A greenhouse study of the factors controlling the use of IPC and CIPC for the control of wild oats (Avena Fatua)

by Tyrus Matsuoka

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
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Abstract:
This study consisted of a series of tests designed to determine certain physical factors which may affect the control of wild oats obtained with the use of isopropyl N-phenyl carbamate (IPC) and Isopropyl N-(3-chlorophenyl) carbamate (CIPC). These two chemicals are two members of a large family of carbamates being tested for their herbicidal action. Factors studied were rates of application, comparative toxicity of IPC and CIPC to oats, differences in the reaction of wild and common oats to IPC and CIPC, placement -of the chemicals in relation to the seed, and the effect of moisture on control.

It was found in the experiment that two pounds- per acre of IPC gave good control of both common and wild oats, but at least three pounds per acre is necessary for control of the same two species with CIPC. There was no significant difference in reaction to the herbicides between wild and common oats. The emergence of sugar beets was not affected by either of the chemicals at any of the rates used.

Placement of the chemicals in relation to the seed is an important factor in control. IPC must be within an inch of the seed to produce good control and the CIPC must be within one-half inch to show similar results. More effective control was obtained with placement of the chemicals above the seed.

The herbicides apparently need to be in moist soil if maximum control is to be obtained.

With the use of herbicide rates adequate to control wild oats, placement and moisture must be considered.

Though dormancy of wild oats must be considered in any control work done, it is possible to control wild oats with the use of these chemicals.

A GREENHOUSE STUDY OF THE FACTORS CONTROLLING THE USE OF IPC AND CIPC FOR THE CONTROL OF WILD OATS (AVENA FATUA)

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ABSTRACT

This study consisted of a series of tests designed to determine certain physical factors which may affect the control of wild oats obtained with the use of isopropyl N-phenyl carbamate (IPC) and Isopropyl N-(3-chlorophenyl) carbamate (CIPC). These two chemicals are two members of a large family of carbamates being tested for their herbicidal action. Factors studied were rates of application, comparative toxicity of IPC and CIPC to oats, differences in the reaction of wild and common oats to IPC and CIPC, placement of the chemicals in relation to the seed, and the effect of moisture on control.

It was found in the experiment that two pounds per acre of IPC gave good control of both common and wild oats, but at least three pounds per acre is necessary for control of the same two species with CIPC. There was no significant difference in reaction to the herbicides between wild and common oats. The emergence of sugar beets was not affected by either of the chemicals at any of the rates used.

Placement of the chemicals in relation to the seed is an important factor in control. IPC must be within an inch of the seed to produce good control and the CIPC must be within one-half inch to show similar results. More effective control was obtained with placement of the chemicals above the seed.

The herbicides apparently need to be in moist soil if maximum control is to be obtained.

With the use of herbicide rates adequate to control wild oats, placement and moisture must be considered.

Though dormancy of wild oats must be considered in any control work done, it is possible to control wild oats with the use of these chemicals.

INTRODUCTION

In the past several years, especially since the end of the Second World War, many new herbicides have appeared on the market. Of these, 2,4-D (2,4-dichlorophenoxyacetic acid) has been the chemical most widely publicized and used. With the use of 2,4-D to control broadleaved plants, the weedy grasses are becoming more and more of a problem and are being noticed more by the public. New herbicides that are selective for grassy weeds may not be the final answer in control, but they can help in a tolerant crop--susceptible weed situation.

Of the weedy grasses that have created problems for a good many years, Wild Oats (Avena fatua), an annual, is one of the more serious. It appears that wild oat infestations have increased in recent years. Possibly this has resulted from reduced competition from broadleaved plants in grain fields treated with 2,4-D. In areas where crops such as sugar beets, flax, or legumes are produced, the use of selective herbicides may be an answer or at least a partial answer to the problem. The herbicides, IPC (isopropyl N-phenyl carbamate) and CIPC (isopropyl N-(3-chlorophenyl) carbamate) are showing considerable promise for controlling wild oats in certain crops.

It was the purpose of this study to determine the effect of kind of chemical, rates of application and placement of the chemical on the control of wild oats.

LITERATURE REVIEW

Wild oats (Avena fatua), is difficult to control because of its delayed germination, shattering, and competitive ability.

Delayed germination or dormancy of the wild oat seed is thought to be caused by the exclusion of oxygen by the seed coat. Atwood (3) demonstrated that the seed coat, formed by the remnants of the original ovary wall, the integuments, and the epidermis of the nucellus was the structure that controlled germination. Injury to the seed coat by scratching or searing resulted in increased germination. He obtained an average of 98 per cent germination by the above treatment while wild oats in the check germinated only 62 per cent. Increasing the oxygen content of a controlled atmosphere also increased germination. L.P.V. Johnson (14) also demonstrated that injury or breaking of the seed coat over or near the embryo tended to increase germination.

Johnson (14) stated that the length of the necessary after-ripening period is heritable. In his experiments using different sources of seed and crossing A. fatua X A. sativa, the results indicated that dormancy is controlled by genetic factors. It was believed that the after ripening process may consist essentially of a series of changes in the tissues of the seed coat which result in an increased permeability to oxygen.

Dormancy may be controlled by the placement of the florets on the panicles. Johnson (14), in his experiment, harvested the wild oats just as the first seeds started to shatter and found that the florets from nearer the base of the panicle and the florets nearer the outer tip of the whorls were riper than in the center of the panicle. These seeds that were riper had a shorter afterripening period than those that were less ripe. The seed from the primary florets had a shorter afterripening period than the seed in the secondary florets.

Johnson (14) found that wild oats seemed to undergo secondary dormancy, i.e., a second dormancy period or apparently a lengthened afterripening period, if certain conditions arise. Secondary dormancy may arise if seeds do not undergo a sufficient length of time for afterripening before they are exposed to enivornmental conditions favorable for good germination. In these tests carried out by Johnson, there was a strong indication that conditions conducive to afterripening such as continued cold, good soil-seed relationship, light or absence of light in certain times of the after-ripening period and other conditions resulted in a shorter dormancy period than if this period was broken before sufficient time had elapsed.

Johnson also found that light and temperature had an effect on the length of dormancy. If the wild oat seeds were subjected to light in the early part of dormancy, the dormancy period may be shortened, but if the seeds were exposed in the latter part of dormancy, dormancy may be lengthened. Under continuous freezing conditions, dormancy was shortened. This breaking or shortening of dormancy by freezing was said to be brought about by injury to the seed coat because of contracting and expanding. Where the temperature was above freezing part of the time, dormancy was lengthened. Secondary dormancy seemed to take place when the seeds were subjected to conditions for germination and then frozen again. Freezing and thawing did not have an effect on the germinability of the wild oat.

Chepil (7), in Canada found that wild oat seed persisted in the soil for as long as four years. He found that 80 per cent of the seeds germinated the first year, 18 per cent the second, and two per cent the third. There were two seeds out of the several thousand planted that germinated the fourth year. He found that a great majority of the seeds, if buried at shallow depths in the soil would germinate in May and could be destroyed before the crop was sown. Contrary to most other weed seeds, wild oat seeds did not germinate readily when lying on the surface of the ground.

Wild oat seed shatter readily, thus enabling the plant to reseed itself before the crops are harvested. In his test, Chepil (7) also measured the date of maturity and shattering ability of many weeds as compared to Thatcher spring wheat. In the case of wild oats, he gave the date of maturity to be July 18, and the shattering ability to be 70 per cent, i.e., 70 per cent of the seed shattered before harvest time of the Thatcher wheat which was approximately a month later.

Bibbey (5) found that fall cultivation increased wild oat emergence in the same fall of treating by 400 per cent as compared to untilled plots. The seeds were sown on the surface and tilled in or left on the surface. This corresponded with Chepil's observation that wild oats did not germinate readily when on the surface of the ground. The increase due to tillage of the same plots in spring emergence was infinite as no germination took place in the untilled plots.

Thurston (22) demonstrated that wild oats can germinate from a number of different depths. In her tests in the greenhouse, she induced germination from depths up to nine inches. The seedlings from this depth were weak and yellow but were growing normally within a month. In the field, emergence of seedlings occurred from seedings six inches deep. There was no evidence of induced dormancy when the seeds were buried, even up to depths of 20 inches. No seeds survived at these depths (down to 20 inches) after three years.

The wild oat is a very good competitor, especially when no measures are taken to control it after its emergence. It germinates most abundantly in cool weather and is able to compete successfully with most annual crops. Pavlychenko (20) found that wild oats cut the yield of barley by 15 per cent and wheat by 28 per cent. This reduction in crop yield was almost exactly proportional to the degree of reduction of the root systems due to competition with wild oats.

Wild oats are a serious weed of the cooler, major cereal producing areas of North America. North Dakota, Montana, Western Minnesota, Northern South Dakota, and the Prairie Provinces of Canada are seriously infested with wild oats. Of the 106,000,000 acres of crop land in this area, 61,000,000 are infested with wild oats of which 29,000,000 are infested seriously (24). In addition wild oats is a serious weed in a number of Western States including winter crop areas in Arizona and California and in several high elevation intermountain areas.

Isopropyl N-phenyl carbamate (IPC) is a grayish white crystalline substance, soluble in some organic solvents, but insoluble in others and nearly insoluble in water (13). Solubility in water is about 100 ppm for IPC and 80 ppm for CIPC (11).

IPC is not translocated as is 2,4-D or 2,4,5-T, but it does act systemically. Instead of causing excessive growth as do the latter two materials in some concentrations, IPC is a growth inhibitor. It is, essentially, a mitotic poison and causes cell division to cease. Since it is a growth inhibitor, the chemical must be used while the plants are in the early stages of growth.

Ennis, (10), found that IPC upset mitosis and caused cells to stop dividing at metaphase or early anaphase. This caused the cells to be multinuclear or to have a giant nuclei. The apical portions of the oat seedlings which were exposed to IPC took on a bulbous appearance. The leaves take on a dark green color and after a short time turn reddish brown when the plants are treated with IPC. Freed (11) found that the dark green color resulting from treatment with IPC was directly due to an increased amount of chlorophyll in the tissues. The treated plants contained from 19 to 28 per cent more chlorophyll per unit of leaf area or per gram of dry weight than comparable checks. In conjunction with the increased chlorophyll content, the nitrogen content in the treated plants was higher than the control.

Since IPC does not move readily in the soil, some means of incorporating it into the soil must be used. Although IPC is nearly insoluble in water, water is the best means to get the chemical into the soil. At least one-half inch of rain or an equal amount of irrigation water is necessary to leach effective amounts of IPC into the soil. If the herbicide is sprayed on the surface of the soil, thorough mixing by disking or similar means to insure good mixing is necessary shortly after application in the absence of rain or irrigation.

Logan et al. (16) found through the use of radioactive materials that IPC tends to move upward in the soil after an initial downward movement with water. The data collected from the tests indicated that most of the IPC remained in the top inch of the soil even when leached with amounts of water equivalent to a three inch rainfall. The water was allowed to leach into the soil from 24 to 120 hours with a difference of 24 hours between each treatment. No IPC was found in the fourth inch of soil until the third day of leaching. The addition of the initial water caused flushing of the material into the soil, but there was an upward movement of the IPC during the succeeding days of the experiment.

High temperature shortens the residual life of the chemical in the soil. Newman et al. (19) found that IPC lost its effectiveness completely after 36 days incubation at temperatures ranging from 10 to 30 degrees Centigrade. The highest temperature caused the IPC to lose its toxicity to plants after eight days. The emergence at the 30 degree Centigrade treatment was as high as the check at the end of the eight days, but the plants were stunted to some extent.

IPC disappeared equally as rapidly at moisture contents from 20 to 80 per cent of the water holding capacity of the soil. After 19 days incubation, the material had no effect on emergence or vigor.

Persistence of IPC was also influenced by rates. Even at very high rates (over 1,000 pounds per acre) the chemical did not persist for more than 39 days under the conditions of the experiment (19).

Soil type plays an important part in persistence of the chemical (12). On heavy, poorly drained clay soils, the residual activity has been observed to be up to one third longer than on porous, well drained soils.

The volatility of IPC and CIPC was demonstrated by Anderson et al. (1). In their experiments the chemicals were sprayed on surfaces similar to leaf surfaces and rate of evaporation was timed. They found that almost 92 per cent of the CIPC evaporated in 24 hours in temperatures of 85 to 88 degrees Fahrenheit. Eighty per cent of the IPC evaporated at the same temperature range in 24 hours. Though neither chemical is used extensively as a foliar spray, the above experiment demonstrates that the chemicals should be incorporated into the soil as soon as possible after application. Because of the high rate of volatization of IPC and CIPC, the Great Western Sugar Company (18) is advocating mixing the chemical thoroughly in the top four inches of the soil immediately or as soon as possible after applying.

Rates of application of these chemicals are influenced by the crop and the weed to be controlled. According to Freed and Bierman (13), rates to use range from two to eight pounds technical IPC per acre. In their trials pre-emergence application rates ranged from two to six pounds per acre and post emergence applications ranged from four to eight pounds per acre. In his test on the tolerance of plants to IPC, Ennis (9) found many dicotyledonous plants which showed varying degrees of susceptibility to the chemicals. Plants in the squash family (Curcurbitaceae) and the potato family (Solanaceae) were most affected. Flax seemed to be affected in this test also. Ennis used a rather high rate of chemical, approximately 12 pounds per acre, which may account for the injury to many of the dicots.

IPC and CIPC may find use in Montana in controlling annual grasses in small and large seeded legumes, flax, and sugar beets. In tests conducted in some of the Western States, control of weedy annual grasses has been obtained in peas, ladino clover, flax, and established stands of alfalfa. Four pounds per acre was the minimum effective rate necessary for pre-emergence applications in peas (21) and three to five pounds per acre controlled the weedy annual grasses in pre-emergence tests in ladino clover (15). The use of IPC for the control of cheatgrass (<u>Bromus tectorum</u>) in established stands of alfalfa is promising, however, at least eight pounds of IPC per acre are needed for satisfactory control (6). IPC was effective in controlling weeds in Arizona in flax trials. CIPC was found to be very toxic to flax in this test (2). Rates of two to three pounds per acre of IPC and CIPC were found to be effective in controlling wild oats with the higher rate being more consistent. Three pounds of IPC per acre is recommended for sugar beets in Montana by the Great Western Sugar Company (18). IPC and CIPC should be applied when the rainfall pattern could be used to the best advantage or in dryer areas, as soon as the seed bed can be prepared and irrigated. Pre-emergence or preplanting applications are desirable because the chemicals must be in contact with the germinating seed or young seeding to be most effective. Good moisture conditions, i.e., rainfall at time of and following application are important to achieve good results. In Washington and Oregon, late winter applications are used, taking advantage of the rainfall pattern of the area. Irrigation may be necessary in the more arid regions of the country to get good control.

There is not a great deal of difference chemically between IPC and CIPC. The residual effect of CIPC seems to be longer, and the toxicity range to plants is different then IPC. Freed (8) states that the two compounds are highly specific in their action and that the plant species which one may control may not respond to an application of the other. Arle (2) reports that flax is one crop that is highly susceptible to injury by CIPC, but is tolerant to IPC. Sugar beets also seem to show more tolerance to IPC than CIPC (18).

MATERIALS AND METHODS

The mechanics studied in this series of tests were (1) placement of the chemical in relation to the seed; (2) rates necessary to control oats; (3) depth of placement of chemical and its effect on control; (4) depth of seeding in relation to depth of chemical; (5) comparison of IPC and CIPC in control of oats; (6) comparison of tolerance of wild oats and common oats to IPC and CIPC; and (7) effect of moisture on effectiveness of the chemicals.

All the trials reported herein were conducted in the Agronomy greenhouse during the winter and spring of 1952 and 1953. The temperature in the greenhouse varied from about 54 to 97 degrees Fahrenheit. The temperature dropped to the low at night and the high was reached on bright, sunny days. The mean daily temperature was approximately 68 degrees Fahrenheit.

The soil used in the tests was Bozeman Silt Loam. Beatty (4) described this soil, (Table I).

This soil has a tendency to puddle with excessive wetting and crust upon drying. Under greenhouse conditions, it was necessary to wet the surface of the pots that crusted to enable the oat and/or beet seedlings to emerge normally.

Clean, one quart oil cans were used as containers for the soil for each treatment. One thousand grams of soil on an air dry basis were used in each can. One inch of the air dry soil passing through a three-sixteen inch sieve weighed about 225 grams. The soil depth in each can was just slightly less than 4.5 inches. Holes were punched in the bottom of the cans tc facilitate watering and allow drainage of any excessive water.

Table I. Total nitrogen, pH, and per cent organic carbon of Bozeman Silt Loam from two locations near Fort Ellis in Gallatin County.

Location	Depth of Sample	Organic Carbon Per cent	Organic Matter Per cent	pH	Total N Per cent
	3-9 inches	3.744	6.455	6.4	.371
Location 1	9-13 "	3.156	5.44	6.3	.282
	13-23 "	.673	1.16	6.5	.09
	½-8 inches	3.5	6.04	6.5	.312
Location 6	8-15 "	1.178	2.03	6.8	.145
	15-21 "	.696	1.2	6.9	.095

Table II. Mechanical analysis of Bozeman Silt Loam by the Hydrometer method.*

Sample Number	sand per cent	silt per cent	clay per cent
Sample 1	27.3	49.65	23.05
Sample 2	27.8	47.4	24.8

* This soil is normally classed as Silt Loam but the data indicates that it borders between loam and silt loam. This is the analysis of a sample which was taken adjacent to the area of the soil used in the experiment.

The chemicals used in this experiment were Stauffer Emulsive IPC[1] and Ortho, 3-Chloro IPC Emulsive.[2]

The chemicals were weighed on a torsion balance. The total amount of chemical needed for the complete test was weighed out on the basis of

[1] Stauffer Emulsive IPC, 25 per cent Technical Isopropyl N Phenyl Carbamate, Stauffer Chemical Company, Pacific Northwest Division, North Portland, Oregon.

[2] Ortho 3-Chloro IPC emulsive. Active ingredient, 46 per cent 3-chloro isopropyl N phenyl carbamate, by weight, California Spray Chemical Corporation, Richmond, California.

.0018 grams of active ingredient per can being equivalent to a two pound per acre application. The chemicals were mixed in water and then mixed into the weighed amount of soil to be treated. To measure effective rates of application of IPC and CIPC, the cans were completely filled with treated soil. The herbicide was added to the weighed amounts of soil equivalent to the highest concentration needed in the particular test. Lower concentrations were obtained by dilution of the treated soil with appropriate amounts of untreated soil. To measure the effect of placement of the herbicides on oat germination, a constant rate of treated soil was put in one-quarter or one-half inch bands with the depth of the bands varying for each treatment.

Because of the variation of germination of wild oats caused by dormancy, Mission, a variety of common oats (*A. sativa*), was used in the complete series of tests. Ten seeds of Mission oats per pot were planted 2.5 inches deep in all the tests except one, where the planting depth was a variable. A comparison of emergence of the wild oat and the common oat was made. Fifteen seeds per pot were used because of the uncertainity of the wild oat germination. The wild oat seeds were collected near Bozeman. The Mission seed was Foundation Seed grown on the Agronomy Farm in Bozeman in 1949.

Sheared sugar beet seeds and Mission oats were planted in several tests set up to measure the effect of rates of IPC and CIPC on emergence of these two plants. Fifteen beet seeds (segments) per can were planted one-quarter inch deep and 10 oat seeds were planted 2.5 inches deep in the same cans.

Watering of the treatments was done from the bottom in the first two tests. The cans were placed in three-fourths inch of water immediately after the test was set up. There seemed to be enough movement of the chemicals with the movement of water, up or down, in the cans to alter the results. In subsequent experiments the soil was wet to approximately 25 per cent moisture before planting so that movement of the chemicals would not be an altering factor and no watering was done until after emergence. In those tests where movement of the chemical wasn't a critical factor, watering was done from the top of the cans. The cans were watered daily after emergence of the seedlings.

All the oat or beet seedlings that emerged were counted. Counting was started a day after the plants started emerging. Vigor readings on the oat plants were taken as soon as differences could be easily seen. Since there wasn't any appreciable difference in vigor of the beet seedlings, no vigor readings were taken on the beets. The vigor readings were based on a scale from 0 to 10, 0 being no growth after emergence and 10 being the vigor of the plants showing the most growth.

The efficiency of the herbicides was measured by multiplying the emergence percentage times the vigor readings. The product was divided by ten so that the resulting number could be scaled in relation to a perfect score of 100. The treatment with a score with 100 must have 100 per cent stand coupled with a vigor reading of ten. A treatment with a score of zero gave complete control in emergence and/or control of growth. This rating (vigor x emergence) will be referred to as the efficiency rating.

EXPERIMENTAL RESULTS AND DISCUSSION

Because many of the tests in this greenhouse experiment were related, the results and discussion are based on the grouping of these related tests. Part I deals with the effect of different rates of IPC and CIPC on wild and common oats. Part II presents the effects of placement of the chemicals in relation to the oat seeds and the role that moisture plays in control of the oats. Part III is a general discussion on the factors influencing the results of the tests and general observations on the symptoms of injury to the oat plants.

PART I. The effect of rates of IPC and CIPC on wild and common oats and sugar beets.

To find how much IPC was needed for the control of oats, a test using rates ranging from one-half to three pounds of active ingredient per acre was carried out. Figure 1 shows that at least one and one-half pounds of active ingredient per acre are needed for any control and two pounds per acre are needed for almost complete control. It was concluded from this test that the minimum rate of IPC needed for good control of oats was two pounds active ingredient per acre.

Because CIPC is being used in the same manner as IPC, a test was planned to measure the differences between IPC and CIPC at various rates. Results (Figure 2) show that IPC gave fair control of common oats at the one and one-half pound per acre application and at two pounds per acre gave practically 100 per cent control. CIPC was less effective in controlling oats since three pounds per acre reduced the efficiency rating by only 50

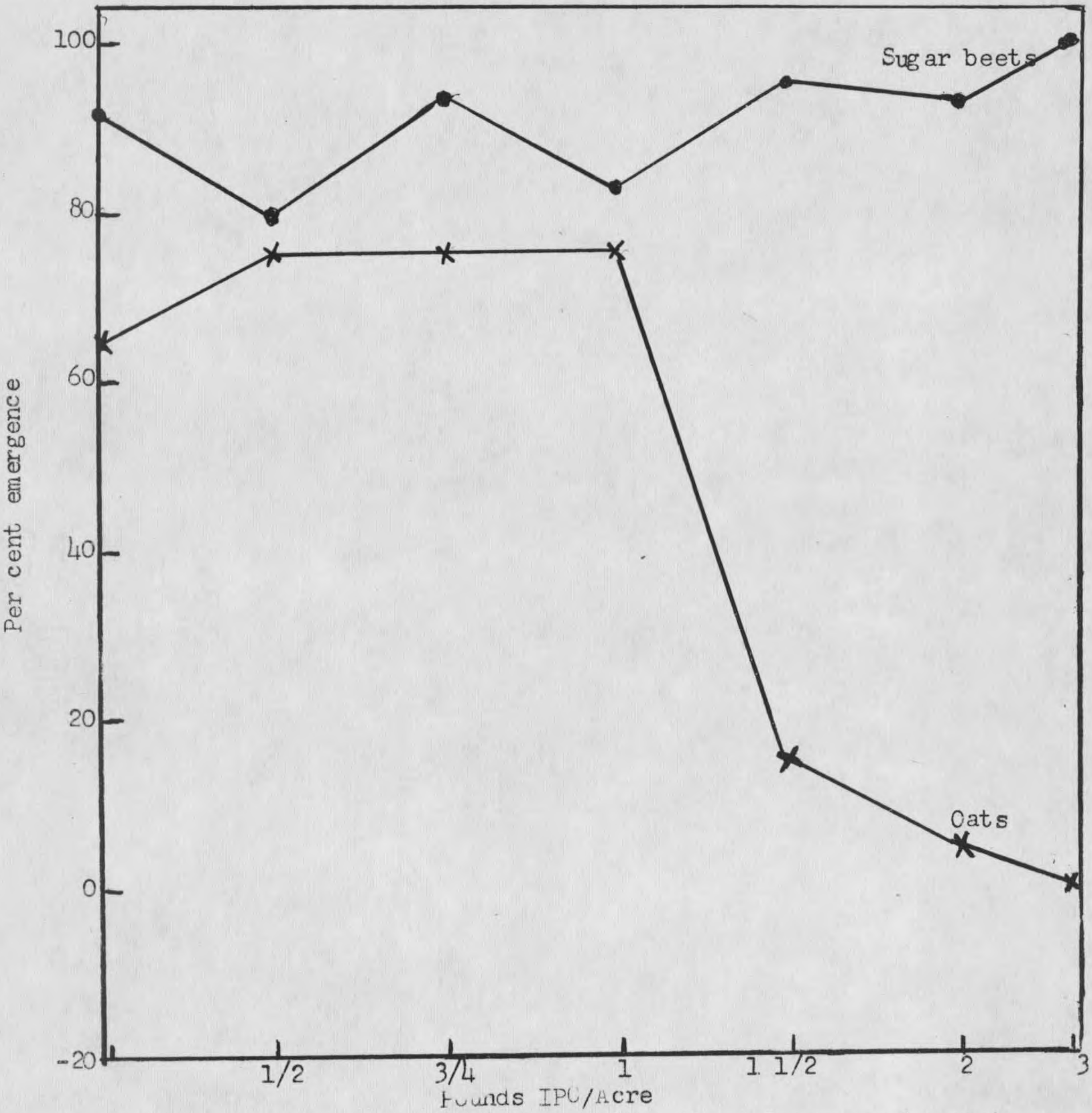

Figure 1. The effect of rates of IPC on the tolerance of common oats and sugar beets.

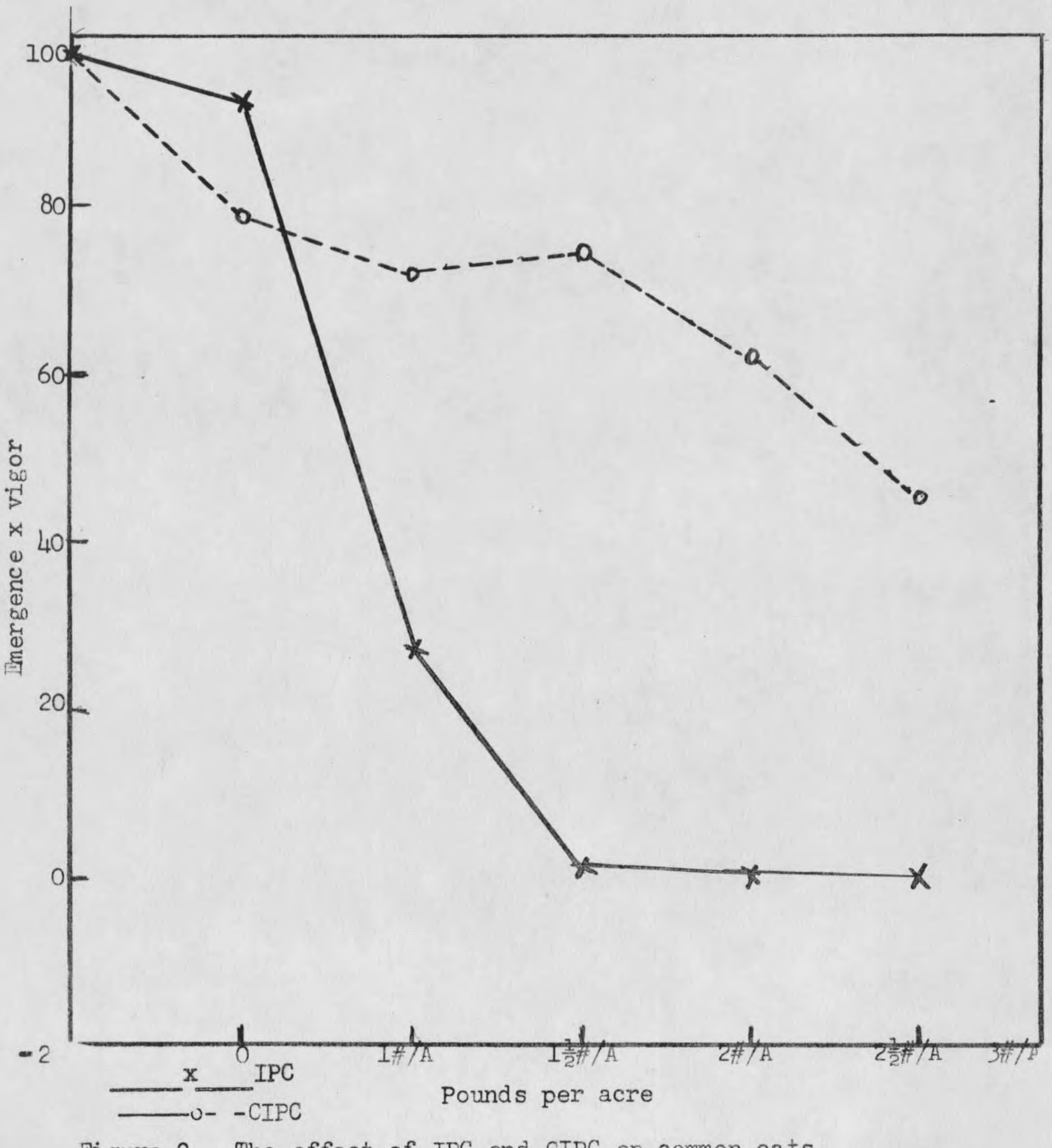

Figure 2. The effect of IPC and CIPC on common oats.

Table III. The effect of rates of IPC on the tolerance of common oats and sugar beets.

Rate pounds/acre	Emergence in per cent of total seeds planted Sugar beets	Common oats
0	92	65
.5	80	75
.75	93	75
1.00	83	75
1.5	95	15
2.00	93	5
3.00	100	0

Table IV. The effect of rates of IPC and CIPC on common oats and sugar beets. Herbicides were incorporated into the entire soil volume of the can.

Treatment pounds/acre	Emergence per cent Beets	Emergence per cent Oats	Vigor Oats	Emergence x Vigor Oats
IPC				
1	67	93	10	93
1½	100	68	4	27
2	87	15	1	1.5
2½	105	3	1	.3
3	107	0	0	0
CIPC				
1	82	88	9	79
1½	105	90	8	72
2	95	93	8	74
2½	88	88	7	62
3	80	75	6	45
Check	88	98	10	98

per cent. Table IV presents the percentage stand of beets and oats, the vigor of the oats, and the efficiency rating of the various treatments.

Since common oats, (Avena sativa) var Mission, was used throughout the experiment, a trial comparing the reaction of wild oats, Avena fatua, with common oats to IPC and CIPC treatments was conducted.

The emergence of common oats was 71 per cent in the check and that of wild oats was 91 per cent. With such a large difference in the percentage emergence in the checks, the analysis of variance was computed as percentage of the respective checks. The common oat seeds apparently had lost some of their vigor as a result of storage under high temperature conditions. The analysis of variance indicated that both species reacted similarly to the two chemicals. The results of (Table V) also indicated that there is no significant difference between the two species of plants in their reaction to the treatments. There was, however, highly significant differences among treatments and between chemicals. Figure 3 gives the range of the efficiency rating which resulted from the different treatments. IPC gave the full range from zero to 100, but CIPC gave only a partial curve, reducing the efficiency rating to 33.

In all these tests the breaking point in the IPC curves in controlling ability of both species of oats used was at the one and one-half pound per acre rate.

According to the results in all comparisons, IPC was more effective in controlling oats than was CIPC. In the trial which compared wild oats with common oats, IPC at a rate of three pounds per acre prevented common oat

Table V. Analysis of variance of the effect of IPC and CIPC on wild and common oats when applied at different rates.

Source of Variance	Degrees Freedom	Mean Square
Replications	3	870*
Rates	2	11827**
Error (a)	6	181
Reps. x Rates	11	
Chemicals	1	40125**
Chem. x Rates	2	2226
Error (b)	9	842
Reps. x Rates x Chem.	23	
Plants	1	391
Plants x Chem.	1	504
Plants x Rates	2	1470
Plants x Rates x Chem.	2	1974
Error	19	673
Total	47	

* Significant to the 5 per cent level.

** Significant to the 1 per cent level.

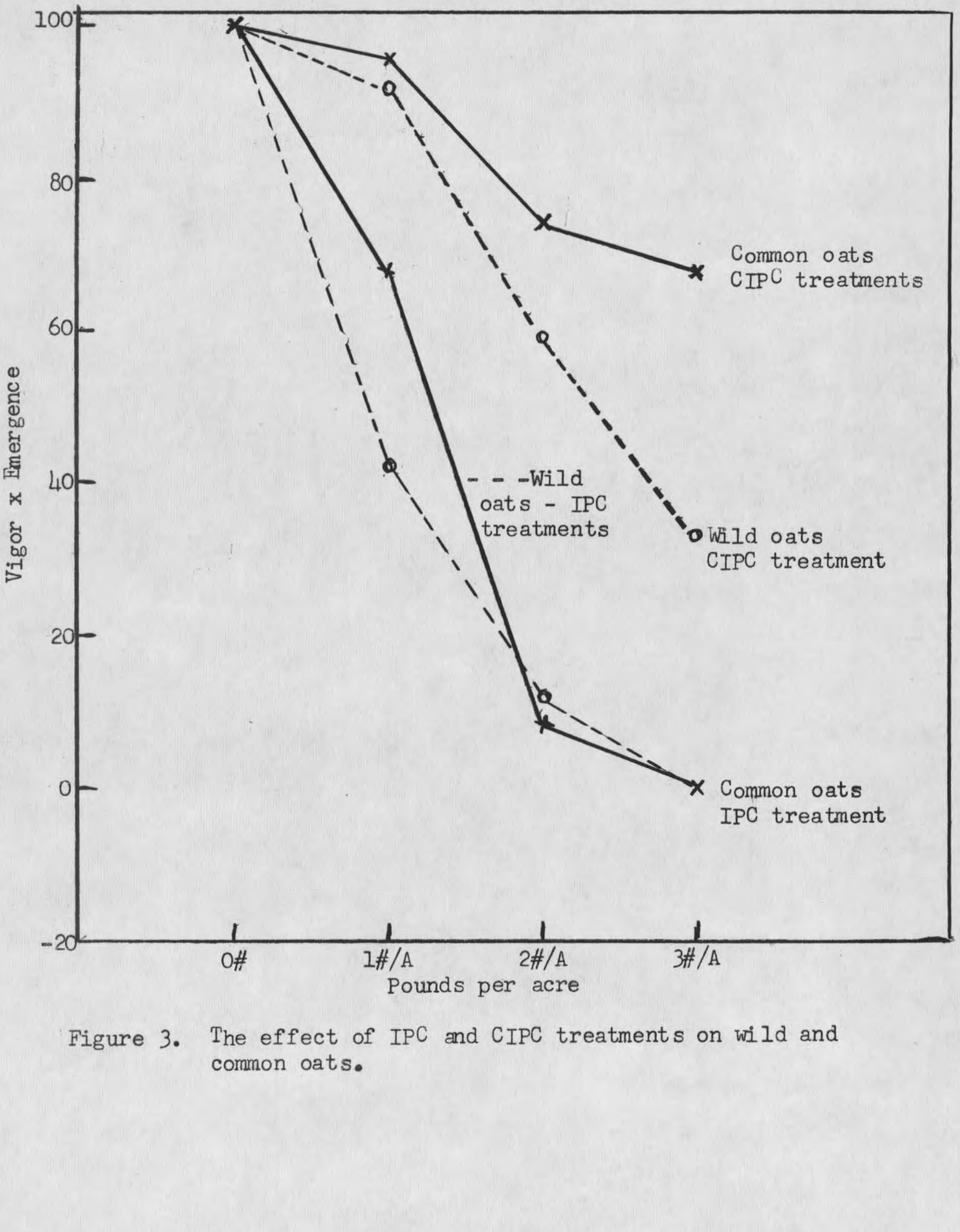

Figure 3. The effect of IPC and CIPC treatments on wild and common oats.

Table VI. The comparative effects of rates of IPC and CIPC on wild and common oats when applied at different rates.

Treatments	Emergence* % check	Vigor	Vigor x emergence
Common Oats			
IPC			
1 lb/A	53.4	8	42
2 lb/A	23	5	12
3 lb/A	0	0	0
CIPC			
1 lb/A	107	9	96
2 lb/A	93	8	74
3 lb/A	93	7	68
Wild Oats			
IPC			
1 lb/A	93	7	68
2 lb/A	20	5	10
3 lb/A	0	0	0
CIPC			
1 lb/A	102	9	92
2 lb/A	84	7	59
3 lb/A	100	5	33

*The actual emergence of the checks were 71 per cent for the common oats and 91 per cent for the wild oats.

Table VII. Effect of IPC in one-half inch layers at various depths on the emergence and vigor of common oats planted two and one-half inches deep.

Depth of bands Inches from surface	Emergence per cent	Vigor	Vigor x emergence
$0-\frac{1}{2}$	87.5	9	78.75
$\frac{1}{2}-1$	85	5	4.25
$1-1\frac{1}{2}$	92.5	2	18.5
$1\frac{1}{2}-2$	47.5	1	4.75
$2-2\frac{1}{2}$	2.5	0	0
$2\frac{1}{2}-3$	0	0	0
$3-3\frac{1}{2}$	0	0	0
$3\frac{1}{2}-4$	35	5	17.5
Check	80	10	80.

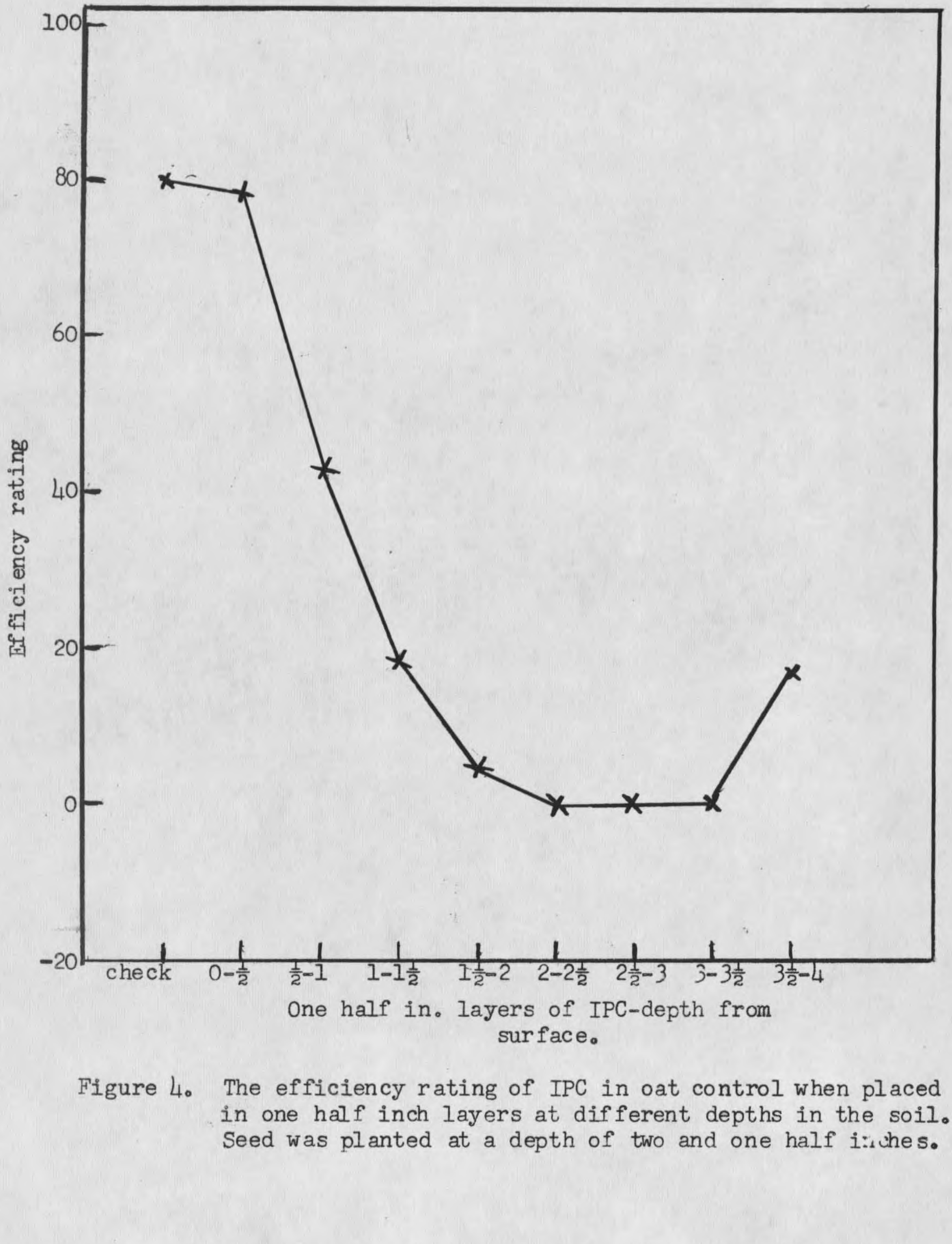

Figure 4. The efficiency rating of IPC in oat control when placed in one half inch layers at different depths in the soil. Seed was planted at a depth of two and one half inches.

emergence, while the CIPC had an efficiency rating of 68 on common oats. In the same trial, IPC at three pounds per acre prevented wild oat emergence while the effects of CIPC produced an efficiency rating of 33. Evidently the breaking point in the curves on the graphs was not reached at the three pound per acre rate of CIPC.

Since there was no significant difference between the reaction of common oats and wild oats, no adjustment is necessary to apply common oat data to wild oats.

The reason or reasons for the differences in the action of CIPC and IPC are not clear. Consideration should be given to differences in plant tolerance to the two chemicals. The oat plants may be tolerant to CIPC at the rates used in these trials. If higher rates were used, the breaking point in the curves for CIPC might be reached.

CIPC had a tendency to flocculate in the water emulsion. Though this probably would not have any effect on the actual concentration in treated soil, it might have affected toxicity. This would also be a factor in getting even mixing of the chemical in the soil. Temperature may have been a controlling factor. Average temperature in the winter months was lower than in the spring months. Temperatures above 100 degrees Fahrenheit were recorded in April. It can be concluded that IPC at two pounds per acre was effective in obtaining good control of both common and wild oats, but CIPC did not give good control even at the rate of three pounds per acre.

Neither the emergence nor the vigor of the sugar beets was affected by any treatment. It seems that sugar beets are tolerant to both chemicals

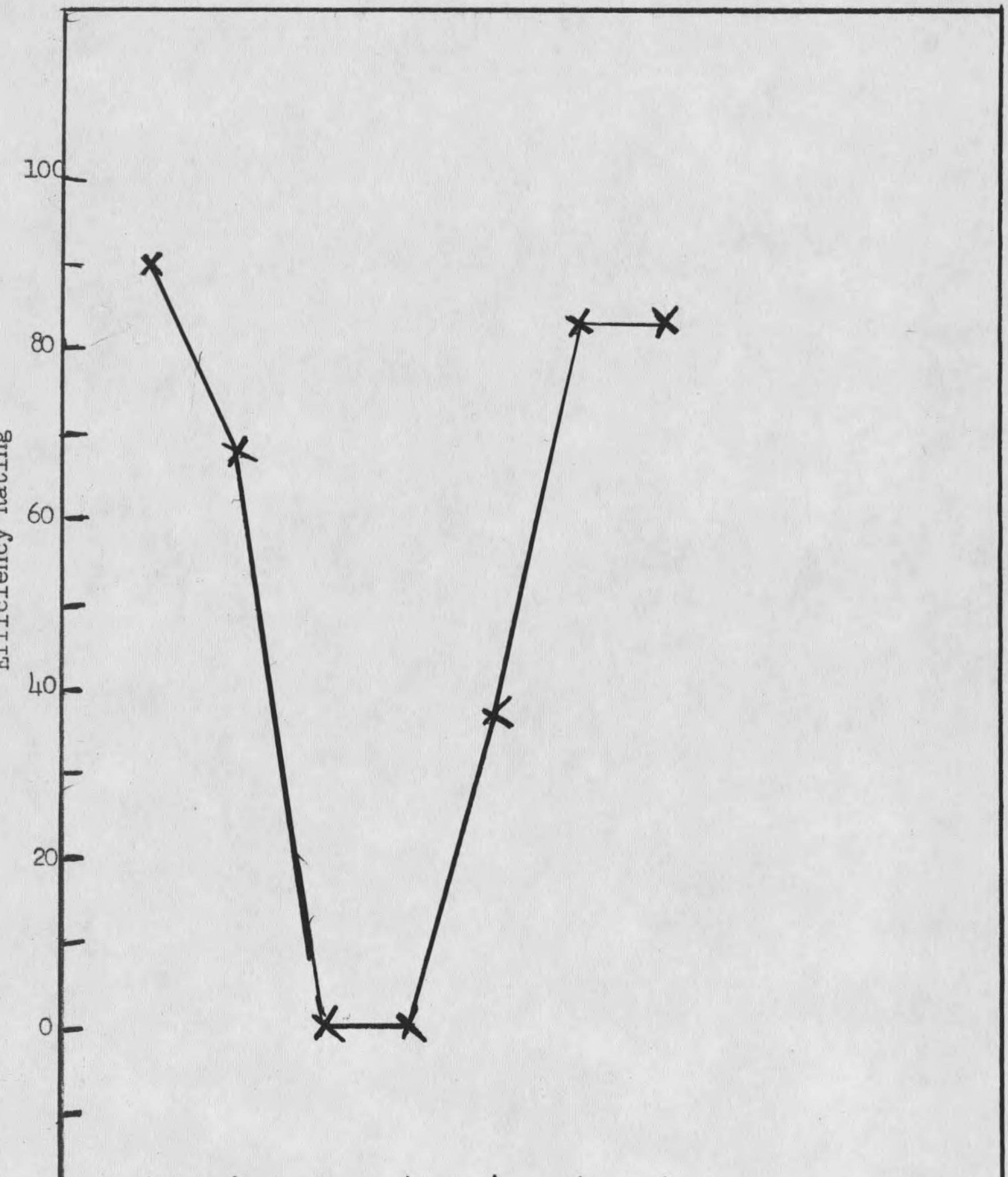

Figure 5. The efficiency rating of CIPC when placed at different depths in the soil.

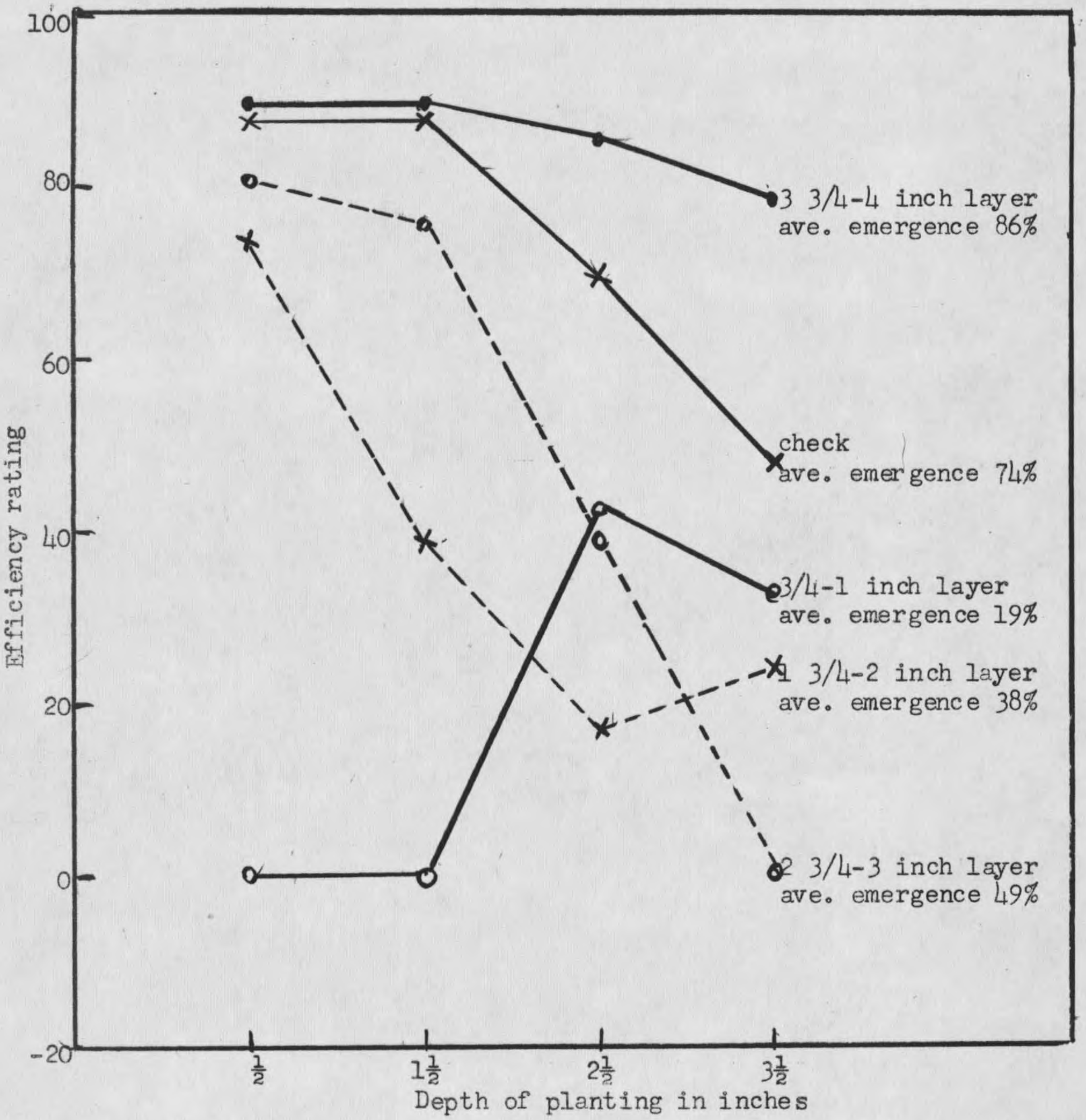

Figure 6. The effect of depth of seeding with depth of application of one-quarter inch layers of soil treated with CIPC at two pounds per acre.

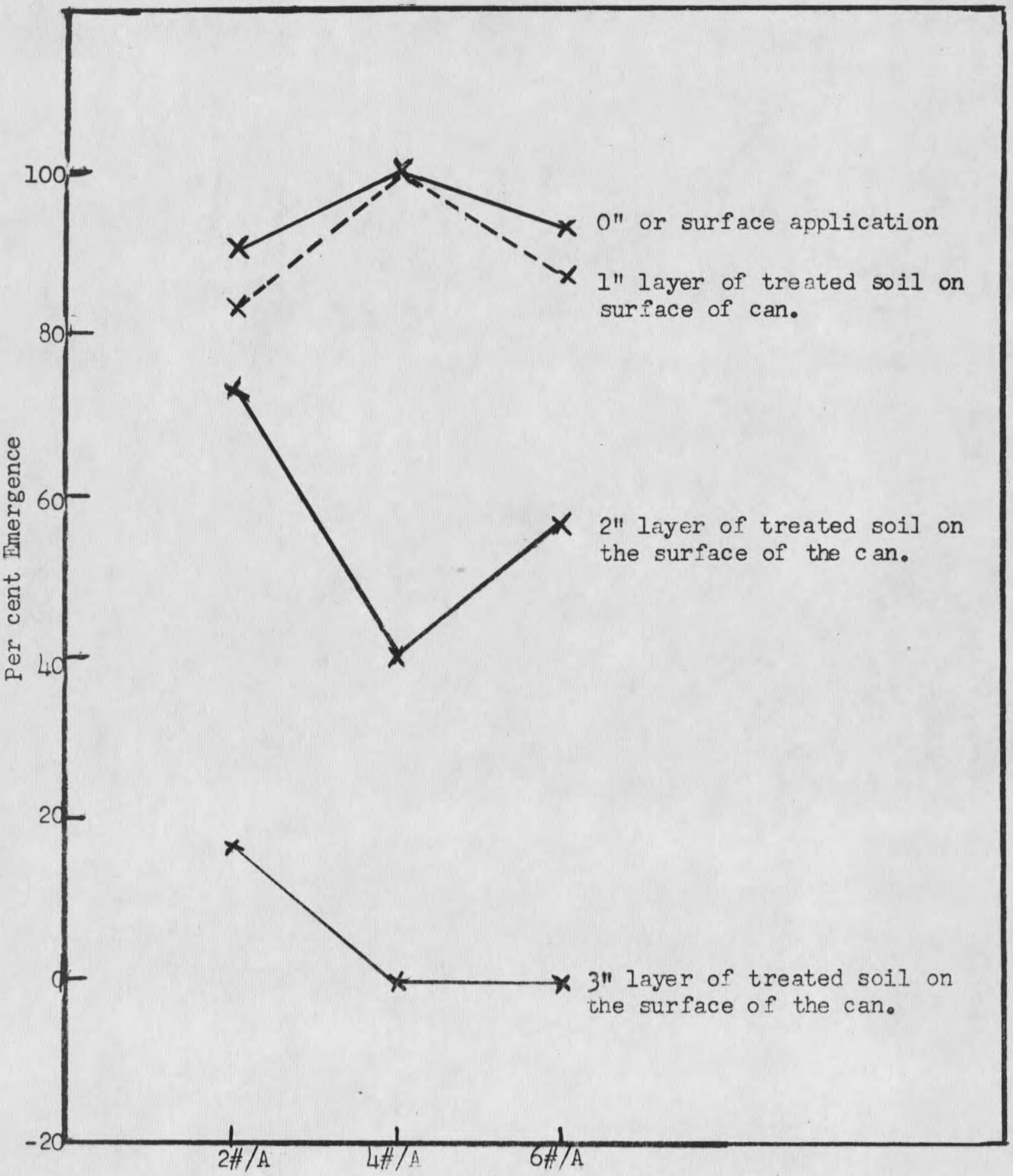

Figure 7. The effect of applying IPC in soil layers of varying thickness and at different rates on the emergence of oats.

Table VIII. The effect of CIPC on the emergence and vigor of oats when one-half inch deep layers of treated soil were placed at different depths.

Depth of layers inches from surface	Emergence per cent	Vigor	Vigor x emergence
1-1½	95	7	68
1½-2	50	0	0
2-2½	0	0	0
2½-3	52.5	7	37
3-3½	92.5	9	83
3½-4	92.5	9	83
check	90	10	90

Table IX. The effect of the depth of seeding combined with various depths of one-quarter inch layers of soil treated with CIPC at two pounds per acre on emergence, vigor and efficiency rating of oats.

Depth of Planting inches	Depth of Layers inches	Emergence per cent	Vigor	Stand x Vigor
½	3/4-1	40	0	0
1½	3/4-1	10	0	0
2½	3/4-1	95	4.5	43
3½	3/4-1	67.5	5	34
½	1 3/4-2	95	7.75	74
1½	1 3/4-2	92.5	4.25	39
2½	1 3/4-2	77.5	2.25	17
3½	1 3/4-2	80	3	24
½	2 3/4-3	95	8.5	81
1½	2 3/4-3	97.5	7.75	76
2½	2 3/4-3	92.5	4.25	39
3½	2 3/4-3	2.5	0	0
½	3 3/4-4	100	9	90
1½	3 3/4-4	100	9	90
2½	3 3/4-4	95	9	86
3½	3 3/4-4	87.5	9	79
½	check plot	87.5	10	88
1½	check "	97.5	9	88
2½	check "	87.5	8	70
3½	check "	80	6	48

up to three pounds active ingredient per acre. Nelson (18) reports that in the tests conducted by the Great Western Company emergence of sugar beets was reduced with the three pound per acre application of CIPC.

PART II. Results of placement of the chemicals in layers in relation to the oat seeds and the effect of moisture in control of oats.

Placement of the chemicals in relation to the seed influences the effect of the chemicals upon the oat plants. The chemicals were mixed into the soil at a rate of 2 pounds per acre and then placed in one half inch layers in the cans, the variable being the depth of the layers. The rate of application of the chemicals was two pounds of active ingredient per acre in all cases. Table VII gives all the depths of treating and the results of the treatments of the IPC layering test and Table VIII gives the same type of data for the CIPC test. In the IPC layering trial, watering was done from the bottom of the cans. The chemicals placed at levels below the seed were most effective which was probably due to the upward movement of the chemical with water. The chemical had to be within one inch of the seed to effect emergence, the levels below the seed giving complete control. In order to get away from movement of the chemical with watering when CIPC was used in the layering test, the soil was wetted to approximately 25 per cent moisture before planting and treating. It is shown in figure 4 that the levels of the IPC layers above the seed allowed the plants to emerge, but that these plants showed very little vigor and growth, if the treated layer was within an inch of the seed. Figure 5 shows that CIPC should be in contact or within one-half inch above the seed. The treatments with CIPC one-half inch or more below the seed failed to control emergence. The results of this test may have been different had higher rates been used as it was found in the comparison test of CIPC and IPC that CIPC did not give control at rates below three pounds per acre.

Another test was designed in order to determine the effect of depth of seeding on emergence control. Quarter inch layers of soil treated with CIPC at two pounds per acre were used. The soil was moistened to approximately 25 per cent moisture before treating and planting. The treatments are shown in Table IX. Figure 6 shows that the CIPC must be within one-half inch of the seed to get good results. The layers immediately above the seed gave better control than those below. Emergence and vigor were reduced in the check where the seed was planted at a depth of $3\frac{1}{2}$ inches. The emergence in the one-half and one and one-half inch planting depths was earlier than for the deeper depths and this may have had an effect upon the time the seedling entered the treated layer as there would not have been as much breakdown of the chemicals.

The presence of the herbicides in amounts that will give control, seem to be most effective if they are above the seed. If herbicide movement with water was not a critical factor, the results indicate that layering above the seeds will give a better efficiency rating than layering below the seeds. It seems that the chemicals must be fairly close to the seed if control is to be obtained. Even at the two pound per acre rate of application of CIPC, there was control if the seed was in the treated layer or within one-half inch below it.

The field application of CIPC and IPC in layers would be a problem. Some device such as the noble blade drill, using sprayer attachments may possibly be designed. It is evident that the herbicides must be mixed thoroughly in the soil in any method of application. In the case of sugar beets, there is a possibility of banding near the seed to obtain control near the beet seedlings and reduce the amount of chemical needed per acre.

It was thought that the chemicals might be most effective in controlling oats if mixed into layers of surface soil of varying thickness. To determine this, a test was designed in which the chemicals at different rates were thoroughly mixed in layers of soil of different thickness. Rates of two, four, and six pounds of IPC per acre were applied in zero, one, two and three inch layers, the zero layer being a surface application with no mixing. The common oat seed was planted three and one-quarter inches deep. As shown in figure 7 there was no control with the zero and one inch layer treatments at any rate. When the IPC was mixed in the two inch layer of soil, it gave some control, reducing the emergence on an average of approximately 40 per cent. The treated three inch layer completely controlled emergence in the four and six pound per acre applications and reduced the stand to 17 per cent of the check in the two pound per acre application. The results indicate that the chemical should be within an inch of the seed to obtain best results.

Moisture seems to be necessary to obtain control of emergence with the use of IPC and CIPC. A test was conducted using CIPC at two pounds per acre and mixed in a layer two inches thick on the surface of the cans. Oat seeds were planted two and one-half inches deep and watered. On the following day the CIPC in near air dry soil was applied in two inch layers over the wet soil containing the seed. These were then watered from the surface at three day intervals for each treatment. Watering dates varied from zero to 15 days. The percentage emergence shows that some control was obtained when the cans were watered within a week following treatment, Table X. The two pound per acre rate of CIPC did not reduce vigor.

Results indicated that a three inch layer of treated soil would give very good control, especially if the seed is within an inch of the chemical and enough moisture is present to enable the chemical to come in contact with the germinating seed or young shoot close to the seed. Thurston (22) reported that wild oat seedlings germinating from six inches deep were very weak and had a yellow color. If mixing to a depth of four inches can be accomplished in the field, good control may be obtained as the chemical should control a great majority of the germinating oat seeds in this layer and within an inch below. With reduced vigor in those seedlings germinating below five inches, they might be completely controlled with the help of the action of the herbicide in reducing vigor.

PART III. General discussion and symptoms of injury.

Watering of the tests seemed to be one of the most critical factors in obtaining accurate results. There seemed to be enough movement of the herbicides with watering to effect the results. The chemicals will move either up or down, depending on the direction of water movement.

Table X. The effect of moisture in obtaining control of oats with the use of CIPC applied in a two inch surface layer in dry soil over oat seed one half inch deep in moist soil.

Treatment - Days after treatment before watering	Emergence per cent	Emergence per cent of check
Check	67	- -
0	45	67.1
3	50	75
6	50	75
9	78.5	117
12	78.5	117
15	80	119

Logan et al. (16) found that IPC moves upward in the soil as it dries. The temperature conditions of the greenhouse may have shortened the residual life of the chemicals to a point that they may have been active for a very short time.

Evaporation of the chemicals following application would be a critical factor, especially if they are not mixed into the soil. Because of the high volatility of these chemicals, it is necessary to incorporate them into the soil as soon as possible. It may be impossible to obtain thorough mixing to a depth of four inches, but any mixing will enhance the chances of getting satisfactory control.

The symptoms of the affected plants are very characteristic when treated with these chemicals. Emerging seedlings tend to show a very dark green color. If the growth is stopped completely with only the first leaf having developed, the plants will soon take on a reddish-brown color. It is possible the growing point is destroyed or that the chemical stops cell division completely, as many of the plants observed stopped growth as soon as they emerged. In digging into the soil where the emergence was controlled, it was noted that the seeds had germinated, but that growth was halted before the seedling reached the surface of the soil. Tillers were borne on elongated stems of many of the abnormal plants. Either the residual effect of the chemical was lost or these plants that formed tillers and culms were more tolerant to the chemicals. If these plants were allowed to grow, they grew normally to maturity and formed normal appearing panicles.

It seemed that the apical portion of the stem of the oat plants were more susceptible to both herbicides than the root portions. Both IPC and CIPC will reduce the extent of root development, but this does not seem enough to stop emergence. Though the residual life of the chemicals was not measured, it was apparently very short. It was probably not more than 15 or 20 days because the plants that were able to form a second leaf eventually recovered from the effects of the chemicals.

SUMMARY

An extensive review of the literature covering the toxic effects of IPC and CIPC is given. It has been pointed out that these two closely related chemicals have some promise for the control of certain species of plants when applied to the soil.

The results obtained in the greenhouse experiments may be summarized as follows:

1. Water movement in the soil may determine to a large degree the effectiveness of the two chemicals studied.
2. The residual life of the chemicals appeared to be not more than 15 to 20 days.
3. IPC is more effective in controlling both wild oats and common oats than is CIPC.
4. At least two pounds of IPC per acre are needed for control and more than three pounds of CIPC per acre are needed for good control (only fair control was obtained with the three pound per acre application).
5. IPC must be within one inch of the oat seed to control emergence and CIPC must be one-half inch of the oat seed to control emergence if only two pounds active ingredient are used.
6. Moisture must be present for securing maximum control with the use of either one of these chemicals.
7. A three inch layer would control most susceptible seedlings germinating from depths down to at least four inches.
8. Sugar beets are tolerant to both chemicals at rates up to three pounds per acre.

LITERATURE CITED

1. ANDERSON, W. P., J. P. LINDER, and JOHN W. MITCHELL. Evaporation of some-plant growth regulators and its possible effect on their activity. Science, 116:502-3. November 7, 1952.

2. ARLE, H. FRED and HOWARD P. CORDS. Chemical control of weeds in Punjab flax. Western Weed Control Conference Research Progress Report, Pp. 95-96. 1952.

3. ATWOOD, W. M. A physiological study of germination of Avena fatua. Bot. Gaz. 57:386-414. 1914.

4. BEATTY, MARVIN. The effect of average precipitation of some chemical properties of soils from three soil groups near Bozeman, Montana. Unpublished data from undergraduate thesis. Montana State College. 1949.

5. BIBBEY, R. O. Influence of environment upon germination of wild seeds. Sci. Agric. 16:141-50. 1935.

6. BRUNS, V. F., and C. O. STANBERRY. Evaluation of chemical sprays for the control of cheatgrass in established alfalfa. Western Weed Control Conference Research Progress Report, Pp. 106-107. 1952.

7. CHEPIL, W. S. Germination of weed seeds, I. Longevity, Periodicity of Germination, and Vitality of Seeds in cultivated soil. Sci. Agr. 26:307-346. 1946.

8. CHYNOWETH, S. G. Control and Eradication of Wild Oats. The Journal of the Department of Agriculture of South Australia. 42(3):301-02. 1938.

9. ENNIS, W. B. Jr. Responses of crop plants to IPC. Bot. Gaz. 109: 473-493. 1948.

10. ______________. Some cytological effects of O-isopropyl-n-phenyl carbamate upon avena. Amer. Journ. Bot. 35:15-21. 1948.

11. FREED, V. H. Herbicide mechanism, mode of action other than aryl oxyalkyl acids. Journ. Agr. and Food Chem. 1(1):47-50. Apr. 1953.

12. ______________. Some factors influencing the herbicidal efficacy of IPC. Weeds 1:48-60. Oct. 1951.

13. ______________ and H. E. BIERMAN. IPC, a new weed killer. Station Bulletin 483, Agricultural Experiment Station. Oregon State College, Corvallis, Oregon. Sept. 1950.

14. JOHNSON, L.P.V. General preliminary studies on the physiology of delayed germination in Avena fatua. Canada. Journ. Res. Sect. C. 13:283-300. 1935.

15. JONES, LUTHER G., and W. A. HARVEY. Herbicides and formulations that are in general use in the control of weeds associated with legume seed production in California. Western Weed Control Conference Research Progress Report. Pp. 102-103. 1952.

16. LOGAN, A. V., N. R. ODELL, and V. H. FREED. The use of C^{14} in a study of the leaching rate of isopropyl n-phenyl carbamate. Weeds 2(1):24-25. 1953.

17. MITCHELL, JOHN W. and PAUL C. MARTH. Sensitivity of grasses and some crops plants to IPC. Science 106:15-17. July, 1947.

18. NELSON, R. T. Control of wild oats and volunteer grain in sugar beets with IPC. Proceedings, Joint Meeting of the North Central Weed Control Conference and The Western Canadian Weed Control Conference. Pp. 73-75. Dec. 1952.

19. NEWMAN, A. S., H. R. DE ROSE, and H. T. DERIGO. Persistence of IPC in soils. Soil Sci. 66: 393-397. 1948.

20. PAVLYCHENKO, T. K. Investigations relating to weed control in Western Canada. Herbage Publication Series. Bul. 27:9-26. 1940.

21. RASMUSSEN, LOWELL W. Control of wild oats in peas. Western Weed Control Conference Research Progress Report. Pp. 105-106. 1952.

22. THURSTON, J. M. Some experimental and field observations on the germination of wild oat seed in soil and emergence of seedlings. Ann. Appl. Biol. 38:812-832. 1952.

23. TOOLE, E. H. and COFFMAN, F.A. Variations in dormancy of seed of the wild oat, Avena fatua. Journ. of Amer. Soc. of Agron. (Agronomy Journal). 32:631-8. August, 1940.

24. WOOD, H. E. "The Wild Oat", occurrence in joint conference area. Proceedings Joint Meeting of the North Central Weed Control Conference and the Western Canadian Weed Control Conference. P. 20, Dec. 1952.