	gms.	in.	gms.
0	4.8	0.4	3.1	0.2	2.7	0.2	2.3	0.2	4.1	0.3	4.1	0.4
1.7	0	0	3.4	0.3	4.8	0.3	3.7	0.3	5.1	0.4	4.1	0.4
5	0	0	0	0	2.6	0.3	3.7	0.3	4.6	0.4	3.6	0.4
15	0	0	0	0	1.4	0.2	2.6	0.2	4.6	0.4	4.3	0.4
45	0	0	0	0	0	0	0	0	4.0	0.4	4.2	0.4
135	0	0	0	0	0	0	0	0	1.1	0.1	3.9	0.4

* R. L. = Root Length

** S.Wt. = Seedling Weight

Appendix IX.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to sandy loam soil on the average seedling weights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
0	0.5	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4
1.7	0	0	0.4	0.4	0.4	0.3	0.5	0.3	0.4	0.5
5	0	0	0.2	0.2	0.5	0.4	0.5	0.3	0.5	0.5
15	0	0	0.2	0.1	0.4	0.4	0.5	0.3	0.5	0.5
45	0	0	0	0	0.3	0.8	0.4	0.3	0.5	0.4
135	0	0	0	0	0	0	0.2	0.2	0.5	0.5

Appendix X.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to sandy loam soil on the average germination percentages and seedling heights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.
lbs.	%	in.	%	in.	%	in.	%	in.	%	in.
0	90	8.1	75	9.4	60	12.7	45	8.2	35	8.6
1.7	0	0	60	8.9	75	10.6	65	12.1	55	8.6
5	0	0	15	4.8	55	11.7	35	10.5	35	10.4
15	0	0	5	0.8	70	10	45	10.8	35	9.5
45	0	0	0	0	5	1.5	45	8.7	35	9.4
135	0	0	0	0	0	0	10	3.3	40	10.1

Appendix XI.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to sandy loam soil on the average root lengths and seedling weights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.
lbs.	in.	gms.	in.	gms.	in.	gms.	in.	gms.	in.	gms.
0	5	0.5	3	0.4	3.1	0.4	2.6	0.3	2.7	0.3
1.7	0	0	3	0.3	2.9	0.4	3.6	0.4	3.1	0.3
5	0	0	2.1	0.3	3.4	0.4	3.6	0.4	3.8	0.4
15	0	0	0.3	0.1	2.8	0.4	3.5	0.4	2.7	0.4
45	0	0	0	0	0.1	0.1	2.2	0.3	2.9	0.4
135	0	0	0	0	0	0	1	0.2	3.1	0.4

Appendix XII.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to clay loam soil on the average seedling weights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	B	O	B	O	B	O	B	O	B	O	B	O
lbs.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
0	0.4	0.3	0.2	0.2	0.4	0.3	0.2	0.2	0.3	0.3	0.2	0.2
1.7	0	0	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.2	0.2
5	0	0	0.1	0.1	0.3	0.3	0.2	0.2	0.3	0.3	0.2	0.2
15	0	0	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2
45	0	0	0	0	0.1	0.1	0.2	0.2	0.3	0.3	0.2	0.2
135	0	0	0	0	0	0	0.1	0	0.1	0.2	0.2	0.2

Appendix XIII.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to clay loam soil on the average germination percentages and seedling heights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment											
	1		25		50		75		100		125	
	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.
lbs.	%	in.	%	in.	%	in.	%	in.	%	in.	%	in.
0	87	7.1	45	3.9	30	6.1	15	6.1	20	5.4	30	7.7
1.7	0	0	50	3.1	70	7.1	20	5.6	40	12.8	45	8.6
5	0	0	15	1.1	45	7.5	40	7.7	60	12.1	30	6.2
15	0	0	35	1.4	25	2.9	15	3.3	50	11.6	25	5.3
45	0	0	0	0	10	0.7	10	1.3	30	6.4	45	7.5
135	0	0	0	0	0	0	5	0.7	5	0.5	25	5.9

Appendix XIV.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to clay loam soil on the average root lengths and seedling weights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment.											
	1		25		50		75		100		125	
	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.
lbs.	in.	gms.	in.	gms.	in.	gms.	in.	gms.	in.	gms.	in.	gms.
0	3.4	0.4	1.6	0.2	1.7	0.2	1.2	0.2	1.0	0.2	1.8	0.2
1.7	0	0	1.4	0.2	1.6	0.2	1.0	0.2	2.5	0.3	2.2	0.2
5	0	0	0.5	0.1	1.5	0.2	1.7	0.3	3.2	0.4	1.9	0.2
15	0	0	0.5	0.1	0.2	0.1	1.1	0.2	2.0	0.3	1.9	0.2
45	0	0	0	0	0.1	0.1	0.1	0.1	1.1	0.3	2.2	0.3
135	0	0	0	0	0	0	0.1	0.1	0.1	0.1	1.8	0.2

Appendix XV.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to clay soil on the average seedling weights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	B	O	B	O	B	O	B	O	B	O
lbs.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
0	0.4	0.3	0.5	0.4	0.5	0.4	0.3	0.3	0.4	0.4
1.7	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.3	0.4	0.4
5	0.4	0.2	0.5	0.4	0.5	0.3	0.4	0.3	0.4	0.4
15	0.2	0.1	0.3	0.3	0.5	0.4	0.3	0.3	0.5	0.4
45	0	0	0.2	0.1	0.5	0.4	0.3	0.2	0.5	0.4
135	0	0	0	0	0.3	0.1	0.3	0.2	0.4	0.4

Appendix XVI.--The effect of different rates of 1,2,4,5-tetrachloro-benzene applied to clay soil on the average germination percentages and seedling heights 18 days after planting of wheat planted at different intervals after soil treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.	Germ.	S.Ht.
lbs.	%	in.	%	in.	%	in.	%	in.	%	in.
0	85	9.3	50	8.7	45	10.4	45	9.2	30	9.4
1.7	80	8.8	70	8.7	40	7.8	40	13.1	60	11.3
5	15	1.6	50	9.0	60	11.8	40	8.8	70	10.8
15	5	0.3	40	6.8	55	10.6	35	8.0	45	12.2
45	0	0	10	0.6	50	12.3	35	8.3	30	6.6
135	0	0	0	0	5	0.5	30	10.1	75	9.0

Appendix XVII.--The effect of different rates of 1,2,4,5-tetrachloro-
benzene applied to clay soil on the average root
lengths and seedling weights 18 days after planting
of wheat planted at different intervals after soil
treatment.

Rate of TCB application per acre	Days after soil treatment									
	1		25		50		75		100	
	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.	R.L.	S.Wt.
lbs.	in.	gms.	in.	gms.	in.	gms.	in.	gms.	in.	gms.
0	4.2	0.5	2.4	0.3	2.6	0.3	2.8	0.3	2.0	0.3
1.7	4.0	0.5	3.4	0.3	3.1	0.3	3.1	0.4	3.2	0.4
5	0.8	0.1	2.7	0.3	3.1	0.3	2.6	0.2	2.5	0.3
15	0.1	0.1	1.8	0.2	3.1	0.3	2.4	0.2	2.6	0.4
45	0	0	0.2	0.1	2.5	0.4	2.6	0.3	2.4	0.2
135	0	0	0	0	0.1	0.1	2.6	0.4	3.3	0.3

Appendix XVIII.--The effect of different numbers of soil mixings following application of 10 pounds of 1,2,4,5-tetrachlorobenzene to sandy soil on the average seedling weights 18 days after planting of barley and oats planted at different intervals after soil treatment.

Number of soil mixings	Days after soil treatment			
	32		52	
	B	0	B	0
no.	gms.	gms.	gms.	gms.
0	0.5	0.5	0.5	0.5
2	0.5	0.4	0.4	0.6
3	0.4	0.4	0.4	0.5
4	0.5	0.4	0.4	0.5
8	0.5	0.4	0.5	0.5
Check	0.5	0.4	0.5	0.5

Appendix XIX.--The effect of different numbers of soil mixings following application of 10 pounds of 1,2,4,5-tetrachlorobenzene to sandy soil on the average germination percentages, seedling heights, root lengths and seedling weights 18 days after planting of wheat planted at different intervals after soil treatment.

Number of soil mixings	Days after soil treatment							
	32				52			
	Germ.	S.Ht.	R.L.	S.Wt.	Germ.	S.Ht.	R.L.	S.Wt.
no.	%	in.	in.	gms.	%	in.	in.	gms.
0	45	11.2	4.2	0.4	25	8.7	3.7	0.2
2	0	0	0	0	25	8.7	2.9	0.2
3	10	2.3	0.8	0.1	25	6.7	2.6	0.2
4	20	4.3	1.2	0.2	20	6.0	2.3	0.2
8	45	9.8	2.9	0.4	25	6.7	2.7	0.2
Check	25	7.1	2.1	0.3	20	6.0	2.3	0.2

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