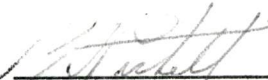


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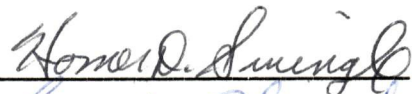
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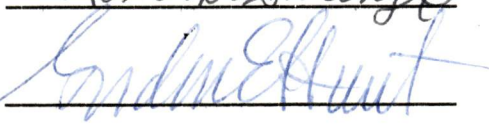
I am submitting herewith a thesis written by Alvin D. Rutledge entitled "The Residual Effects of Four Selective Herbicides Upon the Growth and Development of Winter Cover Crops." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Horticulture.



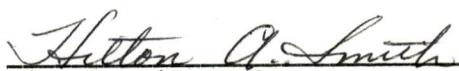
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Vice President for
Graduate Studies and Research

THE RESIDUAL EFFECTS OF FOUR SELECTIVE HERBICIDES UPON THE
GROWTH AND DEVELOPMENT OF WINTER COVER CROPS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Alvin D. Rutledge

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CHAPTER I

INTRODUCTION

Since about 1955, soil applied herbicides have been extensively used in horticultural and agronomic crops for weed control. After the period of desired control, the herbicides must be inactivated or decomposed before susceptible crops can be grown. Herbicidal activity depends upon numerous soil properties, the kind of herbicide, the plant sensitivity to the herbicide, and the climatic conditions under which the herbicide is applied. It is apparent that the herbicide-soil-plant-weather interaction is complex and considerable research is needed before the environmental and physiological problems of herbicide utilization are solved.

N,N-dimethyl- α,α -diphenylacetamide (diphenamid), ethyl N,N-di-n-propylthiolcarbamate (EPTC), and N,N-di-n-propyl-2,6-dinitro-4-trifluoromethylalanine (trifluralin) have been widely accepted as soil applied herbicides. The wide use of these in vegetable crops creates a need for an evaluation of their residual effects on subsequent cover crops commonly grown following vegetables.

The objectives of this investigation were threefold. The first was to determine the residual effects of the above three herbicides and Amchem D-263, a new experimental herbicide, upon the growth and development of fall seeded rye, oats, and crimson clover. The second was to determine whether the herbicides were present in various layers

of the top nine inches of soil at the time of fall seeding in concentrations great enough to impair cover crop growth. The last was to determine the time necessary for complete loss of herbicidal toxicity to the above crops.

CHAPTER II

REVIEW OF LITERATURE

I. FACTORS AFFECTING HERBICIDE ACTIVITY

The effectiveness of any soil applied herbicide depends primarily on three factors: (a) the rate of herbicide application, (b) the chemical and physical properties of the soil, and (c) the environmental conditions of the soil (16).

The soil weighs, on the average, about 3.5 million pounds per acre foot or 292,000 pounds per acre inch. A 3.5 pound application of herbicide per acre foot of soil is equivalent to one part per million. Few chemicals seriously affect plants at this concentration (16), but the rate of herbicide application is considered to be one of the important factors affecting residue levels in the soil (9).

The residual effect of chemicals is greatly influenced by the fixation power of the soil. For example, arsenic is so strongly fixed by the soil colloids that several hundred pounds must be applied before toxic concentrations accumulate in the soil solution (16). Carbon disulfide may be required at a rate of 3,000 pounds per acre to kill roots of perennial weeds, while one to 1.5 tons of borax may be necessary to control weeds in the top acre inch of some soils (16).

Soils vary widely in their water holding capacity. Since most herbicides seem to act through the soil solution, the concentration of a given herbicide in the soil solution will depend not only on the

fixing power of the soil, but also on its water content (16). Factors in a clay soil which enable it to hold a high water content may also enable it to fix a large proportion of an applied chemical (16).

Other soil factors which influence herbicidal action are organic matter content, pH, exchangeable bases, and microorganism activity. Environmental factors such as temperature, light, and rainfall are also influential in herbicide action, but it is difficult to measure the effect of any one of these factors because they are all interrelated (3,18,21,45,54).

Microbiological Decomposition

Many investigators (11,28,51,56) report that microbial action is one of the most important factors which influences herbicide deactivation. According to Martin (41), practically any organic material, including highly resistant and toxic materials, can be partially decomposed by microorganism activity. By using oat (Avena sativa) bioassays, Newman et al. (45) found isopropyl-N-phenylcarbamate (IPC) to persist more than nine weeks in an autoclaved soil while disappearing in two weeks in non-autoclaved soils. DeRose et al. (18) reported that 2,4-dichlorophenoxy acetic acid (2,4-D), 2,4,5-trichlorophenoxy acetic acid (2,4,5-T), and 4-chloro-2-methylphenoxy acetic acid (MCPA) were not lost after six weeks in sterilized soil, but all three were lost within three to six weeks in unsterilized soil.

Warmth and moisture are essential for microbial activity. Most soil microbes are dormant below 40°F. and are most active at temperatures

of 75 to 90°F. (38). DeRose et al. (18) reports that 2,4-D, 2,4,5-T, and MCPA doubles in rate of disappearance when the temperature is increased from 10 to 30°C. and increased as soil moisture was increased from 20 to 100 per cent of the water holding capacity.

Organic matter and oxygen are also important factors which influence microorganism activity. Kries (39) and Rahn et al. (49) found that additions of manure and leaf mold to the soil reduced the persistence of certain herbicides, but decomposition of other chemicals may be temporarily inhibited by large additions of manure or peat.

Holstun et al. (31) and Reid (51) report that near neutral soil reactions accelerate herbicide inactivations over that of soils with a pH of 6.5. Klingman (38) indicates that bacteria are favored by a medium to high pH while fungi are more active at pH values less than 5.5. Gysin (26) and Theigs (63) report that both of these biological groups share an important role in herbicide decomposition.

Alexander et al. (1) and Whiteside et al. (65) report that the halogen position on the benzene ring influences herbicide decomposition. They report that the position of the halogen governs the breakdown of certain phenoxy compounds more than the number of halogen atoms.

Adsorption

Ercegovich (23) reports that Frissel found 2-chloro-4,6-bis-(ethylamino)-s-triazine (simazine), 2-chloro-4-diethylamino-6-ethylamino-s-triazine (trietazine), and 2-chloro-4,6-bis(diethylamino)-s-

triazine (chlorazine) to be most strongly adsorbed by montmorillinite clay, intermediate by illite, and least by kaolinite. It is also reported by the same author that increasing the pH resulted in an increased adsorption of these chemicals while Talbert et al. (62) reported that increasing both the temperature and pH decreased the adsorption of C^{14} labeled atrazine and simazine.

Adsorption of the various triazine herbicides tends to increase with increasing organic matter and clay content of soils (61,62). Organic matter content of soils is usually much lower than the amount of clay, but is much more adsorptive. Sheets et al. (53) and Talbert et al. (62) found both of these factors to be equally important in triazine adsorption, but are in disagreement as to which factor is the more important. Harris (27) reports that atrazine is adsorbed on bentonite, muck soil, and cation exchange resin. Bentonite adsorption was higher at lower pH ranges.

Leaching

Leaching appears to be another mechanism which greatly influences the dissipation of herbicides. Movement of a herbicide through the soil reduces its concentration by dilution and increases the chance of adsorption on to soil particles (57). The amount of leaching is greatest in sandy soils because of greater water percolation and less adsorption on to soil particles (8).

Montgomery et al. (42) found that most of C^{14} labeled simazine remained in the top one-inch soil layer after applying twelve inches

of water to a sandy soil over a three day period. Rauser et al. (50) reports that 3-amino-2,5-dichlorobenzoic acid (amiben) was completely leached from surface sand but only a portion was removed from muck when five inches of water was applied.

Vaporization

Sheets et al. (53) reports that herbicide disappearance is important with herbicides having high vapor pressures. Short chain esters of 2,4-D are more volatile than long chain esters (38). At 25°C., the isopropyl ester of 2,4-D has a vapor pressure of 10.5×10^{-3} millimeters of mercury. By contrast, 3-(p-chlorophenyl)-1,1-dimethylurea (monuron) has a vapor pressure of 5×10^{-7} , or approximately 20,000 times less volatile than the 2,4-D ester. As a result of the difference in vapor pressure, 2,4-D loss from a hot surface would be extreme while monuron loss would be negligible (38).

Davis et al. (17) reported a 50 per cent loss of simazine from metal surfaces after two months of storage at 71 to 74°C. The rate of loss was less at lower temperatures, but was greater from metal surfaces than either sand or clay. Similar results were reported by Kearney (37) with radiolabeled triazines.

Temperature and Rainfall

Since temperature and rainfall both influence the rate of biological activity, it is logical that they would influence the effectiveness of soil applied herbicides. Buchholtz (9) reported that higher temperatures should accelerate herbicidal decomposition by

increasing biological activity and result in less injury to oats. This did not prove to be true, however, because oat injury was more severe in some cases where temperatures were ideal for oats. Comes et al. (13) found that soil temperatures of 140 to 180°F. during the summer directly or indirectly influences the loss of atrazine from the soil surface.

In seasons of adequate rainfall, triazine herbicides are more subject to degradation due to more favorable conditions for biological activity (9). Rahn et al. (49) reported that irrigation did not increase monuron decomposition during the years of normal rainfall, but accelerated decomposition during the years when rainfall was below normal.

Plant Uptake

Behrens (8) and Sheets (56) reported that herbicide inactivation was directly involved with absorption and metabolism by higher plants.

Soil Properties

Cation exchange capacity, exchangeable calcium, organic matter content, moisture equivalent, free drainage value, and total exchangeable bases appear to be positively and highly correlated with the amount of herbicides required to cause a 50 per cent reduction in plant growth (9,46,49,54,64).

Photodecomposition

Comes et al. (13) and Jordan et al. (34,36) reported that the greatest changes in the phenylurea and triazine herbicides are produced by far ultraviolet light.

Cultivation

Residues of spring applied atrazine and simazine resulted in a significantly greater reduction of fall seeded oat yields in disked soils than in fall plowed soils according to Buchholtz (9). Reduced injury in plowed soils was attributed to a greater mixing of the herbicide throughout the plow layer. Rahn et al. (49) indicates that cultivation accelerates the disappearance of monuron by increasing the biological activity.

II. ACTIVITY OF SPECIFIC HERBICIDES

EPTC

Sheets (55) and Talbert et al. (62) found EPTC to be inactivated one-third as rapidly in autoclaved as in non-autoclaved soils. This indicates that microbial breakdown is a major pathway of EPTC loss from soils. EPTC activity may be greatly prolonged when field conditions are unfavorable for microbiological activity. Such conditions exist during the late fall, winter, or early spring. During this period, temperature and moisture conditions are unfavorable for biological activity.

EPTC absorption appears to be greater in soils higher in clay and organic matter in both wet and dry seasons according to Ashton et al. (3). These investigators reported that EPTC was found to be adsorbed to a much greater extent in air dry soils than in soils having a moisture content near field capacity. This is probably due to a thin film of water surrounding the soil particles when the moisture content is near field capacity and thereby prevents intimate contact of the slightly water soluble EPTC with individual soil particles.

Ashton et al. (3) also report that EPTC is highly volatile. Klingman (38) reported that EPTC volatilized from a free liquid surface at the rate of 57 micrograms per square centimeter per hour at 86°F. As a result of this high rate of vaporization, loss of EPTC from soil surfaces could easily occur without adsorption by the soil colloids.

EPTC is an effective pre-emergence herbicide when applied to dry soil, and its performance can be enhanced by irrigation immediately after application. Failure can be expected when EPTC is applied to dry soil without addition of water (29).

EPTC residues are reported to cause injury to oats according to Sweet et al. (59). In their experiment, plots receiving 2, 4, 6, and 8 pounds of EPTC were treated on August 28, 1959 and seeded to oats on April 16, 1960. Oat germination and growth was normal in all plots until about two weeks after planting. At this time, oat seedlings became abnormal in color and stunted in certain plots which had received EPTC as a soil incorporated treatment. Severe damage occurred where

8 pounds had been applied, but very little resulted from the 4 pound application.

Other workers (3,35) report a high negative correlation between soil organic matter content and EPTC injury to oats, but a positive correlation was found between sand and silt content and oat injury.

Diphenamid

Harris (28) found that movement of diphenamid at 8 pounds per acre was not sufficient to allow oat growth in the top inch of soil when five and ten inches of water was applied to a Hagerstown silty clay loam. Bioassays at the lower depths indicate that diphenamid movement was faster when water was applied in 0.25 inch increments than when applied in one inch increments. This was attributed to the herbicide character and soil structure. The silty clay has a well-developed structure and a wide range of pore sizes. Gravitational water movement would be greater in the larger pores and some of the smaller pores would tend to be by-passed. Addition of smaller increments would provide more time for diphenamid in areas of slow water movement to move into areas of fast water movement and subsequently be carried to the lower soil depths.

A twelve-fold increase in organic matter content required fourteen times more diphenamid to cause the same amount of toxicity according to Dubey et al. (21). ED₅₀¹ values for diphenamid was positively

¹The amount of herbicide required to produce a 50 per cent reduction in growth.

correlated with organic matter content, cation exchange capacity, and exchangeable calcium, but not with exchangeable potassium. The ED₅₀ values were more highly correlated with organic matter content than any of the other factors.

Dubey et al. (19) found that diphenamid concentrations above 0.8 parts per million inhibited oats, barley, and ryegrass germination when seeded immediately after treatment. Ryegrass germination was most affected, and shoot weights of all species were reduced with increasing levels of diphenamid. Jones et al. (32) also reported that diphenamid significantly reduced growth of barley when seeded twelve weeks from application.

Trifluralin

Schweizer et al. (52) reported that injury resulted in oats up to thirty-one weeks from trifluralin application in some soil types. Applications consisted of six treatments ranging from 0 up to 16 pounds per acre. Initial toxicity was apparent at all concentrations, but injury persisted longer in soils low in organic matter and high in clay. Injury from all concentrations was of shorter duration in soils high in organic matter.

Amchem D-263

No literature concerning the activity of Amchem D-263 was found.

CHAPTER III

MATERIALS AND METHODS

I. FIELD EXPERIMENTS

Herbicide Application

The experimental design consisted of a randomized block with four replications. Plots occupied a 6 x 15 foot area on a Whitwell loam soil containing 28.5 per cent sand, 44.1 per cent silt, 27.4 per cent clay, 1.5 per cent organic matter and located on The University of Tennessee Plant Science Farm.

The chemicals, rates, and formulations used in this experiment were those commonly used with vegetable crops and are as follows:

<u>Treatment</u>	<u>Rate lb./a</u>	<u>Formulation</u>
1. Cultivated	--	--
2. Diphenamid	4	Wettable powder
3. Amchem D-263	3	Emulsifiable concentrate
4. EPTC	6	Emulsifiable concentrate
5. Trifluralin	1	Emulsifiable concentrate

Trifluralin was applied on May 7, 1965 and immediately incorporated with a rotary tiller. Diphenamid, Amchem D-263, and EPTC were applied on May 11 and EPTC was immediately incorporated. Each herbicide was applied as a spray in 50 gallons of water per acre. No crop was seeded to the area.

Herbicide Evaluation

In order to judge the effectiveness of materials under the conditions of this experiment, evaluations were made at four and eight weeks following herbicide application. The effect on weeds was based on the following scale:

0 = no effect on weed control.

10 = complete control of weeds.

Rainfall data were collected from the time of application until fall seeding.

Following a thorough disking on September 10, an analysis indicated that the soil was moderately low in nitrogen, low in phosphorous, moderately low in potassium, and had a pH of 5.6. On the basis of this analysis, soil amendments were added at the rate of 600 pounds of 5-10-5 fertilizer and 2.5 tons of lime per acre in preparation for cover crops.

On September 13, plots were again disked and leveled. Balboa rye, Forkeddeer oats, and common crimson clover were seeded on the plots receiving herbicides. Each crop was seeded in six rows nine inches apart on each replicate.

Each species was evaluated for plant stand per three feet of row, the fresh and dry weights of twenty-five plants six to eight weeks from seeding, date at which ~~each~~ crop was in 75 to 90 per cent bloom, and the average height of 10 plants at the time of bloom. Oats were evaluated for the total number of tillers per twenty-five plants at ten weeks from seeding.

II. GREENHOUSE EXPERIMENTS

Leaching

The purpose of this experiment was to determine if the herbicides were present at toxic levels in various layers of the top nine inches of soil at the time of fall seeding in concentrations great enough to impair the growth of any of the above cover crops.

On September 11, soil samples were randomly taken from the herbicide treated field plots at four depths as follows:

1. 0-3 inches. This was considered as the average depth of disc penetration.
2. 3-5 inches.
3. 5-7 inches.
4. 7-9 inches.

Each sample was mixed, placed in 5 x 7 x 2-1/2 inch styrofoam flats and seeded on September 16. Each flat contained one row of rye, oats, and crimson clover.

Each crop was evaluated for per cent germination and observations were taken on any abnormalities in growth. Fresh and dry weights per crop per flat were determined at three to six weeks from seeding depending upon the growth of each species.

Residual Effects

Bioassays of rye, oats, and crimson clover were used to determine the interval of time necessary for toxic levels of herbicides to be dissipated from soils.

On September 15, soil samples were taken from the top three inches of an untreated Whitwell loam soil located adjacent to the treated field plots. Samples were thoroughly screened and stored in 18 x 14 x 3 inch wooden flats.

On November 15, the same four herbicides were applied to the flats at the same rates used in the field. Each herbicide was applied in 300 gallons of water per acre by using a 3-gallon hand sprayer. The amount of water used was increased above that used in the field in order to insure a more uniform application. Trifluralin and EPTC were immediately incorporated with a small, hand rake.

A total of sixty flats were divided into three lots in order to make seedings at 6, 10, and 14 weeks from the time of herbicide application. Between application and seeding, each lot received the same amount of water in 1/4-inch increments as the amount occurring for that same period during the previous summer.

At the respective seeding dates, the samples were thoroughly loosened with a hand rake and seeded with rye, oats, and crimson clover. A slight layer of sand was added to the surface to prevent crust formation and facilitate emergence.

Soil samples from the diphenamid treated flats were taken at seeding time and stored at -20°F. for later analysis.

Before the first seeding, all soils were maintained at 80 to 90°F. since this was the normal summer temperature range. After the first seeding, temperatures were dropped to 60 to 70°F. because all of the above crops grow best under cooler temperatures.

The young seedlings were observed for per cent germination, and the number resulting in death and abnormal growth habits. The fresh and dry weight of thirty plants of each crop were taken four to six weeks from seeding depending on the growth and development of each species.

Rye samples taken fourteen weeks after seeding were ashed at 350°C. for 72 hours. These data were used to determine the necessity of further experimentation on the effect of herbicides upon specific mineral matter uptake.

Due to the variations in greenhouse conditions during this experiment, further experiments were conducted in an effort to explain why abnormalities in plant growth occurred.

Since rye was injured in diphenamid treated soils at fourteen weeks and not at six or ten weeks, it was felt that greenhouse temperatures may have influenced diphenamid effectiveness. During the six and ten week period, temperatures averaged 45 to 50°F. On two occasions, they dropped as low as 34°F. In an effort to explain rye injury, two lots of diphenamid treated soils were kept at 45 and 80°F. for four and six weeks. At the end of this period, they were seeded to rye to determine the effect of these extreme temperatures on diphenamid toxicity.

It was also felt that diphenamid may not have moved down into the root zone during the six and ten week period, but was present in concentrations great enough to injure rye at fourteen weeks. As a result, another experiment was initiated to test this hypothesis.

Diphenamid treated soils received the same amount of water that had been given the soils in the previous fourteen-week period. At the end of this period, soils were divided into a top and bottom layer and seeded to rye to determine whether diphenamid was present in the lower layer in greater concentrations than in the top layer.

The experimental design of all greenhouse experiments consisted of a randomized block with four replications. Each flat was considered as a replicate.

The data in all experiments were statistically analyzed by the "Analysis of Variance" method as described by Snedecor (58).

Soil Analysis for Diphenamid

The soil samples containing diphenamid taken at 6, 10 and 14 weeks from application were used in this analysis.

Colorimetric determinations of diphenamid residues were made by the following procedure. A 50-gram soil sample was extracted with dichloromethane, passed over an alumina column and evaporated to dryness using a 70°C. water bath and a Rinco evaporator. The residue was dissolved in acetonitrile, washed with petroleum ether, and again evaporated. The remaining residue was dissolved in dichloromethane, passed over a florisil column, and eluted with chloroform. The eluate was then subjected to a final evaporation. After complete evaporation, the final residue was diluted with concentrated sulfuric acid and the absorbance at 440 m μ was determined with a Bausch and Lomb Spectronic 20 before and after a 30 minute exposure to a Hanovia Letheray

Germicidal unit. Diphenamid residue determinations were based on the following equation:

$$\text{p.p.m.} = \frac{A_{440}(\text{sample}) - A_{440}(\text{blank})}{A_{440}(\text{standard}) - A_{440}(\text{blank})} \times 0.25 \quad .$$

CHAPTER IV

RESULTS AND DISCUSSION

I. FIELD EXPERIMENTS

Weed Control

Ratings in Table I illustrate the effectiveness of diphenamid, Amchem D-263, EPTC, and trifluralin on overall weed control at four and eight weeks from application. Weed control in plots treated with EPTC was no different to that of the cultivated check plots at either the four or eight week period.

Weed control in the EPTC plots was greater than that of other treated plots at both four and eight weeks from treatment (.05 level). At four weeks from application, EPTC was more effective in controlling weeds than either diphenamid or Amchem D-263, but was no greater than trifluralin (.01 level). At eight weeks from application, EPTC was more effective in weed control than all other chemicals (.01 level).

Weed growth on the Amchem D-263 plots became quite intensive at five weeks from treatment. Intensive weed growth occurred on the diphenamid and trifluralin treated plots at seven weeks from treatment, and on plots receiving EPTC after twelve weeks. All plots required mowing at fourteen weeks from herbicide application.

The primary weed growth in these plots consisted of the common morning glory (Ipomea purpurea), field bindweed (Convolvulus avensis),

TABLE I
EFFECT OF SELECTIVE HERBICIDES UPON OVERALL WEED CONTROL
AT FOUR AND EIGHT WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Weed Control ¹	
		4 Weeks	8 Weeks
Cultivate	--	10.00	10.00
Diphenamid	4	8.13	3.75
Amchem D-263	3	7.88	0.75
EPTC	6	9.75	8.75
Trifluralin	1	8.63	3.00
LSD .05		0.89	2.25
LSD .01		1.25	3.15

¹0 = no effect.

10 = complete kill.

crabgrass (Digitaria sanguinalis), and nutgrass (Cyperus esculentus). All herbicides were less effective in controlling broadleaf weeds such as the common morning glory and field bindweed. Crabgrass control was good in all plots receiving herbicides. Nutgrass was a serious problem in all plots except those treated with six pounds of EPTC. EPTC provided good nutgrass control for a period of about ten weeks.

Effect on Cover Crops

The time required for germination and emergence of rye, oats, and crimson clover (Table II), plant stand (Table III), and tiller production of oats (Table IV) were not effected by herbicidal treatment.

Table V indicates that growth and development of rye and oats were not impaired by herbicide treatment since fresh and dry weights were not reduced. Further evidence of this is shown in Figure 1. However, these results do not support those reported by Schweizer et al. (52) or Sweet et al. (59). These investigators reported that trifluralin may injure oats up to thirty-one weeks from application and EPTC may be toxic as long as seven months from application.

Fresh and dry weights of crimson clover were significantly effected (Table V). However, the lower weights were in the cultivated check plots and it is believed that this reduction is partially due to soil moisture variations of the field plots. Observations indicated that the cultivated plots dried out faster than the other plots. This

TABLE II
EFFECT OF SELECTIVE HERBICIDES UPON THE NUMBER OF DAYS
REQUIRED FOR EMERGENCE OF COVER CROPS

Treatment	Rate Lb./A.	Mean Number of Days		
		Rye	Oats	Crimson Clover
Cultivate	--	3.00	7.00	4.00
Diphenamid	4	3.00	7.70	4.20
Amchem D-263	3	3.00	8.10	4.00
EPTC	6	3.00	8.20	4.00
Trifluralin	1	3.00	8.20	4.00
LSD .05		NS	NS	NS

TABLE III
EFFECT OF SELECTIVE HERBICIDES UPON THE STAND COUNT OF
RYE, OATS, AND CRIMSON CLOVER

Treatment	Rate Lb./A.	Stand Count ¹		
		Rye	Oats	Crimson Clover
Cultivate	--	52.50	48.50	43.75
Diphenamid	4	45.25	42.50	22.00
Amchem D-263	3	43.75	46.50	34.50
EPTC	6	50.50	52.75	40.00
Trifluralin	1	47.25	36.75	30.75
LSA .05		NS	NS	NS

¹Total of three feet of row.

TABLE IV
EFFECT OF SELECTIVE HERBICIDES UPON TILLER
PRODUCTION OF OATS

Treatment	Rate lb./A.	Tillers ¹
Cultivate	--	129.00
Diphenamid	4	136.00
Amchem D-263	3	142.00
EPTC	6	134.00
Trifluralin	1	127.00
LSA .05		NS

¹Total per 25 plants.

TABLE V
EFFECT OF SELECTIVE HERBICIDES UPON THE WEIGHT OF COVER
CROPS AT SIX TO EIGHT WEEKS FROM SEEDING

Treatment	Rate Lb./A.	Gram Weight of 25 Plants					
		Rye		Oats		Crimson Clover	
		Fresh	Dry	Fresh	Dry	Fresh	Dry
Cultivate	--	39.42	6.65	21.68	3.76	7.62	1.32
Diphenamid	4	33.63	6.00	26.14	4.49	12.59	2.44
Amchem D-263	3	30.13	5.41	26.96	4.55	15.95	3.03
EPTC	6	38.02	6.60	24.88	4.22	9.26	1.75
Trifluralin	1	32.04	5.68	15.88	2.88	14.89	2.83
LSD .05		NS	NS	7.02	NS	2.40	1.02
LSD .01		NS	NS	NS	NS	3.61	NS



Figure 1. Effect of selective herbicides upon the growth of rye, oats, and crimson clover.

may be partially attributed to the location, by randomization, of the cultivated plots on higher elevated soils.

Herbicidal treatment had no influence upon the percentage moisture of rye, oats, or crimson clover when seeded fifteen weeks from application (Table VI). Plant height taken at the time of bloom (Table VII) was not affected by chemical treatment. Observations also indicated that blooming date was not altered by chemical treatment.

II. GREENHOUSE EXPERIMENTS

Leaching

Residue studies from various soil depths indicated that none of the herbicides were present at the time of field seeding in amounts great enough to affect the percentage germination of rye (Table VIII), crimson clover (Table X), or percentage moisture of rye (Table XIII). EPTC, however, appeared to have accumulated at the three to five inch depth in sufficient amounts to impair oat germination (Table IX). Any accumulations at this depth apparently resulted in quick inactivation since growth (Tables XIV and XV) and percentage moisture (Table XVI) were not affected.

Bioassays (Tables XI, XII, XIV, and XV) show that none of the herbicides were present at any soil depth in concentrations great enough to influence the growth of either rye or oats. Table XVII shows a reduction in fresh weights of crimson clover at a soil depth of 0 to 3 inches (.05 level). It is felt that this reduction is due to a higher incidence of damping off rather than chemical treatment.

TABLE VI

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE MOISTURE OF
 RYE, OATS, AND CRIMSON CLOVER WHEN SEEDED
 FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Moisture		
		Rye	Oats	Crimson Clover
Cultivate	--	82.70	82.30	83.60
Diphenamid	4	82.10	82.80	80.80
Amchem D-263	3	81.80	83.20	80.90
EPTC	6	82.00	82.30	81.20
Trifluralin	1	82.30	81.60	81.00
LSD .05		NS	NS	NS

TABLE VII
EFFECT OF SELECTIVE HERBICIDES UPON THE AVERAGE HEIGHT OF
RYE, OATS, AND CRIMSON CLOVER AT 75 TO
90 PER CENT BLOOM

Treatment	Rate Lb./A.	Height in Inches ¹		
		Rye	Oats	Crimson Clover
Cultivate	--	45.90	34.15	18.30
Diphenamid	4	44.60	33.62	18.55
Amchem D-263	3	44.91	34.10	17.13
EPTC	6	44.00	33.90	17.80
Trifluralin	1	44.15	34.33	18.65
LSA .05		NS	NS	NS

¹Average of ten culms in rye and oats and ten plants in crimson clover.

TABLE VIII

EFFECT OF SELECTIVE HERBICIDES UPON RYE GERMINATION AT FOUR
SOIL DEPTHS FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Germination at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	90.00	92.50	85.00	80.00
Diphenamid	4	77.50	80.00	85.00	82.50
Amchem D-263	3	82.50	85.00	80.00	87.50
EPTC	6	87.50	87.50	85.00	80.00
Trifluralin	1	75.00	82.50	87.50	95.00
LSA .05		NS	NS	NS	NS

TABLE IX
EFFECT OF SELECTIVE HERBICIDES UPON OAT GERMINATION
AT FOUR SOIL DEPTHS FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Germination at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	77.50	85.00	77.50	65.00
Diphenamid	4	82.50	85.00	75.00	77.50
Amchem D-263	3	85.00	67.50	72.50	80.00
EPTC	6	65.00	47.50	62.50	75.00
Trifluralin	1	62.50	90.00	75.00	80.00
LSD .05		NS	22.70	NS	NS
LSD .01		NS	31.90	NS	NS

TABLE X
EFFECT OF SELECTIVE HERBICIDES UPON CRIMSON CLOVER
GERMINATION AT FOUR SOIL DEPTHS
FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Germination at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	67.60	63.30	66.70	63.30
Diphenamid	4	75.00	78.30	71.70	71.70
Amchem D-263	3	75.00	86.70	81.70	76.70
EPTC	6	51.70	71.70	70.00	73.30
Trifluralin	1	63.40	73.40	66.70	85.00
LSD .05		NS	NS	NS	NS

TABLE XI

EFFECT OF SELECTIVE HERBICIDES UPON THE FRESH WEIGHT OF RYE AT
FOUR SOIL DEPTHS FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight Per Flat at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	4.20	3.60	3.11	2.27
Diphenamid	4	3.45	3.15	2.80	2.63
Amchem D-263	3	3.25	2.76	2.21	2.55
EPTC	6	4.84	3.34	2.58	2.57
Trifluralin	1	3.98	2.72	2.26	2.49
LSD .05		NS	NS	NS	NS

TABLE XII

EFFECT OF SELECTIVE HERBICIDES UPON THE DRY WEIGHT OF RYE AT
FOUR SOIL DEPTHS FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight Per Flat at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	0.47	0.40	0.28	0.25
Diphenamid	4	0.34	0.32	0.27	0.25
Amchem D-263	3	0.40	0.24	0.19	0.23
EPTC	6	0.54	0.38	0.26	0.24
Trifluralin	1	0.34	0.27	0.15	0.24
LSA .05		NS	NS	NS	NS

TABLE XIII

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE MOISTURE OF
 RYE AT FOUR SOIL DEPTHS FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Moisture at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	88.80	88.70	90.40	88.80
Diphenamid	4	90.10	90.30	90.20	90.70
Amchem D-263	3	87.60	91.10	91.40	91.60
EPTC	6	88.80	87.80	90.00	90.10
Trifluralin	1	90.90	90.60	92.30	90.50
LSA .05		NS	NS	NS	NS

TABLE XIV
EFFECT OF SELECTIVE HERBICIDES UPON THE FRESH WEIGHT OF
OATS AT FOUR SOIL DEPTHS FIFTEEN WEEKS
FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight Per Flat at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	3.11	3.36	2.68	2.20
Diphenamid	4	3.93	2.76	1.81	1.77
Amchem D-263	3	2.92	2.22	1.83	1.92
EPTC	6	3.17	2.37	1.92	2.01
Trifluralin	1	1.81	2.47	1.82	1.39
LSD .05		NS	NS	NS	NS

TABLE XV
EFFECT OF SELECTIVE HERBICIDES UPON THE DRY WEIGHT OF
OATS AT FOUR SOIL DEPTHS FIFTEEN WEEKS
FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight Per Flat at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	0.55	0.56	0.48	0.41
Diphenamid	4	0.62	0.47	0.31	0.31
Amchem D-263	3	0.50	0.38	0.30	0.32
EPTC	6	0.50	0.42	0.37	0.35
Trifluralin	1	0.36	0.44	0.30	0.28
LSD .05		NS	NS	NS	NS

TABLE XVI

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE MOISTURE OF
OATS AT FOUR SOIL DEPTHS FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Moisture at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	81.80	83.80	82.80	81.10
Diphenamid	4	84.10	81.90	82.50	82.30
Amchem D-263	3	82.50	82.10	82.90	82.80
EPTC	6	83.80	82.20	80.50	82.20
Trifluralin	1	83.40	81.80	82.90	79.80
LSD .05		NS	NS	NS	NS

Residual Effects

General observations on cover crops seeded six weeks from herbicide treatment indicated that germination and growth of rye and crimson clover appeared normal. Oats treated with diphenamid, EPTC, and trifluralin were spindly and showed some browning at the leaf tip. Within a week from emergence, oat seedlings growing in diphenamid and EPTC treated soils overcame any apparent injury and began to grow normally. Seedlings growing in trifluralin treated soils, however, remained spindly and stunted throughout the experiment (Figure 2).

The number of dead plants (Table XVIII), percentage germination (Table XIX), and percentage moisture (Table XX) of cover crops were not effected by herbicide treatment when seeded six weeks from application. Fresh and dry weights of oats were reduced at the .05 level in soils receiving trifluralin (Table XXI). These results agree with those reported by Schweizer et al. (52) in which oats were injured up to 31 weeks from application in some soil types. Dry weights of oats (Table XXI) were also reduced at the .05 level in soils treated with Amchem D-263.

Herbicide residues did not appear to be great enough to effect weights (Table XXII), or percentage moisture (Table XXIII) of rye and crimson clover when seeding occurred at ten weeks from treatment. Tables are not included to summarize the effects of herbicides on oats ten weeks from application because several seeds were destroyed by birds after seeding and would not allow a proper evaluation. However, observations of those seeds which germinated showed some injury

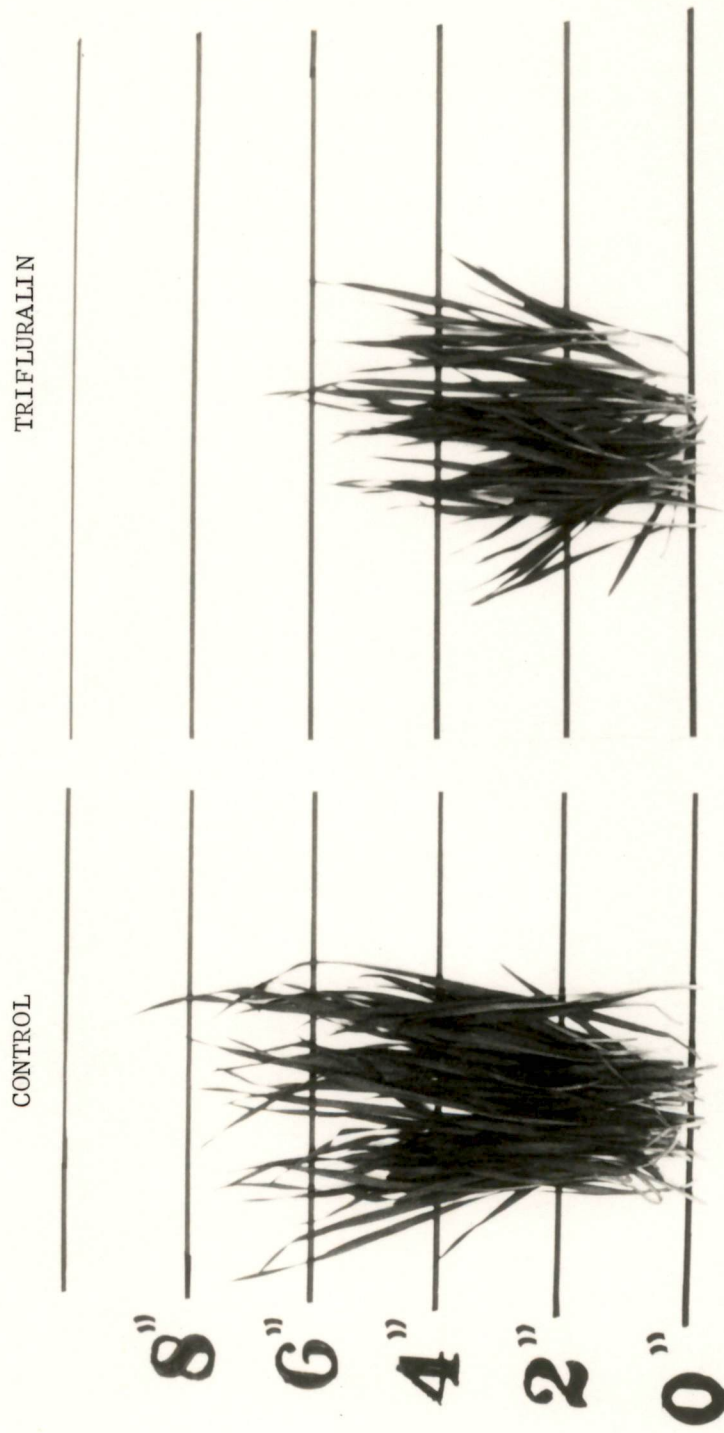


Figure 2. Effect of trifluralin on growth of oat seedlings when seeded six weeks from treatment.

TABLE XVIII

EFFECT OF SELECTIVE HERBICIDES UPON THE NUMBER OF DEAD RYE,
OATS, AND CRIMSON CLOVER SEEDLINGS WHEN SEEDED
SIX WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Mean Number of Dead Plants Per Flat		
		Rye	Oats	Crimson Clover
Cultivate	--	0.25	0.00	0.50
Diphenamid	4	0.75	0.00	0.75
Amchem D-263	3	0.75	0.25	0.75
EPTC	6	0.75	0.25	1.25
Trifluralin	1	2.00	0.00	0.75
LSA .05		NS	NS	NS

TABLE XVII

EFFECT OF SELECTIVE HERBICIDES UPON THE FRESH WEIGHT OF CRIMSON
CLOVER AT FOUR SOIL DEPTHS FIFTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight Per Flat at the Respective Soil Depth			
		0-3 Inches	3-5 Inches	5-7 Inches	7-9 Inches
Cultivate	--	10.09	12.62	10.54	9.45
Diphenamid	4	24.15	11.54	9.90	7.23
Amchem D-263	3	19.58	10.87	15.29	11.15
EPTC	6	8.88	6.88	11.19	7.94
Trifluralin	1	13.34	11.35	10.47	8.80
LSD .05		9.80	NS	NS	NS
LSD .01		NS	NS	NS	NS

TABLE XIX

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE GERMINATION OF
 RYE, OATS, AND CRIMSON CLOVER WHEN SEEDED
 SIX WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Germination		
		Rye	Oats	Crimson Clover
Cultivate	--	80.00	92.50	76.90
Diphenamid	4	75.00	92.50	68.80
Amchem D-263	3	78.10	94.10	68.10
EPTC	6	80.60	92.50	66.90
Trifluralin	1	75.00	95.00	79.40
LSD .05		NS	NS	NS

TABLE XX

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE MOISTURE
OF RYE, OATS, AND CRIMSON CLOVER WHEN SEEDED
SIX WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Moisture		
		Rye	Oats	Crimson Clover
Cultivate	--	89.00	88.60	84.80
Diphenamid	4	89.00	89.50	84.20
Amchem D-263	3	87.80	88.40	80.10
EPTC	6	88.20	88.30	83.80
Trifluralin	1	88.20	86.70	84.00
LSD .05		NS	NS	NS

TABLE XXI

EFFECT OF SELECTIVE HERBICIDES UPON THE WEIGHT OF RYE,
OATS, AND CRIMSON CLOVER WHEN SEEDED SIX WEEKS
FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight of 30 Plants					
		Rye		Oats		Crimson Clover	
		Fresh	Dry	Fresh	Dry	Fresh	Dry
Cultivate	--	16.74	1.84	7.60	0.86	3.63	0.56
Diphenamid	4	16.19	1.73	6.34	0.67	3.51	0.56
Amchem D-263	3	13.10	1.65	7.89	0.42	3.89	0.79
EPTC	6	16.33	1.93	7.95	0.92	3.36	0.55
Trifluralin	1	15.44	1.80	4.75	0.62	3.55	0.56
LSD .05		NS	NS	2.54	0.21	NS	NS
LSD .01		NS	NS	NS	NS	NS	NS

TABLE XXII

EFFECT OF SELECTIVE HERBICIDES UPON THE WEIGHT OF
 RYE AND CRIMSON CLOVER WHEN SEEDED TEN WEEKS
 FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight of 30 Plants			
		Rye		Crimson Clover	
		Fresh	Dry	Fresh	Dry
Cultivate	--	15.45	2.07	2.69	0.48
Diphenamid	4	8.24	1.29	3.35	0.47
Amchem D-263	3	13.81	1.93	3.77	0.73
EPTC	6	15.93	2.25	4.17	0.77
Trifluralin	1	12.24	1.99	4.56	0.66
LSD .05		NS	NS	NS	NS

TABLE XXIII

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE
MOISTURE OF RYE AND CRIMSON CLOVER WHEN
SEEDED TEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Moisture	
		Rye	Crimson Clover
Cultivate	--	86.70	82.00
Diphenamid	4	84.80	83.00
Amchem D-263	3	85.90	80.10
EPTC	6	85.80	81.80
Trifluralin	1	83.40	83.30
LSD .05		NS	NS

in those soils treated with diphenamid and trifluralin.

Percentage germination of cover crops (Table XXIV) was not effected by herbicidal treatment when seeding occurred fourteen weeks from application. Table XXV shows the effects of herbicides upon fresh and dry weights of cover crops when seeding occurred fourteen weeks from application. Fresh and dry weights of oats were not effected by chemical treatment, but fresh weights of crimson clover were increased in soils receiving trifluralin (Table XXV). It was thought that trifluralin may have influenced water uptake of crimson clover, but there was no difference in percentage moisture (Table XXVI), and further experiments did not indicate a continued increase in fresh weights with trifluralin treatment. Dry weights of crimson clover (Table XXV) were not effected by herbicidal treatment.

Fresh and dry weights of rye were reduced at the .01 level in soils treated with diphenamid when seeded fourteen weeks from treatment (Table XXV). Since rye was not effected by diphenamid treatment at six and ten weeks from application, it was believed that the reduction in weight occurring at fourteen weeks could, in part, be attributed to the influence of greenhouse temperatures upon the activity and the leachability of diphenamid during the experiment.

During January and February, greenhouse temperatures dropped to 40-45°F. on three occasions for periods of twenty-four to forty-eight hours each. On two occasions, night temperatures dropped to 34°F. Temperatures during March, the period in which injury occurred in rye, were maintained fairly constant at 60-70°F.

TABLE XXIV

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE GERMINATION
OF RYE, OATS, AND CRIMSON CLOVER WHEN SEEDED
FOURTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Germination		
		Rye	Oats	Crimson Clover
Cultivate	--	80.00	92.50	76.90
Diphenamid	4	75.00	92.50	68.80
Amchem D-263	3	78.10	94.10	68.10
EPTC	6	80.60	92.50	66.90
Trifluralin	1	75.00	95.80	79.40
LSD .05		NS	NS	NS

TABLE XXV

EFFECT OF SELECTIVE HERBICIDES UPON THE WEIGHT OF RYE,
OATS, AND CRIMSON CLOVER WHEN SEEDED FOURTEEN
WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Gram Weight of 30 Plants					
		Rye		Oats		Crimson Clover	
		Fresh	Dry	Fresh	Dry	Fresh	Dry
Cultivate	--	31.59	4.32	14.33	1.97	5.12	0.88
Diphenamid	4	12.68	2.19	10.49	1.41	5.92	0.93
Amchem D-263	3	26.70	3.76	13.68	1.70	5.87	0.93
EPTC	6	28.75	4.06	16.22	2.06	5.07	0.81
Trifluralin	1	37.09	4.94	8.87	1.31	10.58	1.37
LSD .05		11.95	1.17	NS	NS	3.20	NS
LSD .01		16.97	1.64	NS	NS	NS	NS

TABLE XXVI

EFFECT OF SELECTIVE HERBICIDES UPON THE PERCENTAGE MOISTURE
OF RYE, OATS, AND CRIMSON CLOVER WHEN SEEDED
FOURTEEN WEEKS FROM TREATMENT

Treatment	Rate Lb./A.	Percentage Moisture		
		Rye	Oats	Crimson Clover
Cultivate	--	86.30	86.20	82.70
Diphenamid	4	82.40	86.40	84.00
Amchem D-263	3	86.50	87.20	84.40
EPTC	6	85.80	87.30	84.10
Trifluralin	1	85.60	84.10	86.90
LSA .05		NS	NS	NS

It was also believed that diphenamid had not moved into the root zone in amounts great enough to cause rye injury during the six and ten week period, but had concentrated in the root zone at fourteen weeks. As a result of the above two factors, separate experiments were initiated to test each hypothesis.

Figure 3 shows rye grown in diphenamid treated soils which had been held for six weeks at 45°F. Emergence was delayed in flats held at 80°F. by two days, but was delayed in flats held at 45°F. by as much as four days. Seedlings growing in soil held at 45°F. eventually died.

The above results show that higher temperatures can influence the toxicity of diphenamid and may tend to explain why injury occurred when rye was seeded at fourteen weeks from treatment and not at six and ten weeks.

When temperatures are low, biological activity is reduced (38) and herbicide concentration is maintained at a high level (Table XXVII). However, the rate of plant transpiration, respiration and herbicide movement in the soil is reduced. As a result, diphenamid absorption and metabolism is reduced and less injury could occur to rye seedlings. When temperatures become optimum, absorption and metabolism of diphenamid is increased and injury results even though diphenamid concentration is reduced (Table XXVII). The results shown are supported by those reported by Behrens (8), Dubey et al. (19), and Sheets (56).

Observations of experiments to test diphenamid movement into the root zone did not indicate any appreciable difference in emergence and growth of rye at any soil depth tested.

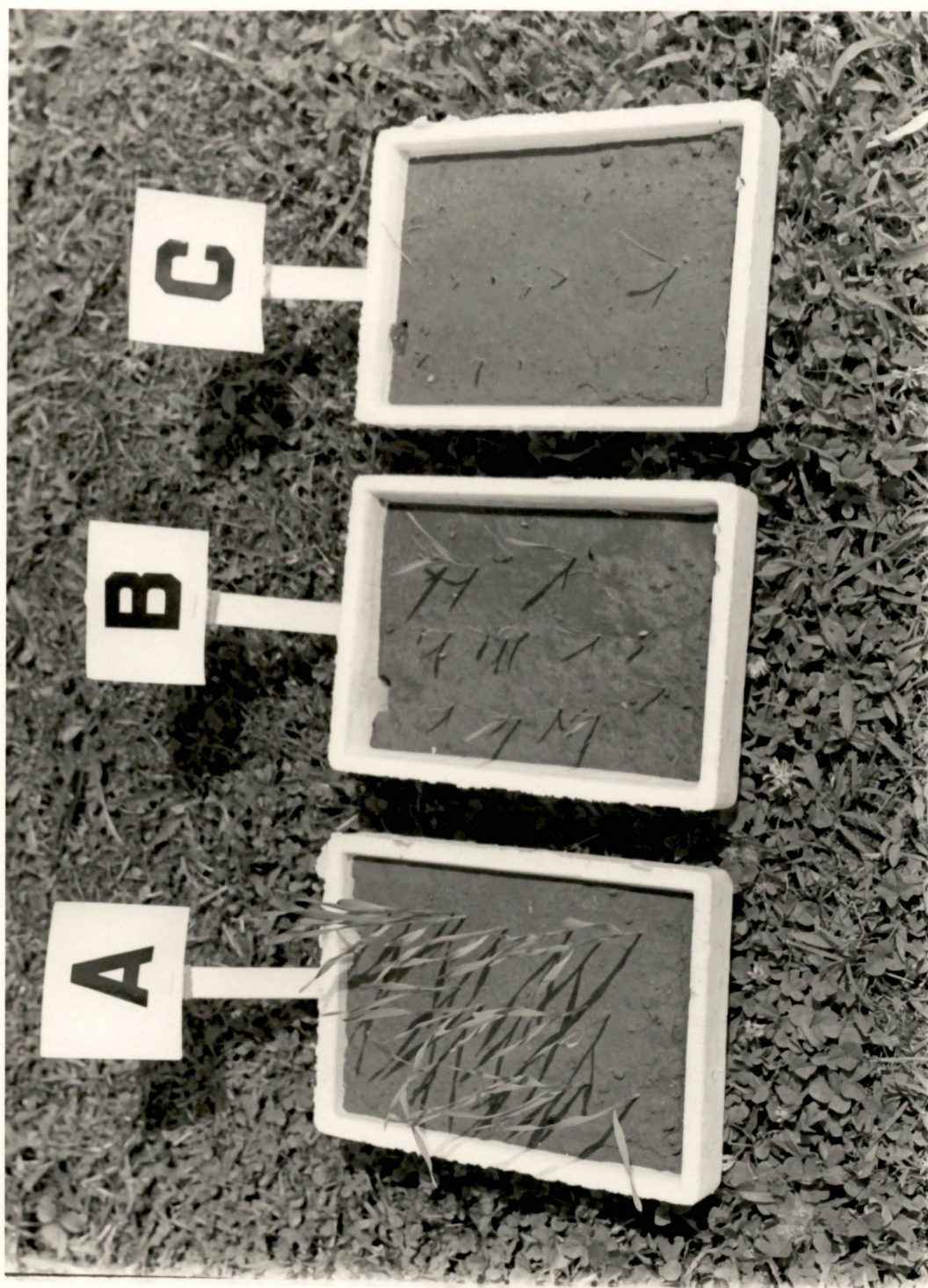


Figure 3. Effect of holding diphenamid treated soils for six weeks at extreme temperatures on the growth of rye. A = control; B = 80°F.; C = 45°F.

TABLE XXVII

SOIL CONTENT OF DIPHENAMID, GREENHOUSE TEMPERATURE, AND
RYE INJURY AT SIX, TEN, AND FOURTEEN WEEKS
FROM TREATMENT

Time from Application (Weeks)	Diphenamid Parts Per Million	Temperature Range Degrees F.	Rye Injury ¹
6	0.75	45-55	8.00
10	0.80	45-55	9.00
14	0.67	60-70	4.00

¹ 0 = complete kill.

10 = no effect.

Table XXVI, page 52, shows that herbicide treatment did not influence the percentage moisture of either rye, oats, or crimson clover when seeded fourteen weeks from herbicide treatment. Mineral content of rye (Table XXVIII) was not influenced by herbicide treatment.

In general, EPTC resulted in the longer lasting weed control of any herbicide used while Amchem D-263 appeared to lose its effectiveness after about five weeks. None of the herbicides used showed residual activity great enough to impair the growth and development of rye, oats, or crimson clover in field or greenhouse leaching experiments at the time of fall seeding.

Amchem D-263 showed some residual activity, but was least effective in providing satisfactory weed control. EPTC appeared to cause a browning of oat leaf tips when seeding was done six weeks from application, but this effect disappeared within a week from emergence.

Trifluralin and diphenamid appeared to impair the growth of oats and rye respectively in the greenhouse residue experiment. Oat injury with trifluralin occurred at six weeks after application but was not apparent at ten weeks. Diphenamid activity at fourteen weeks from application appears to have been strongly influenced by greenhouse temperatures.

TABLE XXVIII
EFFECT OF SELECTIVE HERBICIDES UPON ASH CONTENT
OF RYE PLANTS SEEDED FOURTEEN WEEKS FROM
HERBICIDE APPLICATION

Treatment	Rate Lb./A.	Per Cent Ash
Cultivate	--	14.78
Diphenamid	4	14.94
Amchem D-263	3	15.18
EPTC	6	14.38
Trifluralin	1	14.60
LSD .05		NS

CHAPTER V

SUMMARY

The persistence of four selective herbicides in a Whitwell loam soil were studied during 1965 and 1966 on The University of Tennessee Plant Science Farm in Knoxville. The study was initiated to: (1) determine the effects of these four herbicides upon the growth and development of fall seeded cover crops; (2) determine at the time of fall seeding whether the herbicides had accumulated in concentrations great enough to impair cover crop growth in various layers of the top nine inches of soil; and (3) to determine the time necessary for complete loss of herbicidal toxicity to the cover crops tested. Rye, oats, and crimson clover were used as indicator crops.

Cover crops were seeded in the field fifteen weeks after spring applications of the herbicides. Soil layers to a depth of nine inches were sampled in increments at this time and cover crop response determined in greenhouse studies. The growth of cover crops was also determined when seeded 6, 10, and 14 weeks after application of the herbicides.

The study showed Amchem D-263 to be least effective in weed control and less injurious to the cover crops than any of the herbicides used throughout the experiment. Chemical treatment did not appear to affect field growth of cover crops. However, EPTC appeared to cause

some injury to oats at the three to five inch depth and at six weeks from application. Diphenamid and trifluralin did not appear to have any influence on the growth of cover crops in the field or at any soil depth tested.

In determining the time necessary for loss of herbicidal toxicity, the study showed trifluralin to be injurious to oats at six weeks but not at ten or fourteen weeks. Diphenamid toxicity was not apparent at six and ten weeks, but was very noticeable in rye at fourteen weeks. This appeared to be related to soil temperature previous to seeding.

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