CHEMICAL CONTROL OF WILD GARLIC (*Allium vineale* L.) IN WINTER WHEAT (*Triticum aestivum* L.) AND THE MOVEMENT AND METABOLISM OF AN EFFECTIVE HERBICIDE 2-METHOXY-3, 6-DICHLOROBENZOIC ACID (DICAMBA)

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This is to certify that the

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Chemical Control of Wild Garlic (Allium vineale L.)
in Winter Wheat (Triticum aestivum L.) and the
Movement and Metabolism of an Effective Herbicide
2-Methoxy-3,6-Dichlorobenzoic Acid (Dicamba)

presented by

Larry K. Binning

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ABSTRACT

CHEMICAL CONTROL OF WILD GARLIC (Allium vineale L.) IN WINTER WHEAT (Triticum aestivum L.) AND THE MOVEMENT AND METABOLISM OF AN EFFECTIVE HERBICIDE 2-METHOXY-3,6-DICHLOROBENZOIC ACID (DICAMBA)

By

Larry K. Binning

Wild garlic (Allium vineale L.) is a problem in winter wheat. The aerial bulbils, of the same size and weight as the wheat kernel, are difficult to remove from the harvested grain and reduce wheat quality due to the garlicky odor. Studies were undertaken to find effective control measures for wild garlic in winter wheat and to determine the effect of herbicides on the wild garlic plants.

Wild garlic was controlled with an application of 0.25 lb/A of 2-methoxy-3,6-dichlorobenzoic acid (dicamba) plus 0.5 lb/A of 2,4-dichlorophenoxyacetic acid low volatile ester (2,4-D LVE). This treatment reduced scape production and caused bulb shrinkage. Application at the resumption of spring growth of the wheat was effective in wild garlic control, but caused wheat injury. The

fully tillered stage of wheat growth was the safest time to apply the treatment.

Laboratory results indicated that the bulbs and bulbils acted as metabolic sinks during development. Application timed to correspond to the development of these structures was most effective. Movement of ^{14}C labeled dicamba in the wild garlic plants was toward these areas. Dicamba moved in the xylem and the phloem with xylem movement being much faster than movement in the phloem. More dicamba moved into the plant from leaf treatment than from treatment on the scape. The maximum amount of labeled material was found in the plant 7 days after treatment. Herbicide concentration in the plant decreased 1 month after treatment which was possibly due to volatilization and/or decarboxylation of dicamba. Pretreatment of the plants with 2-chloroethanephosphonic acid (ethrel) prior to treatment with dicamba caused a reversal of dicamba movement. Ethrel possibly stimulated the lower bulb area and caused it to become an active metabolic sink.

Wild garlic does not degrade dicamba rapidly. Seven days after treatment there was no apparent metabolism, however, after 1 month of exposure to dicamba there was some metabolism, but the parent compound accounted for most of the radioactivity.

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INTRODUCTION

Wild garlic (Allium vineale L.) is an immigrant to the United States from the European Continent where it has been a problem for centuries. It was introduced into the United States in the mid Seventeenth or early Eighteenth Century, probably in crop seed (14). Extensive areas of the United States, primarily east of the Mississippi River, are infested with the plant which causes major problems in small grain and pasture production. The offensive odor caused by allyl sulfide in wild garlic can be imparted to plant and animal products making them undesirable.

Wild garlic is a problem in wheat production in Michigan. Aerial bulbils which are of the same size and weight as wheat kernels are produced on scapes that stand as tall as wheat. The weight and size of the bulbils and height of the scapes make field separation in the threshing process difficult and drying is required to shrink the bulbils to facilitate separation.

Wild garlic does not present a severe problem in other crops, but will reproduce and remain a problem when wheat is grown again in the rotation.

Cultural control is not totally effective. Successful herbicide treatments must reduce scape production and cause bulbil shrinkage. Recommended herbicides will not eliminate the problem or approach the 100% control necessary in wheat.

The objectives of this study were to find effective control measures for wild garlic, and to determine the translocation, sites of accumulation, and the metabolism of an effective herbicide.

LITERATURE REVIEW

Wild garlic plants are of two types, scapigerous, or seed stalk producing, and nonscapigerous, or vegetative. Four bulb types are formed by these plants; scapigerous plants producing soft offsets, hard-shelled and aerial bulbils, nonscapigerous plants producing a central bulb, and hard-shelled offsets. Soft offsets or central bulbs are produced 1 per plant, hard-shelled bulbs several, and aerial bulbils 50-200 per plant (10, 11, 12).

In wheat, aerial bulbils cause the immediate problem in the production year. Hard-shelled bulbs may remain dormant in soil up to 6 years. Wild garlic seed production in Michigan is not a problem (12, 31).

Most bulbs germinate in the fall of the year and complete growth in spring with maturation in July. Some aerial bulbs may germinate in spring. Scapigerous plants arise primarily from central or soft offsets, some from hard-shelled bulbs, and rarely from aerial bulbils (23, 25).

Wild garlic is not a serious competitor with crop plants (17). Lazenby (16) in his work noted that plant competition reduced production and establishment of wild garlic. High fertility and coarse soil tilth may also reduce growth of wild garlic plants (16). Lazenby also found that bulbs placed at the surface of the soil did not produce plants as well as those that were buried to moderate depths, with the exception of hard-shelled bulbs which germinated best at the soil surface. Bulbs have the capacity to produce plants when buried deep in the soil. Soft offsets and central bulbs emerge 60% of the time from a 16-inch depth (18). Hard-shelled bulbs buried below 8 inches will remain dormant and aerial bulbs do not consistently emerge from more than 4 inches (18).

In a cultivation study by Lazenby (19), fall cultivation did little to reduce the total production of wild garlic plants. Cultivation buried the vegetative portions of the plant and caused a delay in plant maturity. Spring cultivation caused the greatest reductions in plant numbers and weight.

Wild garlic bulbs when uprooted have been shown to redistribute stored reserves from the main bulbs to offsets which could remain viable for 5-6 months (20). Lazenby (21) indicated that cutting to remove topgrowth reduced production, but did not kill the plants, although it could eliminate aerial bulbil production.

Cultural control was implemented by deep plowing fall and spring in an effort to bury as many bulbs as possible (32). Scape production decreased with depth of planting or burying, although plants still survived vegetatively. Spring tillage caused serious damage to the garlic population. Row crop production added to vegetative destruction (32).

2,4-Dichlorophenoxyacetic acid (2,4-D) has been the most effective herbicide for garlic control (13). Populations have been reduced, but not eliminated, by using 1 lb/A. 2,3,6-Trichlorobenzoic acid (2,3,6-TBA) was found to be more effective by Davis et al. (9) in reducing bulb production than 2,4-D. Davis et al. (11) also found that 2,3,6-TBA caused greater morphological effects on wild garlic bulbs, such as necrosis, softening, and bulb shrinkage than 2,4-D. 2-Methoxy-3,6-dichlorobenzoic acid (dicamba) used at relatively high rates has also been effective. Repeated applications of herbicides in spring and fall over a period of years have caused greater reductions of stand than single applications (1, 15). Klingman (15) found that a fall application was most effective in arresting bulb production. Hard-shelled bulbs were not affected by repeated treatment unless they were induced to germinate (1). Treatment to cause germination

induction may be possible. Beasley (2) found that rhizome buds on Johnsongrass were induced to germinate by a 2-chloroethanephosphonic acid (ethrel) treatment.

Herbicide uptake, movement, and metabolism have been affected by the physiological state of the plant and external conditions which might contribute to this state (28, 30). Sargent (29), using 2,4-D as an example, found that young tissue was much more susceptible to herbicide entry than old tissue. Water stress enhanced 2,4-D uptake. Wetting agents and high temperature also increased uptake. The data of Sargent (28) showed that low pH increased foliar uptake, indicating that ionic and nonionic molecules of herbicide entered the plant. The pH effect was greater in the light than in the dark, indicating both physical and active uptake of herbicide molecules. Inhibition of plant metabolism caused alterations in the uptake rate, indicating active uptake. Typical 2,4-D foliar entry into susceptible species, as indicated by Blackman (3), proceeded rapidly at first, stopped after about 2 hours, and reverted out of the plant tissue by the end of 24 hours. Saunders (30) showed that in resistant species uptake continued in a linear fashion. If weak auxin-type herbicides were applied to susceptible species, uptake was linear. Wheat is a 2,4-D tolerant

species and uptake continues in a linear fashion over time. This linear uptake by resistant species is probably related to some form of detoxification of the parent herbicide molecule. Examples would be glucoside formations, conjugations to some sugar molecule, removal of functional groups from the parent molecule to make it less toxic, or the addition of some functional group to the parent molecule for the same purpose (30). Dicamba is included in the class of auxin-type herbicides where uptake and movement in plants were shown to be somewhat similar to 2,4-D. Dicamba moved freely in the xylem and phloem tissues (8). The physiological state of the plant determined the type of movement (22).

Quimby's work (27) indicated that dicamba was effective in wild buckwheat control at 0.25 lb/A applied at the 2 leaf stage. In this trial, wheat was in the 2-4 leaf stage of growth at the time of treatment. Species tolerance or susceptibility was related to uptake and subsequent metabolism of a compound (27). Wheat was found to metabolize dicamba at a significantly higher rate than wild buckwheat.

Wheat was found by Broadhurst (4) to metabolize dicamba to 5-OH-dicamba as do many of the resistant plant species. After 18 days, all of the original ^{14}C dicamba was converted to the metabolite. Some metabolism by wild buckwheat to salicylic acid was noted by Quimby (26), but very little, if any, to 5-OH-dicamba. Chang (6) found the major metabolite in tartary buckwheat to be 5-OH dicamba, but only 13% of the total label was the metabolite after 40 days of exposure. Metabolism, therefore, proceeds at a relatively slow rate in this susceptible species. Most of this metabolite was isolated from the plant as a conjugate with a sugar molecule.

Magalhaes (22), working with purple nutsedge and ^{14}C labeled dicamba, found that movement depended on numerous factors. The light regime under which the plants were grown greatly altered the distribution in the plant. Under low light, ^{14}C dicamba was uniformly distributed throughout the topgrowth. The physiological stage of the plant also caused various distribution patterns. If the plants had seed heads, the movement of label was primarily to the seed head area. Vegetative and actively growing plants exhibited an even distribution of label throughout the upper leaves. This indicated that if an active metabolic sink existed, translocation proceeded in that direction.

Purple nutsedge is a dicamba-susceptible species and metabolism of dicamba could not be observed in this species. The parent compound was the only material recovered in the extractions. In exudation studies, the parent compound was observed to be exudated.

Chang (5), working with Canada thistle, found dicamba movement to be primarily toward the leaf tips. Accumulation increased in the younger tissue. Metabolism proceeded at a low rate so that 54 days after treatment, 37% was found in a form other than free dicamba. This may have been a conjugate of the parent compound. Substantial amounts of free dicamba still remained. Decarboxylation did take place, but very slowly. After 54 days of exposure, about 8% of total radioactivity was collected as $^{14}CO_2$. Chang (6) in his work also found a small amount of CO_2 produced in buckwheat, but it proved to be an insignificant amount.

MATERIALS AND METHODS

Field and laboratory studies were initiated in the fall of 1965 and continued into 1969.

The field studies were conducted in southwestern Michigan on a silt loam soil. Four hundred and fifty lb/A of a 5-20-20 fertilizer was applied prior to sowing and 30 lb/A of N as ammonium nitrate was topdressed in spring. Wheat (Triticum aestivum L.), variety Genesee, was sown for fall and spring treatment with a six-foot grain drill. Plots were laid out for 2 experiments. The first was a rotation study using 12 by 50 foot plots with 3 replications in a randomized block design. The treatments as active material in lb/A were: 0.25 of dicamba plus 0.50 of 2,4-D low volatile ester (LVE); 1.0 N-oleyl-1,3-propylenediamine salt of 2,4-dichlorophenoxyacetic acid (2,4-D oil soluble amine); 0.125 4-amino-3,5,6-trichloropicolinic acid (picloram); and 0.50 dicamba.

Treatments were applied to wheat at the fully tillered stage with a tractor-mounted boom-type plot sprayer in 23 gallons of water at 30 psi. The same

treatments were also applied after corn harvest and prior to soybean planting on the same plots in subsequent years over the rotation period. In addition, the corn and soybeans were treated with recommended herbicides at the time of planting and cultivated as required for row crop production. Wheat plots were rated visually for control and injury. Yield data was collected as a measure of crop injury and scape counts were made at harvest to determine the level of control. Yield data and scape counts were obtained from the 5 center rows of each plot.

The second experiment with wheat was a timing and screening study. Fall and spring applications were made on separate plots replicated 3 times in a randomized block design. The plots were 7 by 25 feet. Yield and scape counts were taken as above. The treatments as active material in lb/A were: 0.125 picloram; 0.50 dicamba, 0.50 2,3,6-trichlorophenylacetic acid (fenac); 1.0 2,4-D oil soluble amine; 1.0 2,4-D LVE; 1.0 2,3,6-TBA; 0.25 dicamba plus 0.50 2,4-D LVE; 0.25 fenac plus 0.50 2,4-D LVE; 0.25 2,3,6-TBA plus 0.50 2,4-D LVE; 0.25 dicamba plus 0.25 fenac; 0.125 picloram plus 0.25 dicamba; and no treatment.

An experiment was started on fallow soil using increased rates of herbicides applied spring and fall on separate plots in a randomized block design replicated 3 times. The plots were 6 by 25 feet and scape counts were taken as a measure of control.

The treatments as active material in lb/A were: 0.25 picloram; 1.0 dicamba; 0.50 dicamba plus 1.0 2,4-D LVE; 1.0 fenac; 0.50 fenac plus 1.0 2,4-D LVE; 1.0 2,3,6-TBA; 0.50 2,3,6-TBA plus 1.0 2,4-D LVE; 2.0 2,4-D oil soluble amine; 2.0 2,4-D LVE; 3.0 2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine (atrazine); and no treatment.

In 1967, the rotation study was continued with corn as the second crop in the rotation. Picloram was discontinued due to lack of control and crop tolerance. The remaining treatments applied after corn harvest were the same as the 66 spring rotation treatments on wheat. Atrazine at 2 lb/A was used to control broadleaf weeds in the corn.

A time of application study was initiated on wheat in the fall of 1966. The plots were 6 by 30 feet and arranged in a split plot design with 4 replications. Treatment times corresponded to the following stages of wheat growth:

Fall treatments:

1. Two leaf stage.
2. Completion of fall growth.

Spring treatments:

3. Resumption of spring growth, early April.
4. Fully tillered stage, 6-8 inches in height.
5. Late tiller, early boot stage.
6. Late mature stage - 10 days prior to harvest.

The treatments applied at the above times as active material in lb/A were: 1.0 2,4-D LVE; 0.50 dicamba; 0.25 dicamba plus 0.50 2,4-D LVE; 0.25 fenac plus 0.50 2,4-D LVE; 0.50 dicamba plus 0.50 2,4-D LVE; 0.75 dicamba; and no treatment. Yield data was taken to measure crop injury and scapes were counted as an indication of control. In addition, bulbil weight per scape was recorded to determine the degree of control.

Sterilant plots were established in 1966 and rated for 2 years visually to determine the effectiveness of various herbicides on eradication of garlic. These plots were 12 by 50 feet and replicated twice. Garlic control was determined by a 0-10 rating scale, 0 being no control and 10 being complete kill.

The treatments as active material in lb/A were: 10.0 2,3,6-TBA; 1.0 picloram; 10.0 atrazine; 10.0 2-chloro-4,6-bis(ethylamino)-s-triazine (simazine); 20.0 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron); 6.0 dicamba; 2.0 3-amino-1,2,4-triazole (amitrole) plus 10.0 simazine; 10.0 5-bromo-3-sec-butyl-6-methyluracil (bromacil); 0.50 picloram; 10.0 fenac; 8.0 2,6-dichlorobenzonitrile (dichlobenil); 2.0 3-tert-butyl-5-chloro-6-methyluracil (terbacil); 4.0 terbacil; 8.0 dichlobenil incorporated; and no treatment.

In 1967 wheat was planted in the fall for an evaluation of spring treatments and timing of spring treatments. Fall applications were dropped because of extensive crop injury. The plots were 6 by 30 feet in a randomized complete block design with 4 replications. The times of treatment were as follows:

1. Resumption of active spring growth.
2. Fully tillered stage.

The treatments as active material in lb/A were: 1.0 2,4-D LVE at the fully tillered stage; 0.50 dicamba plus 0.50 2,4-D LVE at growth resumption; 0.50 dicamba plus 0.50 2,4-D at the fully tillered stage; 0.25 dicamba plus 0.50 2,4-D LVE at growth resumption; 0.25 dicamba plus 0.50

2,4-D LVE at the fully tillered stage; 0.25 dicamba at growth resumption plus 0.50 2,4-D LVE at the fully tillered stage; and no treatment.

Yield data was recorded for crop injury and bulbil weight per scape recorded as degree of control.

The rotation study was continued in 1968. Rotation treatments were applied prior to preparing the soil for soybean planting. These treatments were the same as those applied after corn. The soybean variety Chippewa 64 was used. Two pounds of 3-amino-2,5-dichlorobenzoic acid (amiben) plus 1.0 pound of 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea (linuron) were applied per acre for broadleaf weed control.

Wheat was planted in the fall of 1968 on the rotation area again to complete the rotation. Harvest data will be taken at maturity.

Protein content of the wheat treated with various herbicides was determined by the micro-kjeldahl method (24). This method was later correlated with the Udy Protein Analyzer[1]. Further testing of protein content in subsequent years used the latter method. Baking quality tests were made by the Soft Wheat Quality Laboratory at Wooster, Ohio.

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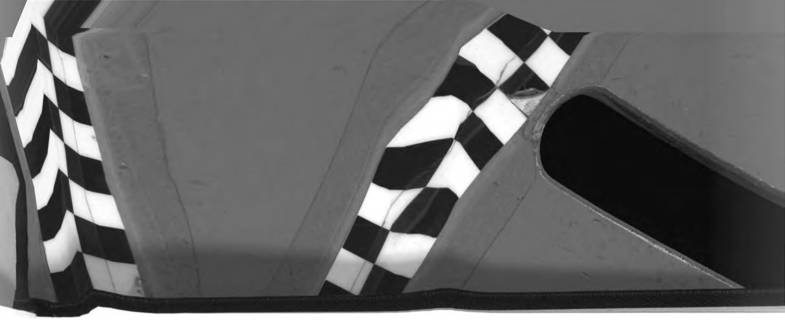
[1] Udy Analyzer Company, Boulder, Colorado.



Experiments using ^{14}C labeled dicamba were begun in 1968 with wild garlic plants and bulbs dug from the field. The ^{14}C labeled dicamba (2-methoxy-3,6-dichlorobenzoic acid) was labeled in the carboxy carbon and obtained from the Velsicol Chemical Corporation. The specific activity was 1.8 μc per μm. The plants used were grown in the greenhouse. Those plants that produced scapes were separated and used in the first experiment. The experiment was arranged so that one-half of the plants would be treated on the youngest fully-developed leaf and one-half would be treated on the scape. All plants were treated on the same day, and about at the time of bursting of the spathes, or umbel enclosure. The treatment rate was 0.1 μc of ^{14}C dicamba per plant applied in 10 μl of solution. The solution contained 0.1% of X77 as a spreader since wild garlic has a waxy cuticle. This was applied to an area approximately 1.5 cm by 0.2 cm which was bounded by a lanolin enclosure. The plants in each series were allowed to continue growth for 1, 2, 7, and 30 days after treatment. At these respective times, duplicate plants were harvested from each series. These plants were washed free from the soil, frozen immediately in dry ice, and freeze dried, a procedure outlined by Crafts and Yamaguchi (7).

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In the second experiment, only vegetative plants with germinated offsets were used. Rate of treatment was the same as above. Only 1 series was involved since the plants were all vegetative. They were harvested and handled as the above series. These plants were grown in a growth chamber with a 16 hr day at 21 C.

A plant that was in an immature stage of growth was treated and prepared as above to determine movement at this stage. The plant was grown for 7 days and freeze dried.

A study was initiated to determine whether root exudation occurred. Two plants were placed in each of two 300 ml erlenmeyer flasks and 250 ml of Hoagland's No. II nutrient solution was added. The solution was aerated with a porous clay aerator and the air pumped by a small diaphragm circulating pump. The experiment was done in the growth chamber with a 16 hr day at 21 C. Treatment was made on 1 of the plants in each flask. The remaining plant was the check plant. These were allowed to grow for 10 days and were then harvested and freeze dried.

One remaining labeling study was conducted with plants treated with ethrel to determine if herbicide movement patterns could be changed by the chemical alteration of plant metabolism.

Six plants were pretreated with ethrel at a concentration of 1000 ppm. This solution was sprayed on the plant to the point of runoff. Seven days after ethrel treatment, they were treated with the standard ^{14}C dicamba treatment of 0.1 μc in 10 μl of solution. Duplicates were then harvested at 2 and 7 days after treatment. At each time 1 plant not treated with ethrel, but treated with ^{14}C dicamba, was harvested as a check. These plants were then frozen in dry ice and later freeze dried.

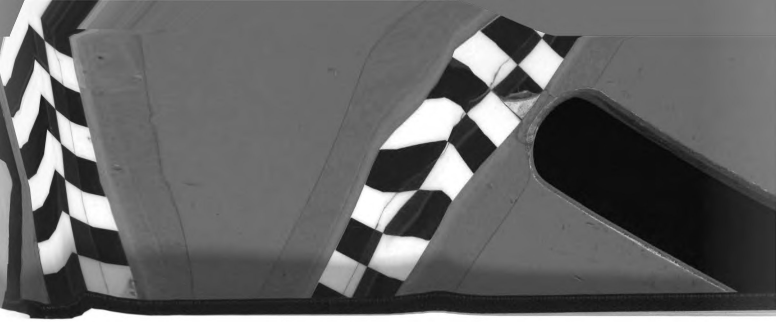
In all of the above ^{14}C labeling experiments after the plants were freeze dried they were prepared for autoradiography. The plants were remoistened in a humidity chamber for flexibility. They were then mounted on blotter paper and held in place with a casein glue. The mounts were air dried and pressed against masonite to get a flat surface for good contact with X-ray film. After being pressed, the mounts were placed in cassettes with no screen X-ray film and exposed for 15 days. After exposure, the film was developed by standard developmental procedures (7).

Qualitative data on the plant metabolism of dicamba was obtained by hot ethanol extraction for chromatographic analysis, the remainder hydrolyzed with 4.0 M HCL to break any glucoside linkages that might have been formed as done

by Broadhurst et al. (4). The hydrolysate was then extracted with chloroform and the aqueous phase discarded. These extracts were then chromatographed on microcrystalline cellulose thin layer plates in solvent systems of butanol, ammonia, and water in the proportions of 8:1:1 (v/v/v) and in butanol, ethanol, and water in proportions of 2:1:1 (v/v/v). Autoradiograms of these plates were made in the first experiments and in subsequent experiments the plates were scraped into vials in 1 cm segments per vial and counted in a liquid scintillation counter. The scintillation solution contained 0.3 g of dimethyl POPOP, 5.0 g of PPO per liter of toluene.

Quantitative data was obtained by separating the plants into 3 portions, foliage, treated area, or area of application of ^{14}C labeled dicamba, and the root system.

The portions were then ground in a Wiley mill through a 40 mesh screen. A sample of this ground material was then combusted in an oxygen atmosphere (Schoeninger combustion technique) and the carbon dioxide collected in a solution of ethanol amine plus absolute ethanol in a ratio of 1:2 (v/v). An aliquot of this was removed and counted (33).



RESULTS AND DISCUSSION

The rotation study indicated that picloram used at .125 lb/A did not control garlic and was injurious to wheat (Table 1). Dicamba at 0.5 lb/A did not cause a wheat yield reduction, although changes in plant structure were observed. Garlic control was not adequate to avoid dockage. 2,4-D oil soluble amine at 1 lb/A did not reduce yield or cause any noticeable effects on wheat, but control was again not adequate. Dicamba at 0.25 lb/A plus 2,4-D LVE at 0.5 lb/A gave the best results of these treatments. Bulbil weights were not taken in this study. From observations made at the time of harvest, the dicamba plus 2,4-D combination caused a greater amount of bulbil shrinkage than all other treatments. There was an 83% reduction in scape production. This, coupled with the shrinkage, made the treatment adequate.

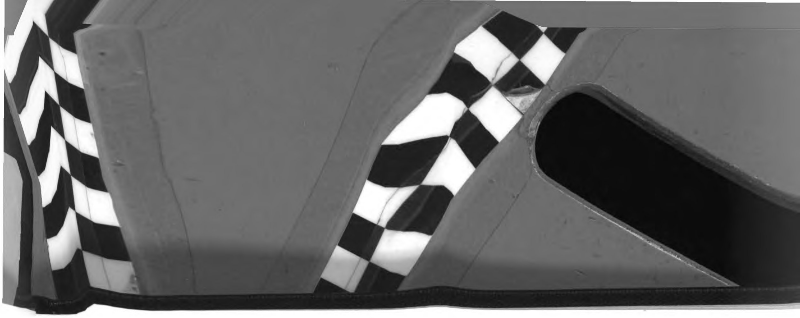


Table 1.--Wild garlic control and wheat yield from 4 herbicide treatments applied in the spring, 1966.

Herbicide	Rate Lb/A	Yield Bu/A	Scape[2] Reduction, %
Dicamba + 2,4-D LVE	0.25 + 0.50	48 a[1]	83
Dicamba	0.50	46 ab	67
2,4-D Oil Soluble Amine	1.0	43 bc	54
Picloram	0.125	32 d	39
No Treatment	-	43 bc	-

[1]Means followed by different letters are significantly different at the 5% level.

[2]The control contained 22,400 scapes/A.

There was only a slight yield reduction of wheat for some fall treatments (Table 2). This was mainly due to cold weather which stopped any further growth and resulted in reduced injury to the crop. The fall application of dicamba plus 2,4-D LVE was effective, but not as effective as spring application. Bulbils from plants that escaped fall treatment were observed to be plumper than those that escaped spring treatment.

Table 2.--Wild garlic control and wheat yield from fall application of herbicides in 1965.

Herbicide	Rate Lb/A	Yield[1] Bu/A	Scape[2] Reduction, %
Picloram	0.25	36 e	100
Dicamba	0.50	49 abc	98
Picloram + Dicamba	0.125 + 0.25	43 bcd	98
Picloram	0.125	43 bcd	97
2,3,6-TBA + 2,4-D LVE	0.25 + 0.50	41 de	95
Dicamba + 2,4-D LVE	0.25 + 0.50	46 abcd	91
2,3,6-TBA	0.50	46 abcd	89
2,4-D LVE	1.0	40 de	86
Dicamba + Fenac	0.25 + 0.25	52 a	86
2,4-D Oil Sol-uble Amine	1.0	42 cde	70
Fenac + 2,4-D LVE	0.25 + 0.50	44 abcd	59
Fenac	0.50	50 ab	42
No Treatment	-	43 bcd	-

[1]Means followed by different letters are significantly different at the 5% level.

[2]The control contained 23,000 scapes/A.

The most effective spring treatment was the combination of dicamba plus 2,4-D LVE (Table 3). This treatment resulted in a 98% reduction in scape production and the bulbils that remained were shrunken. Without shrinkage of bulbils, control was not considered adequate.

The stand of wild garlic in all of the plot areas was a natural stand. In some cases, the check value from fall application of herbicides on fallow soil (Table 4) is lower than some treated plots. This was due to stand variation. Stimulation by herbicide treatment did not seem probable. Dicamba plus 2,4-D LVE was the most effective treatment. 2,4-D LVE was almost as effective as the dicamba plus 2,4-D LVE combination, as indicated by scape number, but those plants that escaped 2,4-D injury produced well formed bulbils. Atrazine had no effect on wild garlic.

Spring application of atrazine, as fall application, had no effect on garlic (Table 5). Dicamba plus 2,4-D LVE gave the best control of wild garlic. Dicamba alone at 1 pound also gave adequate control.

The results from this series of experiments indicated that the combination of dicamba plus 2,4-D LVE was as effective or more effective than either herbicide alone. The combination was better than all other

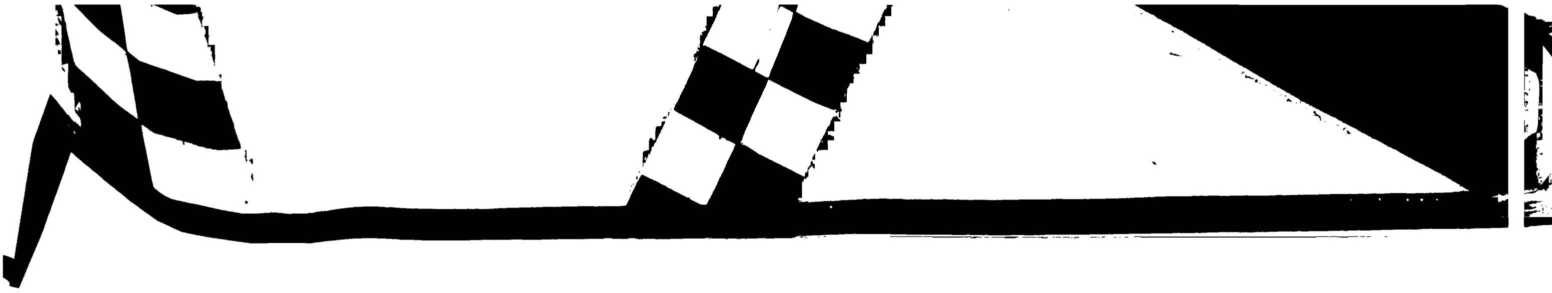


Table 3.--Wild garlic control and wheat yields from spring application of herbicides in 1966.

Herbicide	Rate Lb/A	Yield[1] Bu/A	Scape[2] Reduction, %
Dicamba + 2,4-D LVE	0.25 + 0.50	44 ab	98
Fenac + 2,4-D LVE	0.25 + 0.50	47 a	93
2,4-D Oil Soluble Amine	1.0	37 bc	91
2,4-D LVE	1.0	41 ab	90
Picloram	0.125	23 d	86
Picloram	0.25	17 d	83
2,3,6-TBA + 2,4-D LVE	0.25 + 0.50	42 ab	80
Dicamba	0.50	40 abc	78
Picloram + Dicamba	0.125 + 0.25	33 c	74
Dicamba + Fenac	0.25 + 0.25	41 ab	72
2,3,6-TBA	0.50	45 a	44
Fenac	0.50	45 a	40
No Treatment	-	42 ab	-

[1]Means followed by different letters are significantly different at the 5% level.

[2]The control contained 22,500 scapes/A.

Table 4.--Wild garlic control from fall application of herbicides on fallow soil in 1965.

Herbicide	Rate Lb/A	Scape[1] Reduction, %
Dicamba + 2,4-D LVE	0.50 + 1.0	98
2,4-D LVE	2.0	96
Dicamba	1.0	71
2,3,6-TBA + 2,4-D LVE	0.50 + 1.0	61
2,3,6-TBA	1.0	55
2,4-D Oil Soluble Amine	2.0	45
Fenac	1.0	0
Fenac + 2,4-D LVE	0.50 + 1.0	0
Picloram	0.25	0
Atrazine	3.0	0
No Treatment	-	-

[1]The control contained 12,200 scapes/A.

Table 5.--Wild garlic control from spring application of herbicides on fallow soil in 1966.

Herbicide	Rate Lb/A	Scape[1] Control, %
Dicamba + 2,4-D LVE	0.50 + 1.0	98
Dicamba	1.0	96
Fenac + 2,4-D LVE	0.50 + 1.0	94
2,4-D LVE	2.0	85
Picloram	0.25	79
2,4-D Oil Soluble Amine	2.0	68
2,3,6-TBA	1.0	42
2,3,6-TBA + 2,4-D LVE	0.50 + 1.0	17
Atrazine	3.0	4
Fenac	1.0	0
No Treatment	-	-

[1]The control contained 27,100 scapes/A.

herbicides used, if the visual observation on bulbil shrinkage was included in the evaluation.

These results led to time of application studies with the most effective herbicides from the screening studies, and various rates of dicamba combined with 2,4-D LVE (Table 6). The 2-4 leaf stage of wheat growth was chosen because of wheat tolerance to dicamba at this time. Results from the previous year indicated that control without wheat injury could be attained by late fall treatment. The second application was made at the completion of fall growth. Neither fall application was satisfactory. At the 2-leaf stage, the wheat plants were tolerant to the herbicides, but control was poor. The reverse was true of late fall treatment. The late fall treatment corresponded to the time of application in the previous year which was successful. The variation in results may have been due to weather conditions after treatment. Growing conditions were favorable after treatment in 1966 and crop injury was high. Fall treatments were not considered feasible since weather conditions after late treatment were too critical for consistent results and early fall treatment was ineffective.

Treatments applied at the resumption of spring growth did not give adequate control (Table 7). Wheat

Table 6.--Wild garlic control and wheat yield from herbicide applications made at 2 stages of wheat growth in the fall of 1966.

Herbicide	Rate Lb/A	2-4 Leaf Stage of Growth: Wheat[1] Bu/A Yield	2-4 Leaf Stage of Growth: Scape[2] Control %	2-4 Leaf Stage of Growth: Wt. Grams Per Head	Completion of Fall Growth Stage: Wheat Bu/A Yield	Completion of Fall Growth Stage: Scape Control %	Completion of Fall Growth Stage: Wt. Grams Per Head
2,4-D LVE	1.0	30 e	0	1.86 a	16 d	87	.78 a
Dicamba	0.50	39 ab	0	1.53 a	33 b	47	1.86 a
Dicamba + 2,4-D LVE	0.25 + 0.50	33 de	0	1.63 a	24 c	47	1.68 a
Fenac + 2,4-D LVE	0.25 + 0.50	36 abcd	0	1.37 a	24 c	60	1.21 a
Dicamba + 2,4-D LVE	0.50 + 0.50	35 bcde	47	1.70 a	26 c	80	1.74 a
Dicamba	0.75	38 abc	0	1.36 a	25 c	80	1.40 a
No Treatment	-	39 a	-	1.20 a	39 a	-	1.20 a

[1]Means in the same column followed by different letters are significantly different at the 5% level.

[2]The control contained 9,000 scapes/A.

Table 7.--Wild garlic control and wheat yields from herbicide applications made at 4 stages of wheat growth in the spring of 1967.

		Resumption of Growth[1]			Fully Tillered[2]		
Herbicide	Rate Lb/A	Wheat[3] Bu/A Yield	Scape[4] Control %	Wt. Grams Per Head	Wheat Bu/A Yield	Scape Control %	Wt. Grams Per Head
2,4-D LVE	1.0	39 a	87	0.82 a	39 a	93	2.21 c
Dicamba	0.50	37 a	53	1.65 a	39 a	73	0.41 ab
Dicamba + 2,4-D LVE	0.25 + 0.50	37 a	60	0.80 a	39 a	87	0.40 ab
Fenac + 2,4-D LVE	0.25 + 0.50	39 a	7	1.37 a	40 a	67	0.87 abc
Dicamba + 2,4-D LVE	0.50 + 0.50	37 a	73	0.35 a	38 a	93	0.01 a
Dicamba	0.75	35 a	73	0.52 a	38 a	93	0.05 ab
No Treatment	-	39 a	-	1.20 a	39 a	-	1.20 bc

[1]Resumption of growth corresponded to the time in the spring when wheat resumed active growth.

[2]The fully tillered stage of growth was at the 6-8 inch stage of development.

[3]Means followed by different letters are significantly different at the 5% level.

[4]The control contained 9,000 scapes/A.

Table 7.--(Continued)

Herbicide	Rate Lb/A	Late Fully Tillered Early Boot: Wheat Bu/A Yield	Late Fully Tillered Early Boot: Scape Control %	Late Fully Tillered Early Boot: Wt. Grams Per Head	10 Days Prior to Harvest: Wheat Bu/A Yield	10 Days Prior to Harvest: Scape Control %	10 Days Prior to Harvest: Wt. Grams Per Head
2,4-D LVE	1.0	37 ab	93	0.70 a	35 b	13	1.06 a
Dicamba	0.50	34 b	29	0.83 ab	36 ab	0	1.07 a
Dicamba + 2,4-D LVE	0.25 + 0.50	37 ab	80	1.79 ab	36 b	0	0.63 a
Fenac + 2,4-D LVE	0.25 + 0.50	35 b	27	1.23 ab	35 b	33	0.83 a
Dicamba + 2,4-D LVE	0.50 + 0.50	36 ab	93	0.56 b	35 b	0	0.52 a
Dicamba	0.75	35 b	73	0.59 b	33 b	0	1.00 a
No Treatment	-	39 a	-	1.20 ab	39 a	-	1.20 a

yields were reduced on the average from check yields. The best control occurred with dicamba plus 2,4-D LVE at 0.5 lb/A of each.

Treatments applied to wheat at the fully tillered stage resulted in the highest wheat yield and best wild garlic control. Some changes in the wheat plant caused by rates of dicamba above 0.25 lb/A were observed, but these did not affect yield. Dicamba plus 2,4-D LVE combination at 0.5 pound of each per acre gave the best control.

Dicamba at 0.75 lb/A effectively controlled garlic, but damaged wheat plants. These treatments caused only slight yield reduction. The dicamba plus 2,4-D LVE combination at the 0.25 plus 0.50 lb/A rate was the best treatment for consistent control with minimum crop injury. 2,4-D LVE applied at the fully tillered stage did not adequately control garlic when considering bulbil weight per scape. The garlic scapes that were formed after 2,4-D LVE treatment appeared to be normal. This was not true when dicamba was included in the treatment.

When the treatments were applied at the late tiller-early boot stage, more injury to wheat was noticeable and control was not adequate. The herbicide treatments performed as they had at the resumption of spring growth.

The last time of treatment in this experiment was 10 days prior to harvest. At this time, shrinkage of the aerial bulbs occurred, but was not apparent from the data. The bulbs had been formed at the time of treatment. The herbicides caused a fusion of the bulbs at the base of the umbel and a softening of the bulb.

The shrinkage was severe enough so that field separation of the aerial bulbils in the threshing process was possible. It was not a feasible treatment unless emergency conditions prevailed since physical damage to the crop during application caused a substantial yield loss.

These results indicated that spring application gave the most consistent wild garlic control. The resumption of spring growth and the fully tillered stage of wheat were the most favorable times for treatment. The 0.25 pound of dicamba plus 0.50 pound 2,4-D LVE combination gave the most consistent results when considering yield and control.

In 1968, only 2,4-D LVE and dicamba were used because of the degree of effectiveness observed in previous experiments (Table 8). Time (E) in the table corresponds to the stage at which wheat is most tolerant to dicamba and time

Table 8.--Wild garlic control and wheat yields from herbicide applicat[illegible]

Table 8.--Wild garlic control and wheat yields from herbicide applications made at times in the spring of 1968.

Herbicide	Rate Lb/A	Time of Application	Wt/ Garlic Hd Grams	Scape[1] Control %	Wheat Yield Bu/A
2,4-D LVE	1.0	L[2]	0.00	100	34.0 cd[4]
Dicamba + 2,4-D LVE	0.50 + 0.50	E[3]	0.00	100	36.0 bcd
Dicamba + 2,4-D LVE	0.25 + 0.50	L	0.00	100	33.0 cd
Dicamba + 2,4-D LVE	0.25 + 0.50	E L	0.00	100	40.0 ab
Dicamba + 2,4-D LVE	0.50 + 0.50	L	1.55	83	32.0 d
Dicamba + 2,4-D LVE	0.25 + 0.50	E	0.40	75	38.0 abc
Dicamba	0.75	E	0.64	33	35.0 bcd
Dicamba	0.50	E	1.05	-	38.0 abc
No Treatment	-	-	1.11	-	43.0 a

[1]The control contained 7,200 scapes/A.

[2]Designates the fully tillered or 6-8 stage of growth.

[3]Designates the resumption of spring growth or beginning of active spring growth of wheat.

[4]Means followed by different letters are significantly different at the 5% level.

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(L) most tolerant to 2,4-D LVE. One combination treatment was split, the dicamba applied early and the 2,4-D late. This treatment gave the best wild garlic control with minimum wheat injury. It involved two spray applications and for this reason was less desirable than single applications. The late application of this combination gave excellent control, but wheat injury was observed. If the same treatment was applied early, control was not as good, but yield of wheat was not reduced severely. Wheat had more tolerance to 2,4-D LVE applied early than it had to dicamba applied late. A single application was considered most favorable due to convenience, cost of application, and low crop value. It was, therefore, better to apply the combination at either the resumption of spring growth of wheat or at the fully tillered stage.

Results from sterilant plots to determine if eradication in non-crop areas was feasible indicated that of the 13 treatments applied, bromacil at 10 lb/A was the only compound giving complete control after 2 years of observation. Picloram at 1 lb/A and fenac at 10 lb/A gave 85% control and 2,3,6-TBA at 10 lb/A gave 50% control. Terbacil and dichlobenil produced changes in plant form, but did not remove the plants. All other treatments failed to produce a response that was apparent through visual ratings.

The results of laboratory analysis for protein content of wheat by the micro-kjeldahl method and the Udy method indicated that herbicide treatment had only a slight effect on wheat quality. From 2 years of analysis, only the wheat from the picloram treatment was significantly higher in protein content. Picloram treated wheat was of the poorest baking quality, but was still acceptable. Wheat quality was not significantly affected by herbicide treatment. Yield was the most important criteria for selection of herbicides to be used on wheat.

Changes in wild garlic morphology from dicamba were visibly greater than where other treatments were used. It has been shown that wheat is capable of metabolizing dicamba (4, 26, 27). Since dicamba was found to be effective in wild garlic control and could be metabolized by wheat, it was of interest to determine the movement and metabolism of this herbicide in wild garlic.

The plants used here had produced scapes and bulbils and were in the final stages of development. At this stage, the bulbils provided an excellent sink for photosynthates. Dicamba ^{14}C movement was in the direction of these aerial bulbils. Both xylem and phloem movement was noted from autoradiograms of these plants. Xylem l

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movement appeared to be much faster than phloem movement. The basal bulbs were not labeled. Growth of these bulbs was completed at the time of treatment; therefore, they did not act as metabolic sinks.

Two series of plants are shown. The first series was treated on the scape, Figures I and II, and the second on the youngest fully extended leaf, Figures III and IV. Observations on these plants indicated that after 1 day, treatment on the scape was more effective in translocation of dicamba to the aerial bulbils. After 7 days of treatment, little difference was noted. This occurred because both xylem and phloem movement carried dicamba to the aerial bulbil area. When the leaf was treated, phloem movement was primarily responsible for the initial movement out of the treated leaf. Once out of the treated leaf, dicamba could be swept up the xylem to the aerial bulbils. When treatment was made directly on the scape, the xylem transport was in a direct manner, from the treatment spot to the bulbil area. The difference between scape and leaf treatment could not be detected on the autoradiograms after 1 month of exposure.

Results from the next experiment were obtained using vegetative plants that had germinated offset plants growing attached to the basal bulb area (Figures V and VI).

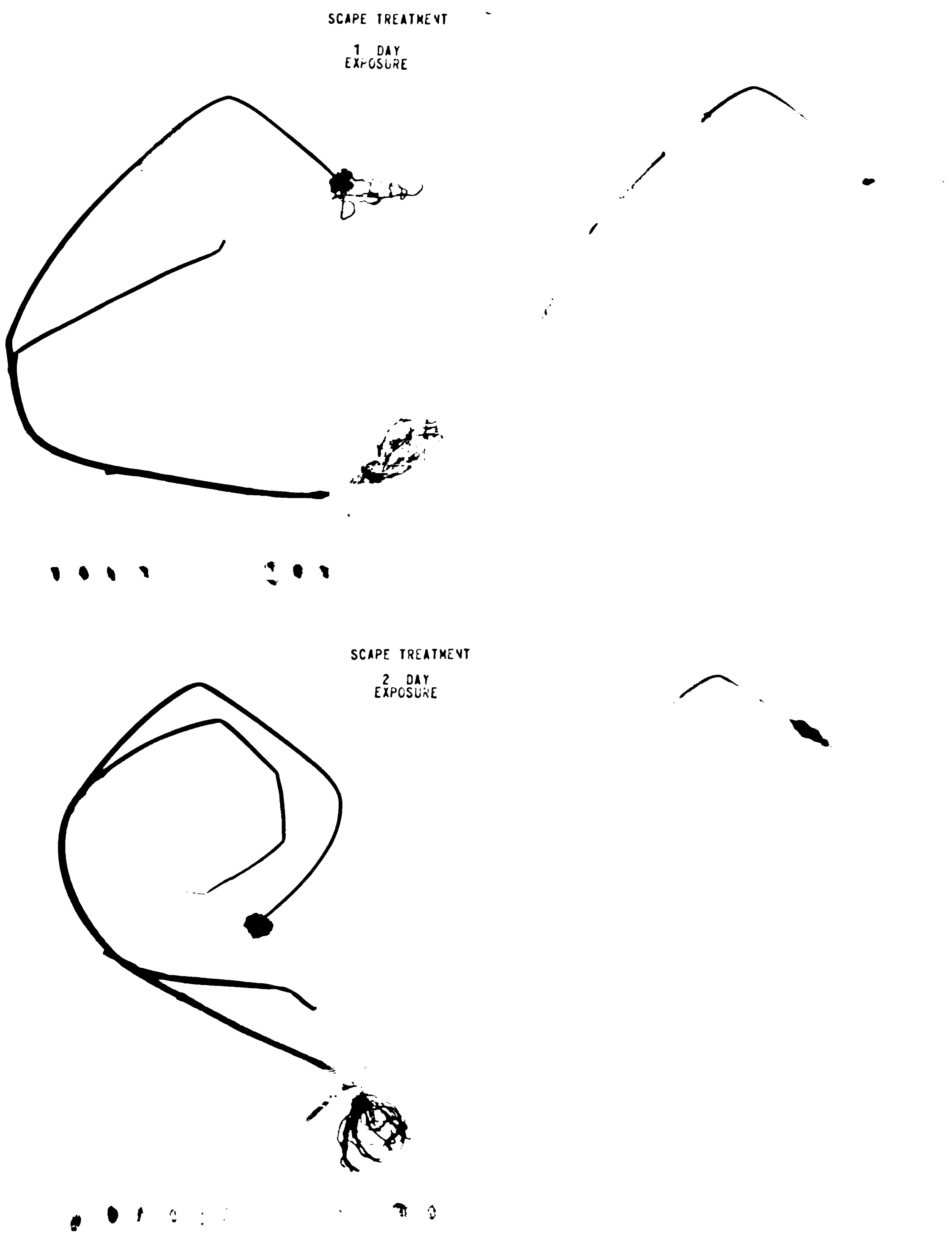

Figure I. Upper: Scape treatment with ^{14}C dicamba harvested after 1 day of exposure. Lower: Scape treatment with ^{14}C dicamba harvested after 2 days of exposure. Treated plants on the left and the autoradiograms on the right.

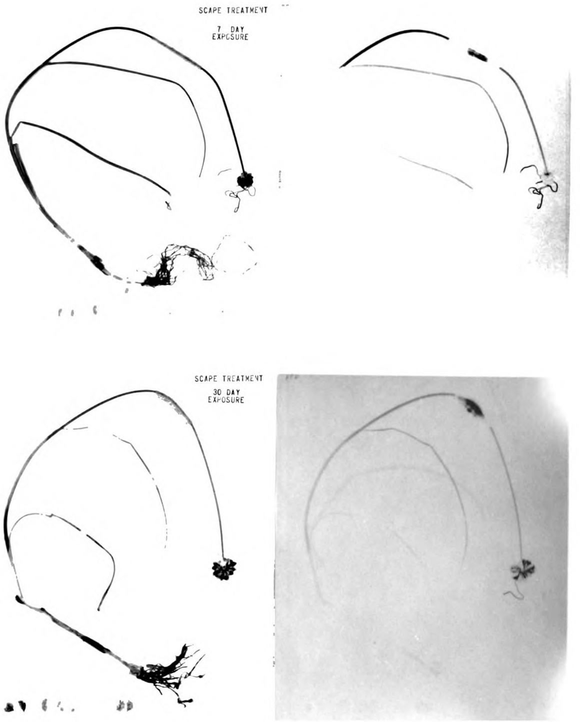

Figure II. Upper: Scape treatment with ^{14}C dicamba harvested after 7 days of exposure. Lower: Scape treatment with ^{14}C dicamba harvested after 1 month of exposure. Treated plants on the left and the autoradiograms on the right.

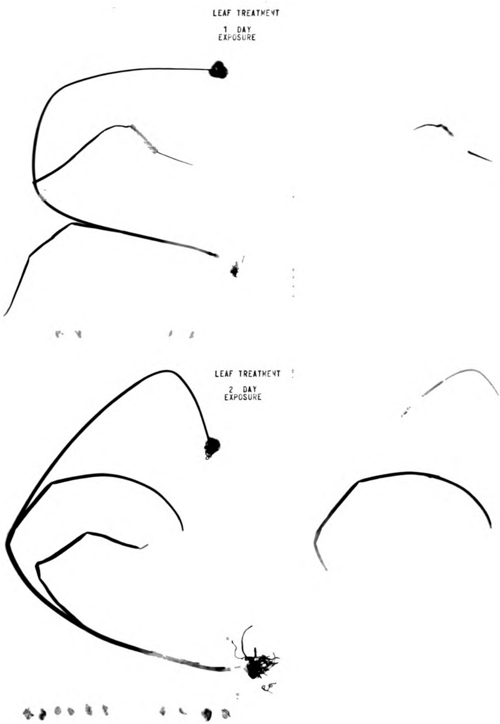

Figure III. Upper: Leaf treatment with ^{14}C dicamba harvested after 1 day of exposure. Lower: Leaf treatment with ^{14}C dicamba harvested after 2 days of exposure. Treated plants on the left and the autoradiograms on the right.

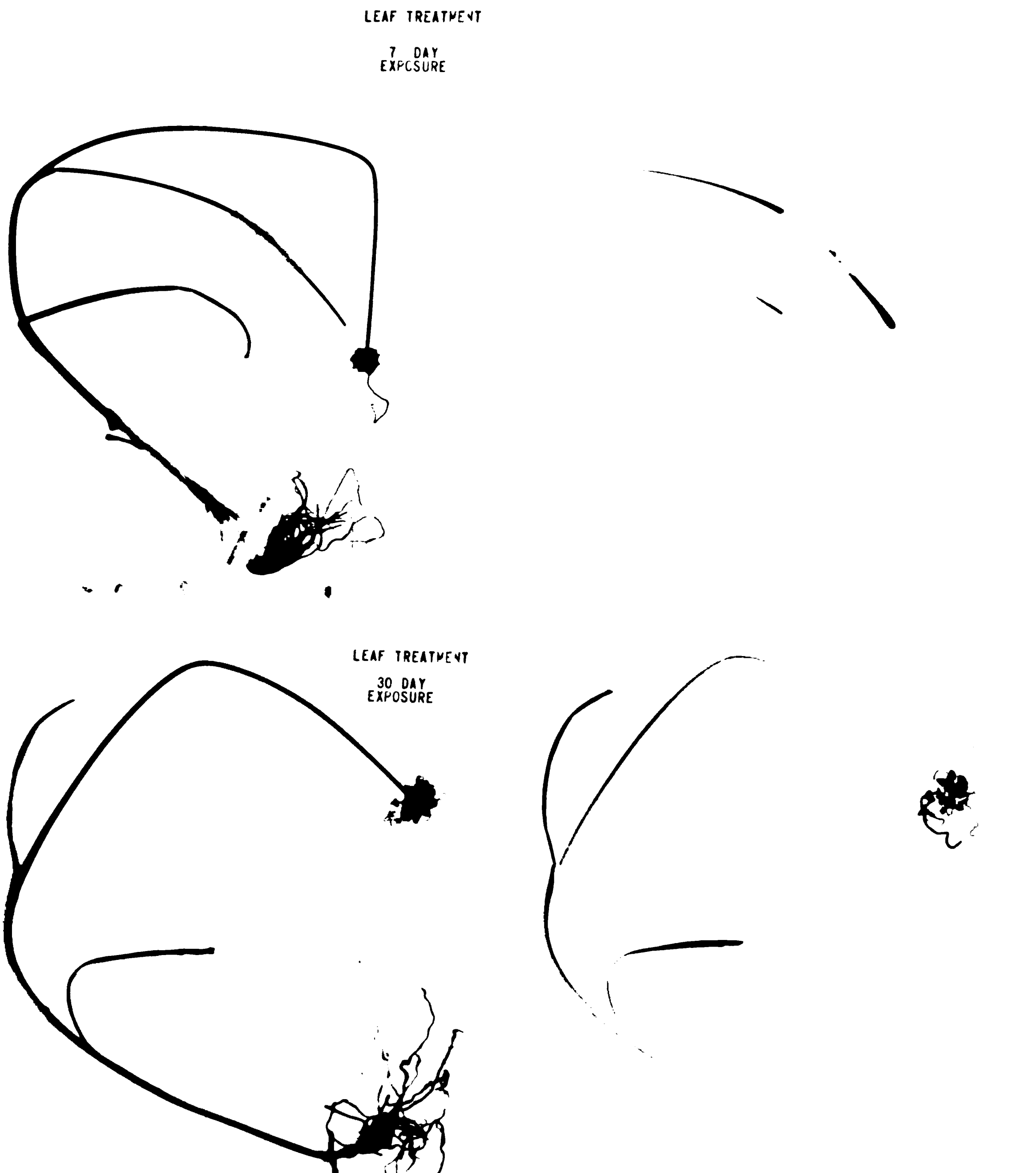

Figure IV. Upper: Leaf treatment with ^{14}C dicamba harvested after 7 days of exposure. Lower: Leaf treatment with ^{14}C dicamba harvested after 1 month of exposure. Treated plants on the left and the autoradiograms on the right.

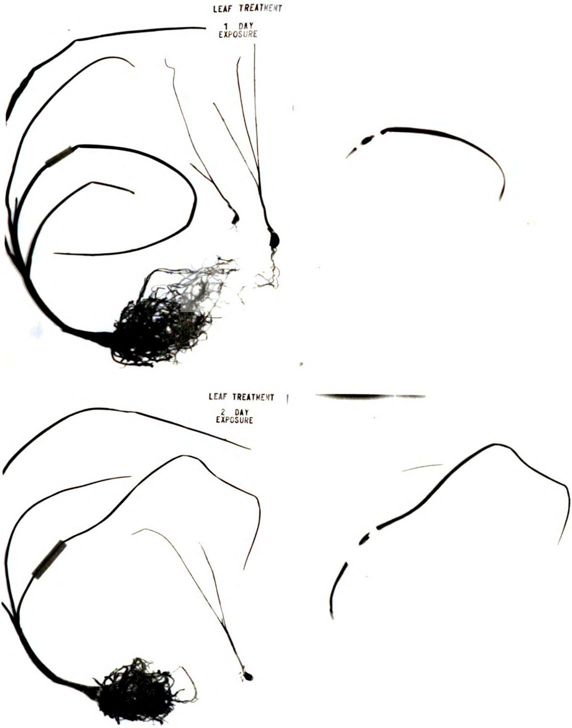

Figure V. Upper: Treatment of vegetative plant with ^{14}C dicamba harvested after 1 day of exposure. Lower: Treatment of vegetative plant with ^{14}C dicamba harvested after 2 days of exposure. Treated plants on the left and the autoradiograms on the right.

Figure VI. Upper: Treatment of vegetative plant with ^{14}C dicamba harvested after 7 days of exposure. Lower: Treatment of vegetative plant with ^{14}C dicamba harvested after 30 days of exposure. Treated plants on the left and the autoradiograms on the right.

If the basal bulbs were being set at the time of treatment, there would have been a metabolic sink similar to the aerial bulbils in the previous experiment. These plants had matured beyond the point of basal bulb development and no accumulation of herbicide was noted in the basal area. It was noted that dicamba moved from the main plant to germinated offsets. This movement was proposed to be through remaining xylem elements between the parent plant and the offset. Movement was slow as indicated by the elapsed time between treatment and appearance of dicamba in the offset plant. Movement toward the base of the plant was probably in the phloem and most of the upward movement in the xylem. The upward movement was much faster and, therefore, no accumulation occurred in the lower portion. The basal bulbs of the offsets were not acting as metabolic sinks at this time since the new growth of the offset was translocating stored reserves from the bulb to the plant.

Figure VII indicates the type of translocation of the herbicide which occurred if a plant was setting basal bulbs. An offset had also germinated from this plant. At that physiological stage, the basal storage area acted as a metabolic sink. The connection between the parent plant and the offset was still functional. The offset was actively

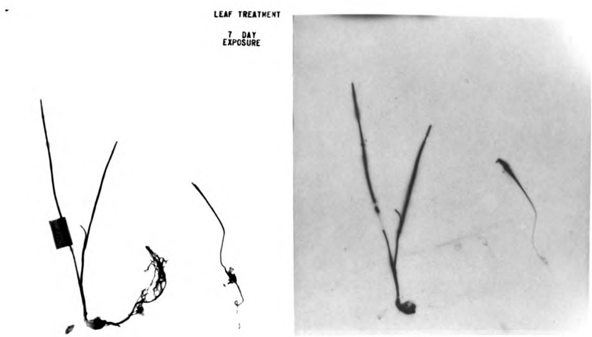

Figure VII. Treatment of a vegetative plant in an immature stage of growth. Treated with ^{14}C dicamba and harvested after 7 days of exposure. Treated plant on the left and the autoradiogram on the right.

growing and the bulb was not being filled at the time of treatment so movement was toward the leaf tip.

The results from an exudation study to determine if the label that was observed in the offset was transported through direct xylem connection or if it was exudated and taken up through the root system of the offset are shown in Figure VIII. Exudation of dicamba by wild garlic apparently was not significant. No label could be detected in the nutrient solution in which the plants were grown. These solutions were extracted and assayed for radioactivity in a liquid scintillation counter 10 days after ^{14}C dicamba treatment. The treated plant was heavily labeled and the test plant grown in the same nutrient solution was not labeled. The lower photograph is of the test plant, and the autoradiogram did not show any label. This experiment indicated that dicamba was moving through remaining xylem connections between the main plant and the offset and was not exuded and taken up through the root system of the offset.

The physiological stage of growth was the major influence on the movement of dicamba in the plant. The following experiment was done to determine if chemical induction of physiological change would cause alterations

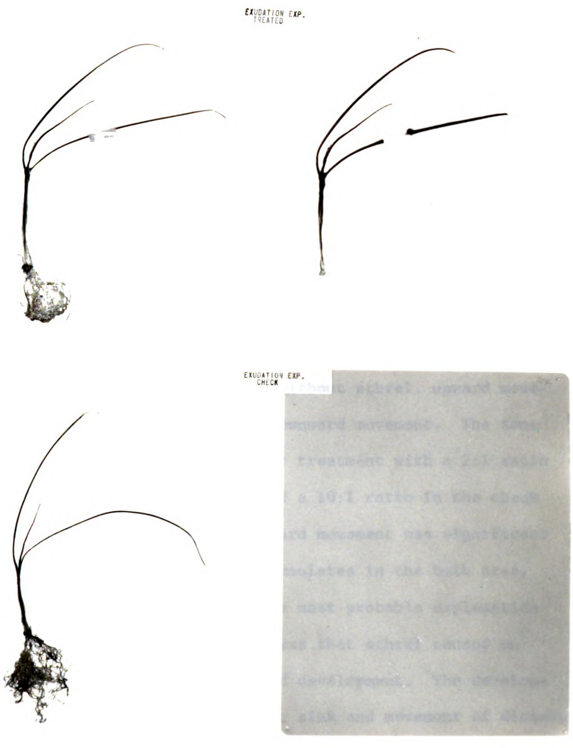

Figure VIII. Plants used in the exudation study. The upper photograph is of the treated plant and autoradiogram and the lower photograph is of the control plant grown in the same nutrient solution.

in translocation patterns. Vegetative wild garlic plants were used. They were pretreated with ethrel 7 days before dicamba application. Ethrel treatment caused an overall reversal of dicamba movement (Figures IX and X). More of the label moved downward from the dicamba treated area in the ethrel treated plants. In the untreated check, dicamba movement was toward the leaf tip.

The ratio of upward to downward movement shows that with ethrel treatment, dicamba movement is about equal in both directions from the treatment spot 2 days after treatment (Table 9). In the check without ethrel, upward movement is 8 times greater than downward movement. The same relationship holds 7 days after treatment with a 2:1 ratio in the ethrel treated plant and a 10:1 ratio in the check plant. This increase in downward movement was significant in that once the herbicide accumulates in the bulb area, the bulbs will degenerate. The most probable explanation for this reversal of movement was that ethrel caused an induction of basal axillary bud development. The developing buds constitute a metabolic sink and movement of dicamba was toward this sink. Autoradiograms of the ethrel treated plants were observed to have dicamba ^{14}C in the root system. These were the only plants in which movement into the root system was observed.

Figure IX. Upper: Dicamba ^{14}C treated plant on the left with autoradiogram on the right. Lower: Plant pretreated with ethrel 7 days prior to dicamba ^{14}C treatment. Treated plants on the left and autoradiograms on the right. Both plants harvested 2 days after dicamba treatment.

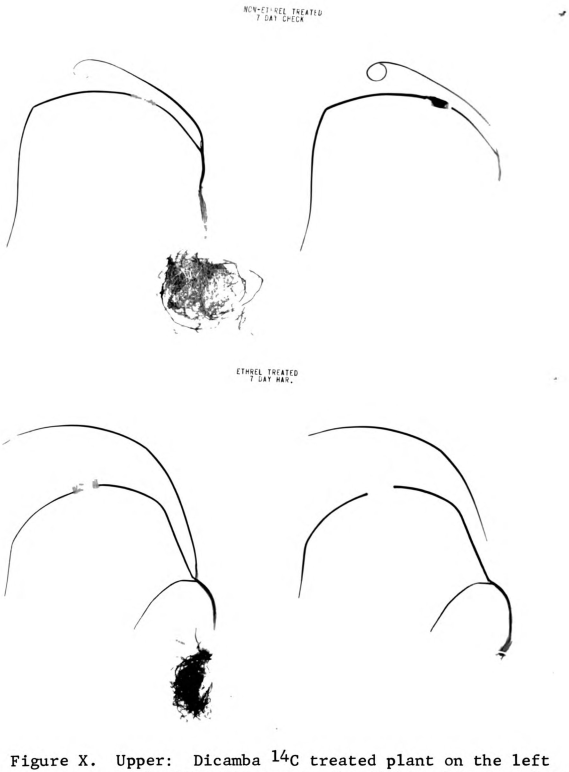

Figure X. Upper: Dicamba ^{14}C treated plant on the left with autoradiogram on the right. Lower: Plant pretreated with ethrel 7 days prior to dicamba ^{14}C treatment. Treated plants on the left and autoradiograms on the right. Both plants harvested 7 days after treatment.

Table 9.--Quantitative determination of ^{14}C dicamba movement in wild garlic pretreated with ethrel 7 days prior to dicamba application.

Treatment	Days After Dicamba Treatment	DPM/mg above Treatment Spot (A)[1]	DPM/mg below Treatment Spot (B)[2]	Ratio of A-B
Dicamba after ethrel	2	770	1,041	1:1
Dicamba alone	2	1,966	242	8:1
Dicamba after ethrel	7	3,304	1,617	2:1
Dicamba alone	7	1,248	123	10:1

[1]Determination made above the treatment spot.

[2]Determination made below the treatment spot.

In support of the movement studies, qualitative results on the metabolism of dicamba by wild garlic were obtained. Plants from the various harvest dates were extracted with ethanol and the extract chromatographed against standard compounds. The 7 day and 1 month old plants were of greatest interest. After 7 days, no dicamba metabolites could be detected. This was confirmed by autoradiography and liquid scintillation counting of chromatographed plant extracts. The extract lagged somewhat behind the dicamba standard on the chromatogram. By sequentially increasing extract concentration, the lag was found to be due to concentration of the extract. The spot appearing at a somewhat lower R_f than the dicamba standard was dicamba. Further confirmation was made by mixing standard dicamba with the extract. Only 1 spot appeared and it lagged behind standard alone. After 7 days of exposure to ^{14}C labeled dicamba, only free dicamba was observed to be present. This indicated that glucosides were not present after 7 days and that metabolites in appreciable quantities had not been formed.

Extractions were made of plants exposed to ^{14}C dicamba for 1 month. Variable results were obtained depending on the plants which were used. The greatest

In support of the movement studies, qualitative results on the metabolism of dicamba by wild garlic were obtained. Plants from [illegible] harvest dates were extracted with ethanol [illegible] chromatographed against standard compounds [illegible] 1 month old plants were of greatest [illegible] After 7 days, no dicamba metabolites could [illegible] This was confirmed by autoradiography and liquid scintillation counting of chromatographed plant extracts. [illegible] lagged somewhat behind the dicamba standard [illegible] By sequentially increasing extract concentration [illegible] was found to be due to concentration of the extract. The spot appearing at a somewhat lower R_f than the dicamba standard was dicamba. Further confirmation was made by mixing standard dicamba with the extract. [illegible] spot appeared and it lagged behind standard alone. After 7 days of exposure to ^{14}C labeled dicamba, only free dicamba was observed to be present. This indicated that glucosides were not present after 7 days and that metabolites in appreciable quantities had not been formed.

Extractions were made of plants exposed to ^{14}C dicamba for 1 month. Variable results were obtained depending on the plants which were used. [illegible] amount of label extracted in all cases was still present as dicamba. A metabolite was observed at R_f .93, when chromatographed in 8:1:1, butanol, ammonia, and water (v/v/v), from the first plants that were extracted. This peak decreased in intensity after hydrolysis, but was still present. The identity was unknown, but could possibly have been salicylic acid. From another extraction, dicamba was the main peak and accounted for most of the label (Figure XI). Acid hydrolysis caused a decrease in intensity of the peak at R_f .83. This indicated that a conjugate could have been present. Where the same extracts were enriched with dicamba standard, the main peak increased in intensity and the other peaks remained the same (Figure XII). This indicated that the main peak was dicamba. The peak at R_f .125 corresponded to 5-OH-dicamba. 5-OH-Dicamba spots were detected by iodine color development. Color development was required for the standard since ^{14}C 5-OH-dicamba was not available. When the extracts were chromatographed in 2:1:1, butanol, ethanol, and water (v/v/v), the dicamba and the 5-OH-dicamba could not be separated. An unknown peak, however, did appear and was observed to diminish when hydrolyzed. Table 10 gives the R_f values for these results.

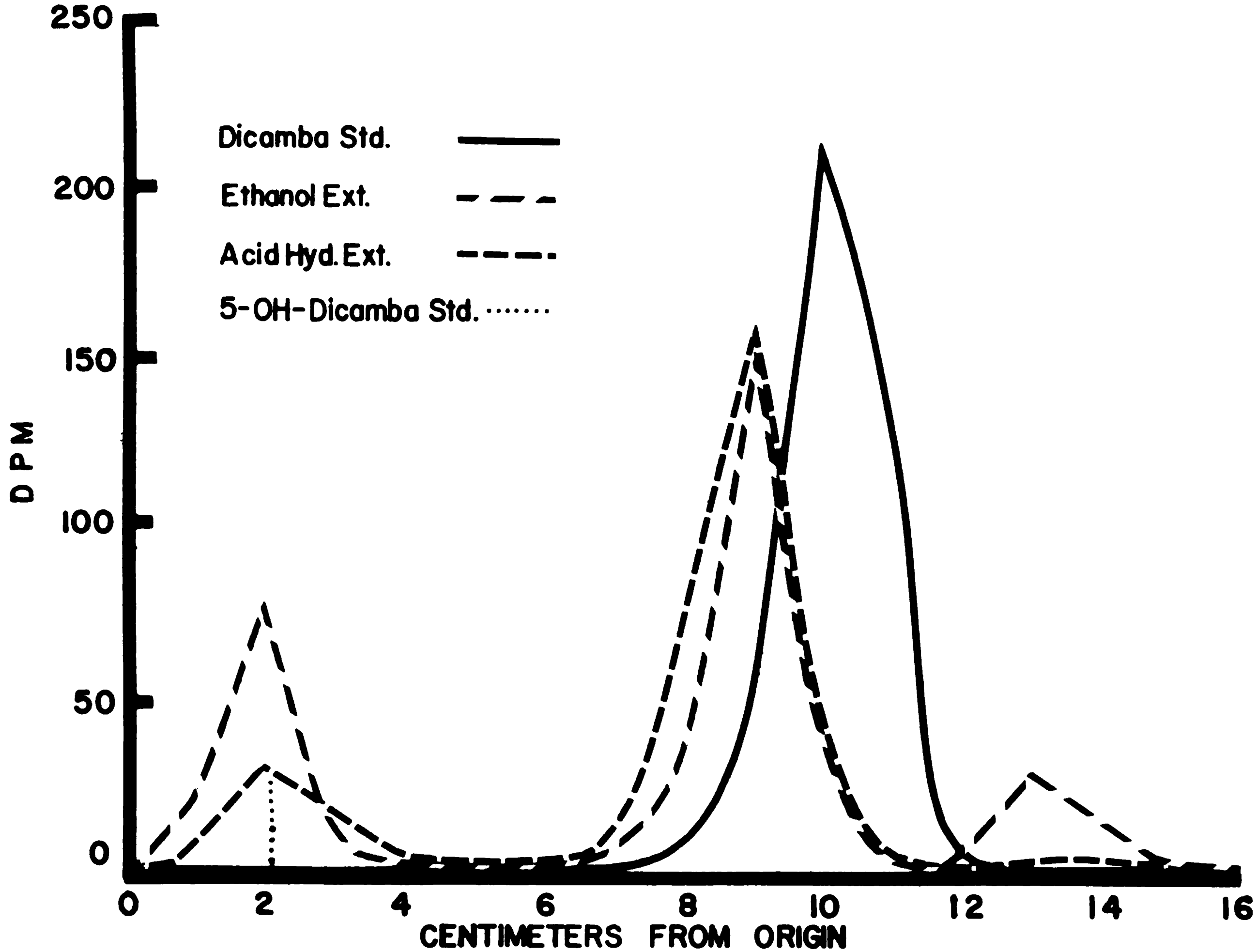

Figure XI. Scan of TLC plate developed in 8:1:1 butanol, ammonia, and water (v/v/v).

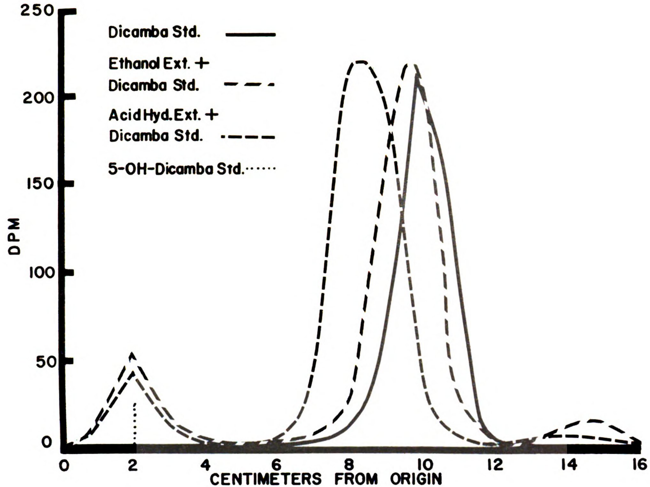

Figure XII. Scan of TLC plate with dicamba ^{14}C enriched extracts developed in 8:1:1 butanol, ammonia, and water (v/v/v).

Table 10.--R_f values for extracts and standards chromatographed in 2 solvent systems.

	Solvent System	
	A[1]	B[2]
Material	R_f Values	R_f Values
Dicamba	.88	.66
5-OH-Dicamba	.85	.13
Ethanol Extract		
Peak 1 - 5-OH-Dicamba	-	.13
2 - Dicamba	.89	.56
3 - Unknown	.55	.83
Acid Hydrolysis		
Peak 1 - 5-OH-Dicamba	-	.13
2 - Dicamba	.89	.56
3 - Unknown	-	.88

[1]2:1:1, Butanol, ethanol, and water (v/v/v).

[2]8:1:1, Butanol, ammonia, and water (v/v/v).

The discrepancy observed between plants that were exposed for 1 month may have been due to the physiological stage of development of individual plants. Dicamba remained as the main compound observed after ethanol extraction and accounted for 62% of the label. After acid hydrolysis, 84% of the recovered label was dicamba. Conjugates of dicamba plus plant constituents accounted for the increase in dicamba after hydrolysis. This indicated

that wild garlic did not have an efficient degradative system for this compound. After an extended period of time, it did metabolize dicamba; however, only a small portion of total compound present was metabolized. These results are supported by the work of Chang (5), Quimby (26,27), and Magalhaes (22) where they found that susceptible species metabolized dicamba very slowly while resistant species, such as wheat, were capable of rapid dicamba degradation.

Quantitative results from the collection of radioactive CO_2 after combustion in an oxygen atmosphere indicated that the percent of material found in the plant as compared to that which remained at the point of treatment increased with time after treatment. Seven days after treatment the maximum amount had left the treatment area. This amount varied from 70-80% with appreciable variability from plant to plant. This was attributed to the physiological state of the plant at the time of treatment. More material was translocated from the treated area when the plants were leaf treated than when they were treated on the scape. The root systems of the plants did not accumulate appreciable amounts of labeled dicamba. The maximum amount recovered from the root system of the plants was 3% (Table 11).

Table 11.--Percent distribution of recovered ^{14}C labeled dicamba from wild garlic.

Point of Application of ^{14}C Dicamba	Days After Treatment	Recovery of ^{14}C Dicamba From (%): Root	Shoot
Leaf	1	0.2	20.0
Leaf	2	0.2	68.0
Leaf	7	0.6	89.0
Leaf	30	3.0	72.0
Scape	1	0.2	43.0
Scape	2	0.2	51.0
Scape	7	0.2	21.0
Scape	30	0.2	39.4

The total percent recovered from the plants decreased with time after treatment. This was thought to be due to 2 factors, volatilization of dicamba and decarboxylation. Both processes were slow, but after 1 month could probably account for the loss of the compound from the plant. After 7 days as much as 70% of the label still remained in the plants. After 1 month, 30-50% was recovered. Considering that the major portion of the label recovered was still in the form of dicamba, an effective amount was thought to remain in the plant.

SUMMARY

Herbicides were evaluated in field studies to find effective control measures for wild garlic, a problem in winter wheat. Translocation and metabolism of dicamba in the plant were studied in the laboratory.

Wild garlic was effectively controlled in winter wheat with a treatment of 0.25 pound of 2-methoxy-3,6-dichlorobenzoic acid (dicamba) plus 0.50 pound of 2,4-dichlorophenoxyacetic acid, low volatile ester (2,4-D LVE) per acre. This treatment caused the least injury to wheat over a range of application times. The most effective times of application were at the resumption of spring growth and at the fully tillered stage. In an emergency situation application 10 days prior to harvest would permit removal of the bulbils in the threshing process. This treatment reduced wheat yield from physical damage caused by driving through the field during application. Where dicamba was used, the bulbil shrinkage was always more pronounced. Shrinkage was considered necessary if the treatment was

effective. In non-crop situations, a higher rate of a combination of dicamba plus 2,4-D LVE was effective in control. One-half pound of dicamba plus 1 pound of 2,4-D LVE/A gave 100% control when applied in the spring. The most effective sterilant treatment was 10 lb/A of 5-bromo-3-sec-bulyl-5-chloro-6-methyluracil (bromacil) which completely controlled wild garlic for 2 years.

When wild garlic is setting bulbils or bulbs these structures act as metabolic sinks to which dicamba is translocated. The translocation of dicamba to these areas caused structural changes which allowed the aerial bulbils to be removed in the threshing process. The movement of the labeled compound in the plant depended on the stage of plant development at the time of treatment. Increasing time after treatment allowed for a greater percent of the herbicide to move into the plant. The maximum amount of label was found in the plant 7 days after treatment. After 1 month, the percent recovered was less than the amount recovered after 7 days. The decrease in recovery was probably due to volatilization and decarboxylation of the compound.

Wild garlic does not effectively metabolize dicamba. Seven days after treatment, dicamba metabolites were not detected; however, after 1 month metabolites were found.

The identity of 1 of the metabolites is unknown, but could possibly have been a salicylic acid. The other metabolite was 5-OH-dicamba. Both were found in small amounts when compared to the amount of parent compound remaining in the plant. 5-OH-Dicamba was found in greater quantities than the other metabolite. A small amount of label was found in conjugation with plant products. This conjugate was hydrolyzed in a 4.0 M HCL solution. After hydrolysis the peak thought to be salicylic acid decreased in intensity.

Alteration of wild garlic metabolism with 2-chloroethanephosphonic acid (ethrel) prior to treatment with dicamba caused a reversal of dicamba translocation. The flow was now in the direction of the previously dormant basal bulbs. This was probably due to the increased metabolic activity in these bulbs caused by ethrel treatment which again made them metabolic sinks.

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