THE RESIDUAL INFLUENCE OF SOME CHLORATES UPON CROP PRODUCTION

THESIS FOR THE DEGREE OF M. S.

Ralph W. Lipscomb

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Chlorates
Mids

Farm crops

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Respectfully submitted in partial fulfillment
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Introduction

In most of the published literature on the eradication of noxious weeds with chemical sprays, scant consideration has been given to the possibility that the chemicals might have a deleterious effect upon the soil and therefore upon the succeeding crop growth. The majority of the previous work deals with the effectiveness of the various chemicals as weed destroyers, the rate of application, and the time of applying. Statements have been made to the effect that the soil is not injured or that the injury is only temporary. These statements have been made with little or no proof except for the work of Aslander (1) who reports that an application of herbicides in the fall had no influence on the ammonification and nitrification processes in the soil the following spring and Latshaw and Zahnley (9) who report a good growth of wheat on soil where three applications of sodium chlorate had been made the year preceding seeding.

Some chemicals, such as common salt and crank case oil, have a deleterious effect on the soil which lasts for an indefinite period. Other chemicals, such as, sodium arsenite, iron sulphate, copper sulphate, corrosive sublimate, carbolic acid, and sulphuric acid, have certain undesirable characteristics which prevent their use as herbicides. At present, chlorates are increasing in use as weed eradicators. Since it has become an established fact that chlorates can be successfully used as a means of eradicating noxious weeds, the question

naturally arises, what toxic influence, if any, do these chemicals have upon the succeeding crop growth? This is a vital question because of the economic importance of the land. If the soil is rendered unproductive for an indefinite period, the use of chlorates would not be practical as a means of eradicating weeds.

In the present study sodium chlorate, ($NaClO_3$), magnesium chlorate, $Mg(ClO_3)_2$, and "Atlacide", a commercial compound consisting approximately of 60 percent sodium chlorate, 39 percent calcium chloride, and 1 percent zinc chloride were used. The work was undertaken with the object; first, to determine if there is a toxic influence upon crop growth from applying chlorates to weeds; second, to determine how long the residual influence lasts; third, to determine the movement of the chlorates through the soil; and fourth, to make a study of the toxicity of chlorates upon different crop plants.

Review of Previous Investigations

Many workers have reported on the eradication of noxious weeds with chlorates. However, most of the work deals with the effectiveness of the different chlorates, the best time to apply, and the rate of application.

Aslander, A. (1) conducting experiments on the eradication of Canada thistle, (Cirsium arvense), states that the effectiveness of chlorates is due to their rapid penetration through soil and their slow decomposition, especially at low temperatures. The disapperance of chlorates under field conditions is not wholly due to leaching. In soil kept at 30° C. ($NaClO_3$) decomposed markedly during 10 weeks. Barley planted 10 weeks after the chlorate was applied grew to full size while that planted earlier died. Sodium thiocyanate, and to a greater extent sodium cyanide, decomposed so rapidly in the soil that no harm was done to Canada thistles under field conditions. An application of sodium chlorate in late autumn killed the Canada thistles and did not injure the oats that were sown on the plats the following spring.

Latshaw, W. L. and Zahnley, J. W. (9) report that sodium chlorate applied in amounts necessary to kill bindweed does not have an injurious effect on the soil. A slightly injurious effect upon plant growth may be observed on crops seeded very soon after applying sodium chlorate, but this is only temporary. They state that a crop of wheat grown on plats which had been sprayed three times the year preceding, gave a yield of 27 bushels per acre. Salt applied on land

infested with bindweed at the rate of 20 tons per acre will kill practically all the bindweed plants. Salt is too expensive to use over large areas and it also ruins the land for an indefinite period.

Rogers, C. F. and Hatfield, I. (11) report that carbon disulphide, as a chemical spray for eradicating weeds, does not have an injurious effect upon the soil. To the contrary, it has a tendency to stimulate crop growth after the temporary effect is over. The temporary poisonous effect lasts for only a few weeks.

Latshaw and Zahnley (8) conducting experiments with sodium chlorate and other chemicals for the eradication of field bindweed found that soils that had been treated with herbicides contained nitrates to a depth of seven inches. These samples of soil were incubated and additional nitrates were formed, showing that bacterial action had not been seriously interferred with by the various treatments. Two of the plats on which bindweed had been killed by sodium chlorate, were sown to wheat in September 1926. This crop made a normal growth throughout the fall and came through the winter in excellent condition. So far as could be observed the sodium chlorate had no deleterious effect upon the growth of the wheat. Therefore, we may conclude that no permanent detrimental effect upon the soil is noted.

In an experiment conducted for the purpose of determining the effectiveness of sodium chlorate, potassium chlorate, and sodium arsenite on Canada thistle Aslander (2) found that the chlorates were very effective - the larger amounts killed the Canada thistles completely. The growth of annual weeds on the plats seemed to indicate that the poisonous action of the applied chemicals was only of a short duration.

Hawkins, R. S. (4) states that hydrocyanic acid, if present in the soil solution in a concentration of one part per million or more would, quite likely depress growth in most plants.

Willard, C. J. (12) states that sodium chlorate does not sterilize the soil. Even after heavy sprayings crops can be grown within a year and sometimes within a month.

A considerable decrease in the yield of oats is reported by Harper (6) on areas that had been sprayed twice with sodium chlorate at the rate of 100 pounds per acre in the summer and fall preceding planting. He states that the decomposition of chlorates is probably complete after a week's time under favorable moisture conditions and summer temperatures, consequently the toxic effect could hardly be due to sodium chlorate since several months had elapsed between the time the last spray was applied and when the oats were planted. The decrease in the yield of oats was probably due to a retarding action that sodium chlorate has upon the nitrification of compounds of organic and inorganic nitrogen.

Hulbert, H. W., et. al. (7) states that 15 pounds of sodium chlorate per square rod immediately surrounding a prune tree did not prove fatal under irrigation. The leaves turned yellow and the fruit dropped off before maturity one year after the treatment was made. The following year the tree appeared normal. In irrigated areas, grain crops seeded the spring following chlorate treatments turn yellow. The first application of water usually restores them to normal growth. In rainfall areas, treated patches sometimes show the effect of the chlorate treatment throughout the subsequent season. Such damages are apparent only in seasons when winter precipitation is not sufficient to wash the chlorate from the soil. There is no permanent damage to the soil by the application of chlorates in the amounts recommended in Idaho.

Hansen (5) states that crab grass, orchard grass, and other vegetation appeared within a month on an area that was sprayed with sodium chlorate at the rate of one pound per five square feet, indicating that the chlorate does not injure the soil.

According to Latshaw and Zahnley (10) magnesium and calcium chlorate will be more effective within a wider range of weather conditions than sodium chlorate. This is because of the fact that magnesium chlorate normally carries six and calcium chlorate two molecules of water of crystallization., while sodium chlorate forms an anhydrous salt. There is also the danger of a fire hazard from sodium chlorate when it comes in contact with organic material.

Materials and Methods

Field Work

In 1928 Megee conducted experiments on the eradication of quackgrass, Agropyron repens (L) Beauv. with sodium chlorate, ($NaClO_3$) and magnesium chlorate, ($Mg(ClO_3)_2$). The object of these experiments was to study the relative effectiveness of the chlorates when applied at different rates and at different times of the year. Complete eradication of the quackgrass resulted where applications of 200 and 300 pounds of chlorate per acre were made. In the spring of 1929 it was thought desirable to continue these experiments, together with an additional experiment with the object of studying the residual effect of the chlorates upon the soil and hence upon crop growth.

The experiments were conducted under the following divisions:

1. Chlorates applied in the early spring, the land plowed, the seed bed prepared, and the crops planted during the late spring, summer, and fall months of the same season.
2. Chlorates applied in varied numbers and rates of application during late summer. The following season the land spaded and corn planted to determine the residual influence of chlorates.
3. Chlorates applied in the spring, land not plowed, and the residual influence determined at various soil depths.
4. Chlorates applied during late summer and corn, beans,

potatoes, and buckwheat planted the following season to determine the residual influence of chlorates.

Chlorates Applied During the Spring, the Land Plowed, the Seed Bed Prepared, and the Crops Planted During the Late Spring, Summer and Fall Months of the Same Season.

In April, 1929, a field on the college farm was secured for this experiment. This field had been in pasture and at that time had a dense sod of quackgrass. The soil was of a Hillsdale Clay loam type and of fair drainage. Plats 1/30 of an acre in size were laid out in four series, five plats to the series. Each series of plats received a different treatment of Atlacide. The applications were made with a three gallon knapsack compressed air sprayer at ten day intervals. The quantities of Atlacide used ranged from 150 pounds per acre to 375 pounds per acre. The applications were made in accordance with a certain scheme which enabled the crops that were to be planted to form a checker board condition with the different rates of application. Series one was left as a check, series two received one application of 150 pounds Atlacide per acre on April 15, series three received two applications of 150 pounds atlacide each per acre on April 15 and April 25, series four received three applications of which the first was 150 pounds, second 150 pounds, and the third, 75 pounds of Atlacide per acre on

April 15, April 25, and May 11, respectively.

After all applications were completed, the soil was plowed to a depth of eight inches, a seed bed prepared, and crops planted. The following crops were planted: M.A.C. yellow dent corn, Robust beans, Russet Burbank potatoes, Silverhull buckwheat, Sudan grass, American Banner wheat, and Rosen rye. Notes were taken on all crops from the time of germination as to vigor, color, and size. Pictures were taken of corn, bean, and buckwheat seedlings ten days after germination. Pictures were also taken of the individual crops when they were fully mature. Notes were taken at the time of harvesting on yields and relative size of plants.

Chlorates Applied in Varied Numbers and Rates of Application During Late Summer. The Following Season the Land Spaded, and Corn Planted to Determine the Residual Influence of Chlorates.

In the late summer of 1928, plats 20.86 feet square were laid out on a dense quackgrass sod. Both sodium chlorate and magnesium chlorate were applied to these plats in varied numbers and rates of application, table no. 4. Complete eradication of the quackgrass resulted where applications of 200 pounds or more of chlorate per acre were made.

One year later or during the spring of 1929 one fourth of each of these plats was spaded, fertilizer applied, and corn planted. Likewise, an untreated plat was planted.

Notes were taken and observations made at regular intervals to determine any difference in the growth of the corn. Pictures were taken when the corn was fully mature in order to compare the residual influence of the different rates of application.

The pictures which follow show the corn as it appeared in late August. There was no apparent difference in the growth of the corn on plats that received 300 pounds chlorate per acre and that on plats that received 50 pounds per acre. The yield of corn from these plats also indicates that no difference is apparent between the heavy treatments and the light treatments. Figure No. 26 is a plat on which common salt was applied at the rate of 20 tons per acre. A residual influence is apparent in the growth of the corn on this plat as compared with the remaining plats. This indicates that the chlorates had been dissipated during the winter while the salt was not.

Chlorates Applied in the Spring, Land not Plowed, and the Residual Influence Determined at Various Soil Depths

During the spring of 1929, applications of both sodium chlorate and Atlacide were made on plats 20.86 feet square. The applications were made at the rates of from 100 to 400 pounds per acre. About 10 weeks after the chlorates had been applied, layers of soil from one to four inches, from four to eight inches, and from eight to twelve inches deep were removed from both treated and untreated plats and the soil placed in four inch pots in the greenhouse. Beans were planted in these pots,

seven beans per pot, and the rapidity of germination, the vigor of the plants, and the color of the leaves was noted at regular intervals.

Chlorates Applied During Late Summer and Corn, Beans, Potatoes, and Buckwheat Planted the Following Season to Determine the Residual Influence of Chlorates

During the summer of 1923 three acres of quackgrass sod were divided into halves in order that both sodium chlorate and magnesium chlorate could be applied in equal amounts. Two applications were made of 100 pounds per acre. These applications completely killed the quackgrass.

The following season at the usual planting time corn, beans, potatoes, and buckwheat were planted on this area. These crops were planted across the area in such a way that half of the crop was growing on soil that had been treated with sodium chlorate and the other half growing on soil that had been treated with magnesium chlorate. The crops were cultivated three times during the growing season. Notes were taken on the individual crops from the time of germination to the time of harvesting in order that a check could be made as to the relative toxic effect of the two chlorates. Yields were also taken at the regular harvest time of each crop. When the crops were fully mature pictures were taken to show the comparative size of the plants growing on the soil treated with sodium chlorate and the plants growing on soil treated with magnesium chlorate.

Table 1. Height and yield of corn planted on plats that had been sprayed with Atlacide at the rate of 150, 300, and 375 pounds per acre one month before corn was planted.

Treatment	Ht. of plants (inches)	Yield per acre (Bu.)
CK	69.6	18.98
150	64.4	15.75
300	59.2	14.99
375	34.6	4.74

Table 2. Size and yield per acre of potatoes planted on plats that had been sprayed with Atlacide at the rate of 150, 300, and 375 pounds per acre one month before potatoes were planted.

Treatment	Yield per acre (Bu.)	Size of potatoes
CK	25.14	Medium
150	28.04	Medium
300	11.60	Small
375	4.35	Very small

Table 3. Yield per acre of beans planted on plats that had been sprayed with Atlacide at the rate of 150, 300, and 375 pounds per acre one month before beans were planted.

Treatment	Yield per acre in Bushels
CK	6.25
150	3.51
300	1.25
375	0.23

Fig. No. 1 - Corn seedlings 10 days after germination, showing residual influence of Atlacide when applied at different rates one month before corn was planted. Left - check - no treatment. Center - 300 pounds Atlacide per acre. Right - 375 pounds Atlacide per acre.

Fig. No. 2 - Duplicate of above in reverse order.

Fig. No. 3 - Bean seedlings from check plat 10 days after germination.

Fig. No. 4 - Bean seedlings 10 days after germination from plat that had an application of 375 pounds Atlacide per acre one month before beans were planted.

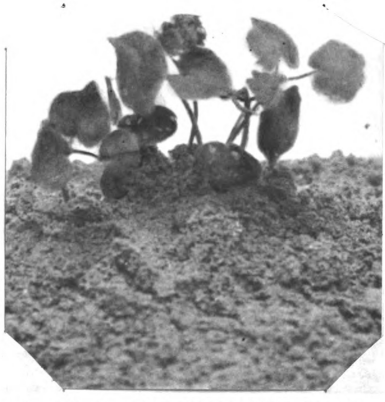

Fig. No. 5 - Buckwheat seedlings from check plat 10 days after germination

Fig. No. 6 - Buckwheat seedlings 10 days after germination from plat that had an application of 375 pounds Atlacide per acre one month before buckwheat was planted.

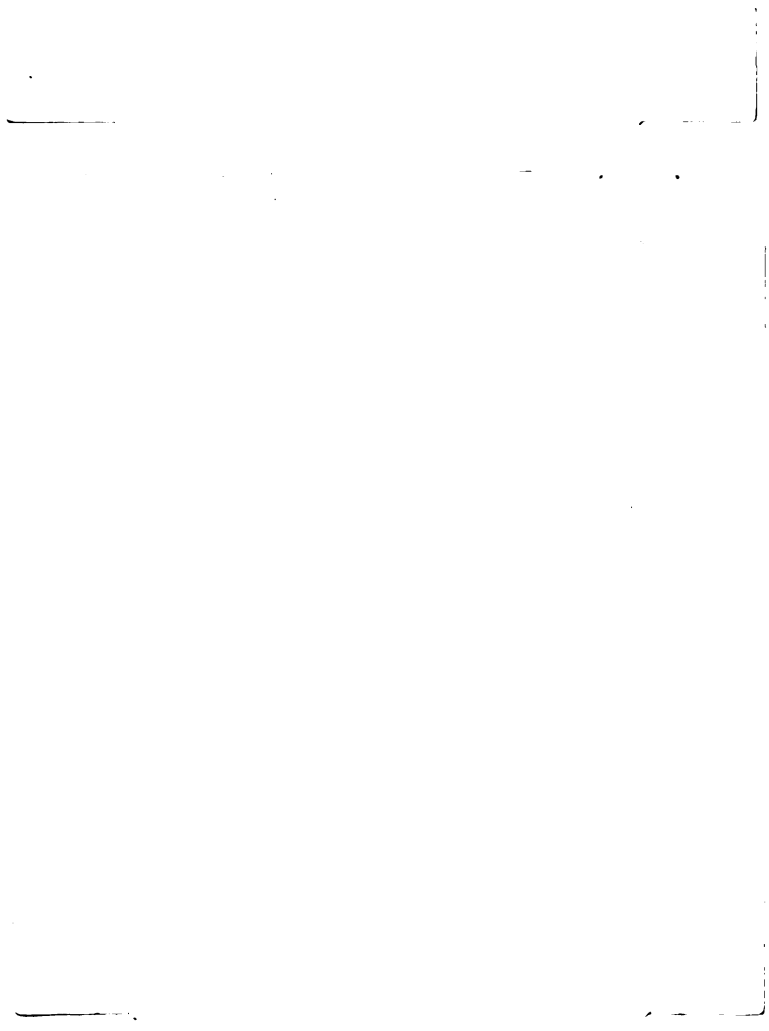

Fig. No. 7 - Corn growing on check plat

Fig. No. 8 - Corn growing on plat that received 150 pounds Atlacide per acre one month before planting.

Fig. No. 9 - Corn growing on soil that received 300 pounds Atlacide per acre one month before planting.

Fig. No. 10 - Corn growing on plat that received 375 pounds Atlacide per acre one month before planting.

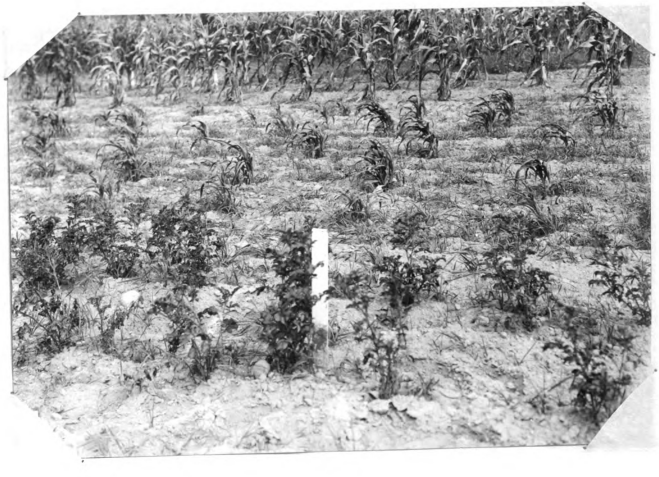

Fig. No. 11 - Potatoes growing on check plat.

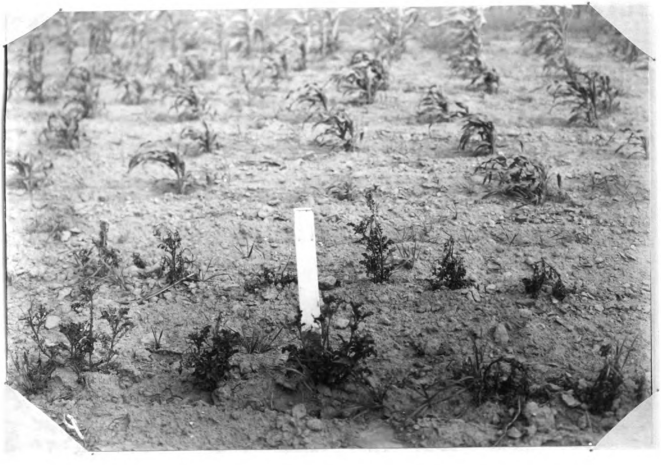

Fig. No. 12 - Potatoes growing on plat that received 300 pounds Atlacide per acre one month before planting.

Fig. No. 13 - Potatoes growing on plat that received 375 pounds Atlacide per acre one month before planting

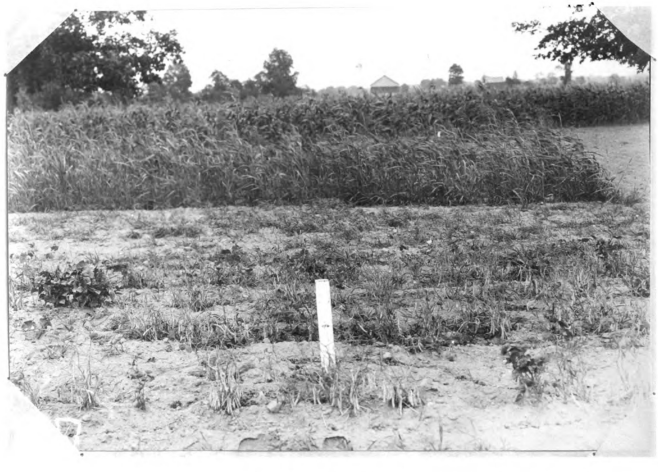

Fig. No. 14 - Beans growing on check plat

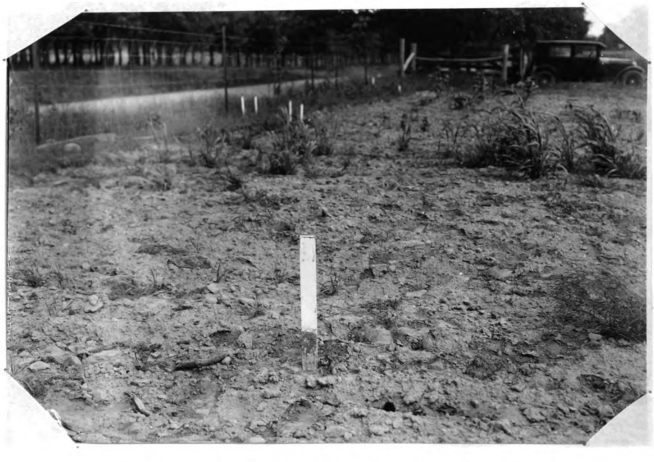

Fig. No. 15 - Note that only a few straggling bean plants remain on plat that received 375 pounds Atlacide per acre one month before planting

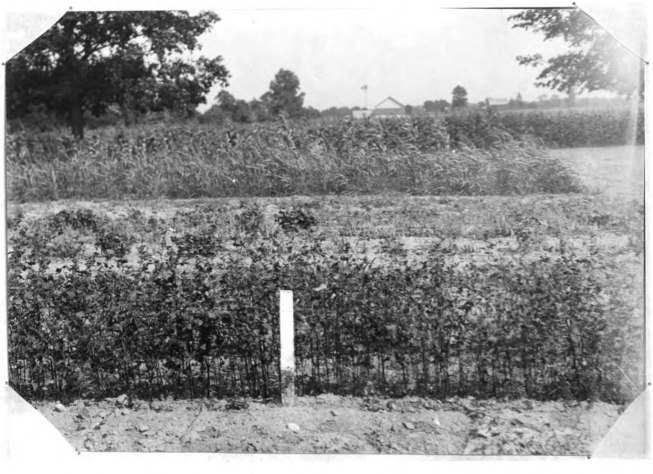

Fig. No. 16 - Buckwheat growing on check plat

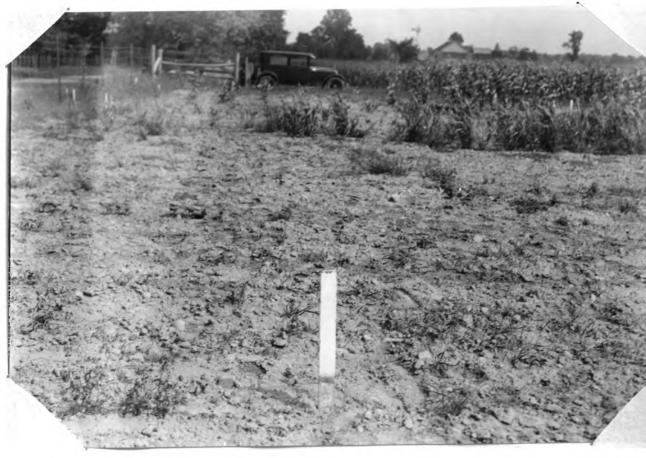

Fig. No. 17 - Note few straggling buckwheat plants growing on plat that received 375 pounds Atlacide per acre one month before planting.

Fig. No. 18 - Sudan grass growing on check plat

Fig. No. 19 - Sudan grass growing on plat that received 375 pounds Atlacide per acre one month before planting.

Results

A Study of the Residual Influence of Atlacide on Crops Planted One Month After Application

Atlacide was applied at the rates of 150, 300, and 375 pounds per acre in one, two, and three applications respectively, during the latter part of April and the first of May. One plat was left as a check. Crops were planted one month later on all plats. In this way it was possible to study the residual influence of Atlacide on crop growth within one month after applying.

As experimental crops the more important crops grown in Michigan were used. These consisted of corn, beans, potatoes, sudan grass, buckwheat, wheat, and rye.

The corn germinated well on all plats and there was no apparent difference in the vigor and color of the young seedlings for the first six days after germination. On the seventh day there was a slight loss of chlorophyll from the plants growing on the plats receiving 300 and 375 pounds Atlacide per acre, but no difference could be noted between the plat receiving 150 pounds Atlacide per acre and the plat receiving no treatment. On the seventeenth day the plants growing on the plats that received 300 pounds and 375 pounds Atlacide per acre were noticeably smaller than the plants growing on plats that received 150 pounds per acre of Atlacide and no treatment. The plants also possessed a light yellow color w ere the heavier applications of Atlacide were made,

showing a lack of chlorophyll. There was a slight loss of chlorophyll from the plants growing on the plat that received 150 pounds Atlacide per acre as compared to the plat that received no treatment. Fifteen days later or July 2, the plants growing on the plat that received 375 pounds Atlacide per acre had reached their maximum growth which ranged from three to four feet in height. Several of the plants died outright. The differences between the plants growing on the plats that received 150 pounds Atlacide per acre and no treatment were never so marked as to be very noticeable. There was, however, a slight difference in the color of the plants. A slight loss of chlorophyll could be noted in the plants growing on the plat where one application of 150 pounds Atlacide per acre was made. At the time of harvesting only a slight difference could be noted, Table No. 1. The yields on the plats that received two and three applications were much lower than those on the plats that received one application and no treatment. The plat that received three applications gave much the lowest yield.

The beans germinated within nine days. All plats germinated alike. Within five days after germinating the young seedlings growing on the plats that received 300 and 375 pounds Atlacide per acre showed a loss of chlorophyll by yellowing. The seedlings growing on the plat that received 150 pounds Atlacide per acre did not show a loss of chlorophyll until the second week after germinating. There was a gradual decrease

of chylorophyll from all three plats that received applications of Atlacide. At the end of the fifth week practically all the plants on the plat that received 375 pounds Atlacide per acre were dead Fig. No. 15 . The plants growing on the plat that received 300 pounds Atlacide per acre showed no signs of growth after the fifth week. The plants were yellow at this time but turned brown after three days and the leaves dropped off. The plants growing on the plat that received 150 pounds Atlacide remained a light green color for eight weeks at which time they turned yellow. The leaves turned brown and dropped off five days later. The plat that received no treatment was green ten days longer than any of the plats receiving Atlacide. Yields of both vines and beans together, and shelled beans were taken at harvest. As would be expected the check gave much the highest yield. The plat that received 150 pounds Atlacide per acre gave a yield of shelled beans 123.5 grams lower than the check, the plat that received 300 pounds Atlacide gave a yield 234.5 grams lower than the check, and the plat that received 375 pounds Atlacide gave a yield 282.5 grams lower than the check. The above results would seem to indicate that the heavier applications of Atlacide have a decided toxic effect upon shallow rooted crops, as beans.

It was thought that potatoes would be a good experimental crop because of its method of planting. The potato tubers were much slower in sprouting on the plats that received applications of 300 and 375 pounds Atlacide per acre than those on the plats that received 150 pounds Atlacide and

no treatment. The tubers on the plat that received no treatment were up three days before any tubers on plats that received applications of Atlacide were. The tubers on the plat that received 150 pounds Atlacide was second to sprout, the plat that received 300 pounds Atlacide was third, and the plat th t received 375 pounds fourth. There was a marked difference in the growth of the plants on the plats that received heavy applications and those that received light applications. The potatoes were dug in October and the weight and relative size of the tubers from all treatments taken. The tubers from the plat that received 375 pounds Atlacide per acre were very small in size and only a few of them. The average size was about that of marbles. The tubers from the plat that received an application of 300 pounds Atlacide per acre were also very small but there was a greater number of them. The plot that received an application of 150 pounds Atlacide per acre gave just as good yield as the plat that received no treatment and the tubers were about the same size.

The sudan grass germinated well on all plats and not until after the seventh day was a difference noted in any plat. The plants on the plat that received an application of 375 pounds Atlacide showed a lack of chlorophyll on the eighth day. Ten days later there was a decided difference in the size of the plants growing on the check and those growing on the plat that received an application of 375 pounds Atlacide. The plants on the check plat had a dark green color while those on the lat that received the heavy application were

light green in color and very much smaller. Five days later several of the plants died on the heavy treated plat. There was not a great difference in the growth of the plants on the check plat and those on the plat that received an application of 150 pounds Atlacide per acre. There was a marked difference however, in the plants growing on the plat that received an application of 300 pounds Atlacide per acre and those growing on the plat that received no treatment. The difference was manifested by a lack of vigor in the plants growing on the plats of heavier treatment. At the time of maturity this difference was very pronounced.

The buckwheat followed the same general reactions as the sudan grass, that is, it showed a decrease in vigor from the check to the heavier applications. Many of the buckwheat plants died within fifteen days after germinating.

The series of plats that were summer-followed were seeded to wheat and rye September 21, or approximately six months after the applications of Atlacide had been made. Normal germination resulted and the young seedlings were equally as vigorous on the plat that received an application of 375 pounds Atlacide as on the plat that received no treatment. Later observations showed no change in vigor or any loss of chlorophyll on any plat. Normal growth of both wheat and rye resulted.

Table No. 4. Results obtained on plats 108.8 square feet in area that had been treated with sodium chlorate and magnesium chlorate one year preceding planting of corn--corn harvested September 4, 1929

Plot No.	Treatment lbs. per 1/100 acre	Number of stalks on plats	Yield of Corn Sept. 4, 1929 lbs. per 108.8 square feet	
			Grain	Stalks
	$NaClO_3$			
1-1	1-1-1	27	1.50	12.24
1-2	1-1-0	35	.50	11.00
1-3	1-0-0	33	3.75	15.25
1-4	0-1-1	35	1.50	10.50
1-6	0-1-1	35	1.25	10.75
1-7	0-0-1	35	1.75	10.75
Total		200	10.25	70.50
Average		33	1.71	11.75
	$Mg(ClO_3)_2$			
2-1	1-1-1	36	3.25	14.50
2-2	1-1-0	34	.75	9.75
2-3	1-0-0	31	3.25	13.00
2-4	0-1-1	29	3.75	14.00
2-6	0-1-1	33	2.25	11.75
2-7	0-0-1	33	1.25	10.50
Total		196	14.50	73.50
Average		32.4	2.42	12.25

Table No. 5. Results obtained on plats 108.8 square feet in area that had been treated with sodium chlorate and magnesium chlorate one year preceding planting of corn - corn harvested September 4, 1929

Plat No.	Treatment lbs. per 1/100 acre	Number of stalks on plats	Yield of corn Sept.4, 1929 lbs. per 108.8 square feet	
			Grain	Stalks
	$NaClO_3$			
3-1	2-0	31	3.50	16.50
3-2	½-0	34	2.75	13.00
3-3	1-½	29	4.00	11.25
3-4	½-½	33	3.25	14.00
3-5	2-½	35	1.50	9.00
3-6	2-2	33	2.00	9.50
Total		195	17.00	73.25
Average		32.5	2.83	12.21
	$Mg(ClO_3)_2$			
4-1	2-0	34	5.25	22.00
4-2	½-0	34	4.00	13.75
4-3	1-½	34	2.75	11.50
4-4	½-½	32	3.75	13.50
4-5	2-½	32	3.00	12.50
4-6	2-2	33	1.25	8.25
Total		199	20.00	81.50
Average		33	3.33	13.58

Fig. No. 20 - Corn growing on soil that received three applications of sodium chlorate, each at the rate of 100 pounds per acre during August, September, and October preceding planting.

Fig. No. 21 - Corn growing on soil that received two applications of sodium chlorate, each at the rate of 100 pounds per acre during August, and September preceding planting.

Fig. No. 22 - Corn growing on soil that received one application of sodium chlorate at the rate of 100 pounds per acre during August preceding planting.

Fig. No. 23 - Corn growing on soil that received three applications of magnesium chlorate, each at the rate of 100 pounds per acre during August, September and October preceding planting.

Fig. No. 24 - Corn growing on soil that received two applications of magnesium chlorate, each at the rate of 100 pounds per acre during August and September preceding planting.

Fig. No. 25 - Corn growing on soil that received one application of magnesium chlorate at the rate of 100 pounds per acre during August preceding planting.

Fig. No. 26 - Corn growing on soil that received common salt at the rate of 20 tons per acre during August September and October preceding planting.

Results of Chlorates Applied in the Spring, Land not Plowed, and the Residual Influence Determined at Various Soil Depths.

Both sodium chlorate and magnesium chlorate were applied in amounts ranging from 100 to 400 pounds per acre. The plats treated with sodium chlorate received about twice as much chlorate (ClO_3) as those receiving Atlacide.

The beans showed a decided residual influence in the one to four inch zone in the case of the sodium chlorate pots, a somewhat less influence in the four to eight inch zone, and little if any, influence in the eight to twelve inch zone. In the case of the Atlacide pots, a residual influence was noted in the one to four inch zone, very little in the four to eight inch zone, and none in the eight to twelve inch zone.

Fig. No. 27 - Corn, beans, potatoes, and buckwheat growing on soil that received two applications of 100 pounds each of sodium chlorate and magnesium chlorate per acre during August and September preceding planting.
From sign back to road received magnesium chlorate, and from sign back to stakes received sodium chlorate.

Fig. No. 28 - Corn growing on soil that received two applications of 100 pounds each per acre of magnesium chlorate and sodium chlorate August, September preceding planting. In the foreground the soil received magnesium chlorate and in the background sodium chlorate.

Fig. No. 29 - Corn growing on soil that received two applications of 100 pounds each per acre of sodium chlorate and magnesium chlorate August and September preceding planting In the foreground the soil received sodium chlorate and in the background magnesium chlorate.

Fig. No. 30 - Potatoes growing on soil that received two applications of 100 pounds each per acre of sodium chlorate and magnesium chlorate August and September preceding planting. In the foreground soil received sodium chlorate and in the background magnesium chlorate.

Fig. No. 31 - Potatoes growing on soil that received two applications of 100 pounds each per acre of magnesium chlorate and sodium chlorate August and September preceding planting In the foreground soil received magnesium chlorate and in the background sodium chlorate.

Fig. No. 32 - Beans growing on soil that received two applications of 100 pounds each per acre of magnesium chlorate and sodium chlorate August and September preceding planting. In the foreground soil receivedmagnesium chlorate and in the background sodium chlorate.

Fig. No. 33 - Beans growing on soil that received two applications of 100 pounds each per acre of sodium chlorate and magnesium chlorate August and September preceding planting. In the foreground soil received sodium chlorate and in the background magnesium chlorate.

A Study of the Residual Influence of Sodium Chlorate and Magnesium Chlorate Upon Crops Planted the Season Following Application

Sodium chlorate and magnesium chlorate were applied during the summer of 1928 in two applications of 100 pounds each. The following season at the regular planting time corn, beans, potatoes, and buckwheat were planted on this area.

All crops germinated normally. A normal growth of all crops resulted, indicating that the chlorates had been sufficiently dissipated during the winter months for crops to be planted the following spring.

The pictures which precede show the crops as they appeared at the time of maturity.

Discussion

The results obtained from crops grown on plats that had been sprayed with Atlacide one month before the crops were planted indicate that heavy applications have a decided toxic effect upon crop production. Due to an abnormally dry late spring and early summer the untreated plat did not give a very high yield. Late preparation of the seed bed probably had an influence on the yields. The difference in the yields of the check and the heaviest treatments indicate that residual effect is present. In the case of corn, a yield of 16.98 bushels per acre was obtained from the untreated plat, while only 4.74 bushels per acre was obtained from the plat that received an application of 375 pounds Atlacide per acre. The lighter applications gave yields intermediate between these yields, indicating that the heavier the applications the greater the toxic effect.

The yield of potatoes was also very low on the check because of the unusually dry spring and summer. There was no indication that the light application of 150 pounds per acre had a residual influence on the growth of the potatoes. In fact, a higher yield was obtained from the plat that received 150 pounds Atlacide than was obtained from the check. A decided decrease in the yield was found in the plats receiving 300 and 375 pounds Atlacide per acre.

Beans, because of a shallow root system were more susceptible to the toxic effect of the Atlacide than any of the

other crops. Buckwheat was also very susceptible due to its shallow roots. This would indicate that the chlorate remained in the top few inches of soil which was found to be the case when an experiment was conducted in the greenhouse for this purpose. A probable explanation for this condition would be the fact that there was very little rainfall during the spring and summer and no leaching of the chlorate could take place. Had there been a normal rainfall, the results would probably have been different.

Results obtained from corn that was planted the spring succeeding applications of sodium chlorate and magnesium chlorate in the late summer, indicate that the chlorates had been sufficiently dissipated to plant crops. No apparent difference was noted in the corn growing on plats that received applications of 300 pounds per acre and that growing on plats that received 50 pounds per acre.

In reviewing the results obtained where applications of chlorates had been made in the spring and the residual influence determined by removing layers of soil ten days later at various soil depths it was found that a decided toxic effect was present in the one to four inch zone. Very little toxic effect was found in the four to eight inch zone and none was found in the eight to twelve inch zone. This indicates that the chlorates did not penetrate the soil very deep. Such a condition as this probably

resulted from the unusually dry spring and summer of 1929. In a year of normal rainfall the chlorates would probably have leached through the soil to a greater depth.

Corn, beans, potatoes, and buckwheat grew normally on soil that received applications of 200 pounds of sodium chlorate and magnesium chlorate during August and September preceding planting. It is safe to grow crops on soil that was treated with chlorates the summer before planting in the spring.

It was found from a careful study of the chlorates used in these experiments that a desirable herbicide should have the following characteristics: it must be effective, it must be non-poisonous, it must be easy to apply, it must not have a toxic influence on succeeding crop growth, and it must be reasonably cheap.

MATERIALS AND METHODS

Greenhouse Work

An experiment was conducted in the greenhouse for the purpose of studying the depth in the soil that chlorates are most likely to be present. Atlacide was used for this experiment. Three months after the Atlacide had been applied, layers of soil from one to four inches, four to eight inches, and eight to twelve inches deep were removed from both treated and untreated plats and the soil placed in four inch pots in duplicate in the greenhouse. Atlacide was applied at the rate of 150 pounds, 300 pounds, and 375 pounds per acre on this soil. Beans were planted in these pots, and notes taken as to rapidity of germination, the vigor of the plants and the color of the leaves.

Results

The beans were planted on October 2, seven seeds per pot. On October 14, the beans had germinated in all pots except one containing soil from a depth of one to four inches where an application of 375 pounds Atlacide per acre had been made. In this pot only six seeds, germinated by October 30. Three of these plants died ten days later. Two of the plants in the duplicate pot died at the same time. There was no apparent difference for the first ten days in the untreated

pot and the pot containing soil where an application of 150 pounds Atlacide per acre had been made. After the tenth day there was a slight residual influence noted in the 150 pounds application. At maturity there was a decided difference between the check and the 150 pounds application, Fig. 34. At the time of maturity there was a slight difference noted in the 300 pounds application and the 150 pounds application. A residual influence was apparent in both, but the heavier application showed more loss of chlorophyll and less vigor. In the case of the four to eight and eight to twelve inch zone no difference could be noted between the checks and the heaviest treatment. It will be noted from Fig. 36 that the plants in the pot containing soil from the eight to twelve inch zone are lacking in vigor. This may be explained by the fact that these plants were infested with red spiders and when treated for them a retarded growth of the plants resulted.

Discussion

A residual influence was found in the one to four inch zone only. This condition was probably due to capillary action because the soil was plowed to a depth of eight inches soon after the Atlacide was applied. Such a condition is highly possible because of the unusually dry spring of 1929. If there had been a normal amount of rainfall a leaching of the chlorates would have resulted and the residual influence found at a greater depth in the soil.

Results of Greenhouse Work with Beans.

Pots were Planted in Duplicate, 7 Seeds to the Pot.

Pot No.	Date Planted	Date Germinated	No. Germinated	Vigor	Color of Chlorophyll	No. of Plants Died
CK 4	Oct. 2	Oct. 14	7	Good	Green	None
CK 4 a	" 2	" 14	7	"	"	"
CK 8	" 2	" 14	7	"	"	"
CK 8 a	" 2	" 14	7	"	"	"
CK 12	" 2	" 14	7	"	"	"
CK 12 a	" 2	" 14	7	"	"	"
150-4	Oct 2	Oct. 14	7	Good	Green	None
150-4a	" 2	" 14	6	"	"	"
150-8	" 2	" 14	7	"	"	"
150-8a	" 2	" 14	7	"	"	"
150-12	" 2	" 14	7	"	"	"
150-12a	" 2	" 14	7	"	"	"
300-4	Oct.2	Oct. 14	7	Fair	Light green	None
300-4a	" 2	" 14	7	"	" "	"
300-8	" 2	" 14	7	Good	Green	"
300-8a	" 2	" 14	7	"	"	"
300-12	" 2	" 14	7	"	"	"
300-12a	" 2	" 14	7	"	"	"
375-4	Oct. 2	Oct. 14	7	Poor	Slightly Yellow	2
375-4a	" 2	" 30	6	"	" "	3
375-8	" 2	" 14	7	Fair	Light green	None
375-8a	" 2	" 14	7	"	" "	"
375-12	" 2	" 14	7	Good	Green	"
375-12a	" 2	" 14	7	"	"	"

Fig. No. 34 - Beans growing in greenhouse in pots containing soil that was secured from a depth of 4 inches where Atlacide had been applied at the rate of 150, 300, and 375 pounds per acre.

Fig. No. 35 - Beans growing in greenhouse in pots containing soil that was secured from a depth of 8 inches where Atlacide had been applied at the rate of 150, 300 and 375 pounds per acre.

Fig. No. 36 - Beans growing in greenhouse in pots containing soil that was secured from a depth of 12 inches where Atlacide had been applied at the rate of 150, 300, and 375 pounds per acre.

Summary

A study was made of the residual influence of chlorates upon subsequent crop growth. A residual influence was found to be manifested on crops planted one month after the last application of chlorates. In every case the heavier applications gave a more decided toxic effect. Crops planted the spring following applications in the late summer and fall gave normal growth, indicating that the chlorates had been dissipated.

Crops of wheat and rye planted six months after the last application of Atlacide germinated normally and the young seedlings grew as vigorously on the plat that received 375 pounds Atlacide per acre as on the plat that received no treatment, indicating that the toxic effect of the Atlacide had been dissipated in six months.

An experiment conducted in the greenhouse for the purpose of studying the movement of chlorates through the soil showed that the chlorates remained in the top four inches of soil. This may be due to the fact that the late spring and summer of 1929 was unusually dry and no leaching of the chlorates through the soil took place.

Shallow rooted crops, as beans, showed a much more decided susceptibility to the toxic effect of the chlorates than did the deeper rooted crops.

Conclusions

1. Crops planted one month after last application of chlorates are greatly injured by the toxic influence of the chlorates. When chlorates are applied during the spring, it does not appear feasible to attempt to grow crops during that spring or summer of the year in which the chlorates were applied.
2. Chlorates applied during the late summer and fall months are not likely to influence crop production the following spring.
3. When chlorates are applied during the spring, the residual influence is sufficiently dissipated by late September so that wheat and rye may be sown.
4. Heavy applications of chlorates penetrate the soil to a greater extent than light applications.
5. Shallow rooted crops, such as beans, are more susceptible to the residual influence of chlorates than deep rooted crops.
6. In seasons of light rainfall, such as the spring and summer of 1929 chlorates tend to remain in the top four inches of soil. In seasons of normal rainfall there would probably be a greater leaching of chlorates.
7. A normal crop may be expected on soil that was treated with chlorates six to eight months before the crops are planted.

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