This is to certify that the

thesis entitled

Efficacy of Oxyfluorfen[2-chloro-1-(3-ethoxy-

4-nitrophenoxy)-4-(trifluoromethyl) benzene]
in Deciduous Fruit Crops
presented by

Joe M. Dolby

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Horticulture

Major professor

Date July 6, 1981

EFFICACY OF OXYFLUORFEN [2-CHLORO-1-(3-ETHOXY-4-NITROPHENOXY)-4-(TRIFLUOROMETHYL) BENZENE] IN DECIDUOUS FRUIT CROPS

By

Joe Meredith Dolby

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

1981

ABSTRACT

EFFICACY OF OXYFLUORFEN [2-CHLORO-1-(3-ETHOXY-4-NITROPHENOXY)-4-(TRIFLUOROMETHYL) BENZENE] IN DECIDUOUS FRUIT CROPS

BY

JOE M. DOLBY

Tests were conducted to establish weed control activity and selectivity of oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene] on a wide range of newly planted deciduous fruit species. Additional objectives were to establish behavior of oxyfluorfen in coarse textured soils and to determine absorption and translocation in grape (Vitis labrusca L. 'Concord') and cherry (Prunus cerasus L. 'Montmorency'). Oxyfluorfen at 4.4 kg/ha applied to the surface or incorporated in a sandy loam caused no injury to peaches (Prunus persica Batsch) grown in containers. When oxyfluorfen was surface applied at rates up to 8.8 kg/ha to newly planted peaches on a sandy loam, no injury occurred. Suckering 'Mahaleb' rootstock was treated with 4.4 kg/ha of oxyfluorfen and no top injury occurred. Oxyfluorfen applied to the surface of sandy soil did not move out of the 0-7.6cm layer, even at 4.4 kg/ha and there was no residual activity after 90 days. Cherry roots absorbed 10% ^{14}C-oxyfluorfen from nutrient solution, while grape roots absorbed 41%. Of that absorbed, only 2% was translocated. When ^{14}C-oxyfluorfen was applied to leaves and

green stems of cherry and grapes, less than 2% was absorbed with no significant translocation occurring. There was no difference between absorption by young and old leaves of cherry. These studies indicate that oxyfluorfen will be a useful new herbicide for deciduous fruits, particularly new plantings on coarse textured soils.

ACKNOWLEDGMENTS

Special appreciation is expressed to Dr. Alan R. Putnam for his guidance and assistance during my studies at Michigan State University.

My thanks are extended to Drs. William Meggit, James Clark, James Flore, Charles Laughlin, Hugh Price, Ronald Perry, Bernard Knezek, and Michael Barrett for their valuable assistance at various times during my graduate work.

I would also like to thank cooperators Dwight Brown of Lawton, Michigan and Chris Rajzer of Hilltop Nursery for their assistance with field studies.

Appreciation is expressed to Mr. William Chase and Mr. Michael Willis, and to the fellow graduate and undergraduate students, who were of great assistance during the past two years.

Support from the Rohm and Haas Company is gratefully acknowledged.

Finally, and most importantly, a very special thanks is expressed to my wife, Linda, and son, Clint, for their continuous support that has meant so much.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Growers have been battling weeds since crops were first cultivated, and the growers of deciduous fruit crops are no exception. Researchers and growers know that if new plantings are to be established properly and if desired growth is to be obtained, then weeds must be controlled.

Weeds compete for soil nutrients and water, and provide habitats for other fruit pests. Hull (28) indicated that weed competition could slow young fruit trees in reaching maximum fruiting potential and could cause trees to fail to develop their strongest trunk and scaffold systems. With grapes, reduced vine vigor and commercial production delays result from weed competition (37). If new plantings are to become established and develop as desired, then weed control is a requirement.

This study focuses on a new herbicide which may be integrated into orchard or vineyard floor management systems. Chapter 1 of this thesis provides a brief history of weed control in trees and vines and some of the problems associated with various methods. In addition, a new family of herbicides, the diphenyl ethers, is discussed with specific interest in oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoremethyl) benzene] which has shown promise for fruit systems.

In Chapter 2, observations of oxyfluorfen efficacy on a variety of deciduous fruits are presented. Chapter 3 reports on oxyfluorfen selectivity, with emphasis on stone fruits which have shown limited tolerance to other orchard herbicides.

Chapter 4 discusses soil movement and persistence of oxyfluorfen under Michigan conditions. Chapter 5 discusses uptake and translocation

of ^{14}C-oxyfluorfen using grapes (*Vitis labrusca* L. 'Concord') and cherry (*Prunus cerasus* L. 'Montmorency') trees as model species.

CHAPTER 1

REVIEW OF LITERATURE

EVOLUTION OF WEED CONTROL METHODS FOR DECIDUOUS FRUITS

"It is said that no weed-control method has ever been abandoned, only new ones added" (7).

In order to understand the needs, methods, and some of the problems associated with weed control, a brief history of weed problems and weed control in deciduous fruit is presented here.

Before the turn of the century, growers learned there was less mouse damage and fire injury (51) where weeds were controlled. With time, the reduction in loss of water and nutrients, as well as reduction in insects and disease (3, 33) became common knowledge.

An 1893 publication (6) stated:

> During the first year after planting, nothing will be required but to keep the ground free from weeds and grass. Vineyards, as a rule, are not kept cultivated. By having the vines at least eight feet apart each way, cultivators and harrows can be freely used, and there is no excuse for weeds. The vines respond to this thorough cultivation in a remarkable manner. Let the ground be given up entirely to the vines and no attempt made to double-crop it. For the first year it may do to grow potatoes or other crops in the vineyard that need cultivating during the season, but not thereafter. Hoeing around the vines, especially in dry weather, is the best stimulant, and mulching with coarse manure will help to retain moisture for the roots and is far better than watering. With proper care and cultivation the vines should have obtained a growth from three to five feet the first season.

The early writer (6) did not stop there; he went on with a better method:

> One of the greatest labor-saving tools ever invented for use in the culture of grapes is the Morgan Grape hoe. After cultivating between the rows, this hoe will take out all grass and weeds that remain under the wires and around vines and posts and will stir the soil close to the vine. Without any careful attention to driving, the hoe is guided in and out around post and vine by the disc castor wheel to which a handle is attached. The horse is hitched on one side of the pole, which gives plenty of room for the plow to work under the vines and without injury to them by horse or whiffletree. The saving of time and labor will soon pay the cost of this tool, for this work is usually done by hand-hoeing, a slow and expensive way.

Mathews (42) also recommended cultivation for grapes and Savage (60) indicated cultivation of peaches [Prunus persica (L.) Batsch], in the United States, had been going on for over 150 years. However, with apples (Malus sylvestris Mill.) attitudes were mixed. Clean cultivation was probably the superior system, but "sod mulch" was also used (51). Sod mulch involved a permanent grass cover in the orchard and grass was cut and left or raked and placed under the trees as a mulch. Fire and mouse damage increased with this method. But some growers used this grass for hay or pastured the orchard, both of which were thought to be detrimental.

For heavy soils, an April or early May plowing may have occurred "to obtain the greatest invigorating effect" (51), for weeds growing in a plowed orchard caused less injury than sod. And after the initial plowing, three or four cultivations would suffice for the year. When seasonal tillages stopped, buckwheat [Fagopyrum talaricum (L.) Gaertn.], millet [Setaria italica (L.) Beuv.], oats (Avena spp.), rape (Brassica napus L.), rye (Secale cereale L.), or barley (Hordeum spp.) was sown to be turned under the next summer. Where nitrogen was needed, legumes were used.

However, Chandler (14) indicated that in some years the cessation

of cultivation and sowing a cover crop or permitting the weeds to grow could deplete moisture to the extent of reducing fruit size. Yet if cultivation continues late in the summer, weed growth and cover crop growth will not be sufficient to add organic matter to the soil.

Hull (28) indicated cultivation of orchards to control weeds gave rise to more uniform tree growth and increased vegatative growth. But cultivation had some problems too. If cultivation continued into summer too far, grapes continued to grow and fruit ripening was delayed (42), and winter injury was increased to apples and peaches (23). The growth of crab grass (Digitaria spp.) and other annual weeds in late summer was desired by some growers, because the weeds reduced soil erosion and reduced winter injury. With apples, where soil erosion was a problem, an area cultivated at the base of the tree was recommended (34). Sod strips became the method of erosion control (28).

Clean cultivation of orchards caused concern for moisture deficits (23), even though earlier with corn (Zea mays L.) no difference was shown between moisture content of a soil with a layer of loose soil kept on the surface by tillage and of a soil with a hard surface that had the weeds kept off by scraping (14, 23). Kenworthy (32) reported that at first sod culture may deplete moisture more than clean cultivation, but with time, if both practices were continued, more moisture may exist under sod than with clean cultivation. Chandler (14) indicated the primary way to conserve moisture was to prevent weed growth.

Water, light, and mineral nutrients are the main factors involved with plant competition (15). This order holds true for the growth and yield of apples, and artificial mulching usually is the best means of

reducing evaporation (23, 31). Mulching also reduces water run-off (23). When orchards were converted from sod to tillage, increased yield occurred; if the orchards were converted from tillage to sod, reduced yield and vigor occurred. These responses resulted from increased and decreased water supply. Yet, for Michigan Toenjes et al. (64) reported sod culture to conserve the greatest amount of soil moisture.

Higher soil temperatures resulted from clean cultivation, while mulching provided cooler temperatures. Yet those two practices resulted in tree growth that was nearly the same (14).

Another consideration with cultivation systems is the depletion of organic matter, which in turn reduces the exchange sites making nitrogen rapidly available, and which with time may require more nitrogen than the sod system (23). However, in general the sodded orchard required more nitrogen than did the cultivated orchard for sod caused a reduction in available nitrogen in the soil (14)

Tree root damage became a topic of concern with clean cultivation. Feeder roots have their highest concentration in the top 10 cm of soil (41). As cultivation was done, feeder roots were destroyed, causing plant stress (23). Cultivation was credited with forcing deeper rooting but this may not be the case (23). Lyons and Yoder (41) reported several trees with deep crown roots also had roots growing toward the soil surface. The direction of root growth due to a cultural practice (i.e., cultivation or mulching) cannot always be predicted (14, 23).

As equipment became bigger and more powerful and cultivation depth increased, retrogression occurred (60). "The disadvantages of cultivation are: shallow feeder roots are town up, soil structure is changed, soil erosion increases, especially on hill sides, weeds under

trees are difficult to control by mechanized methods and cultivation brings new weed seeds to the surface where they may germinate and grow" (33). If cultivation continues at the same depth, a hardpan may bevelop. Savage (60) reported more soil compaction in cleanly cultivated plots than in plots kept in sod or summer cover crops. Also, due to the lack of skilled laborers, many tractor operators try to cultivate as close to the trees as possible, resulting in injured tree trunks with openings for disease organisms to enter.

Hull (28) indicated that during the last two decades, cultivation had been replaced by herbicides being used in band application. Yet Savage (60) felt that herbicides were not the ideal solution for weed control because many peach trees had been killed by herbicide use or, most likely, misuse.

With new plants, weed control is necessary if desired growth and establishment are to be accomplished. Weed competition may restrict young tree growth, resulting in a delay of reaching maximum fruiting potential as well as failure to develop strong trunk and scaffold systems (28). Peaches grown in sod make less growth than clean cultivated trees (60). Lange et al. (37) reported that weed competition caused serious reductions in vine vigor and delayed production of young grapevines. Mechanical cultivation was not satisfactory for nursery or young vineyard rows, leaving weed removal to hand labor. The fact that herbicides may injure young fruit plants is apparent when one reads the labels of various compounds. This information is repeated by extension publications (3, 4) and weed control manuals (8) so that growers are aware of the hazard. Yet, growers realize that weeds must be controlled and that hand hoeing is too expensive,

giving rise to circumstances of herbicide misuse.

Lider et al. (39) reported that injury occurred when simazine [2-chloro-4,6-bis(ethylamino)-s-triazine] or diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] was applied to grapes. However, the response varied with varieties. Putnam and Price (58) reported terbacil (3-tert-butyl-5-chloro-6-methyuracil) caused varied responses on seedlings of peach, pear (Pyrus communis L.), apple, and cherry with peach being the most tolerant and cherry most susceptible. Skroch (61) reported simazine and terbacil reduced the growth of young apple and peach trees, while trifluralin (a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) and dichlobenil (2,6-dichlorobenzonitrile) were toxic only when high rates were mixed in the soil around the tree root systems. Robinson and Lord (59) reported reduced root development of 'McIntosh' apple trees when simazine was soil incorporated.

The herbicides did not always cause the same response. Lange et al. (35) found herbicides caused varied responses to young peach, plum (Prunus domestica L.), cherry, pear, and walnut (Juglana spp.) with different locations. Soil type (i.e., sand or clay) was also a key factor relating to herbicide injury (35, 57). Persistence differed with herbicides, with diuron and linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] lasting the longest (47). Slack et al. (62) reported less persistence of simazine under no-till and less simazine remaining in soil or low pH. Also, heavy sprinkler irrigation increased simazine injury to young Prunus rootstocks (36).

Due to the selectivity problems with the phenylureas, uracils and triazines on young deciduous fruit plantings, new herbicidal families are of interest to horticulturists. The hope is to find herbicides that

are safer but still as effective as the present methods. One herbicide family that appears promising is the diphenyl ethers, with oxyfluorfen [2-chloro-1-(3-ethyoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene] being of specific interest.

DIPHENYL ETHER HERBICIDES

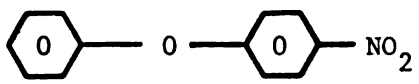
Properties

Since the two alkyl groups of ethers may be the same or different, ethers are classified as simple (R-O-R) or mixed (R-O-R'). Ethers are quite stable and undergo few reactions. For example, diethyl ether is an excellent solvent for a variety of organic compounds (12). The lower members of the aliphatic ethers are highly volatile and very flammable. Ethers in general are excellent solvents of fats, waxes, oils, plastics, and lacquers (40, 70). Ethers are very mobile liquids of neutral reaction and are only sparingly soluble in water (13). Oxyfluorfen solubility in water is 0.1 ppm (5). The $\equiv$C-O-C$\equiv$ is not readily broken (13), and the strong electron-attracting effect of the phenoxy groups makes the cleavage of aromatic ethers easier than that of aliphatic ethers (63).

The first diphenyl ether herbicides were used in Japanese rice (*Oryza sativa* L.) production due to their low toxicity to fish and shellfish (43). In 1962, fish kills resulting from PCP flowing from rice paddies opened the door for the use of nitrofen (2,4-dichlorophenyl *p*-nitrophenyl ether) in 1963. Nitrofen had a wide herbicidal spectra and low toxicity to fish (43), however, oxyfluorfen is toxic to fish (5).

Anderson (2) states that members of the substituted diphenyl ether herbicide family have as a common nucleus two phenyl rings joined by an

ether (-O-) bond and a nitro (NO_2) group located at the 4- position, or p-position, of one of the phenyl rings. Individual members differ from one another in the substituents on one or both phenyl groups.



Herbicidal Action

Diphenyl ether herbicides are used for the selective preemergence control of seedling broadleaved and grass weeds in croplands. In general, these herbicides are also effective when applied postemergence to weed seedlings one to two inches tall (2).

Anderson (2) listed the following characteristics for diphenyl ethers: (a) in general, they are more effective in control of broadleaved weed seedlings than grass weed seedlings; (b) they apparently undergo little or no translocation following root or foliar application; and (c) they are strongly absorbed to soil colloids and are apparently leached little, if at all, in soils.

When diphenyl ether herbicides are applied preemergence, they form a chemical barrier on the soil surface, killing seedling weeds as they emerge through the soil. The diphenyl ether herbicides should not be incorporated for they will lose their effectiveness. Also, diphenyl ether herbicides do not control established perennial weeds (2).

Matsunaka (44) divided the diphenyl ether herbicides into two groups. One group, without the ortho-substituent on one benzene ring, is active in the light or dark. The other group, with ortho-substituent-(s), requires light for activation.

Ashton and Crafts (9) stated that in general the diphenyl ethers are contact herbicides; however, certain compounds also induce growth

responses. They are absorbed by both leaves and roots of plants, but very little long-distance transport occurs once they are absorbed.

Absorption and Translocation

A considerable amount of work has been done with regard to absorption and translocation of the diphenyl ethers. Eastin (16) indicated fluorodifen (p-nitrophenyl a,a,a-trifluoro-2-nitro-p-tolyl ether) was rapidly absorbed and translocated by cucumber (Cucumis sativus L.) seedlings and continued to be absorbed by peanut (Arachis hypogaea L.) seedling roots throughout a 72-hour treatment period. Ashton and Crafts (9) stated that fluorodifen was not translocated symplastically to any appreciable extent in plants and that when fluorodifen was applied to soybean [Glycine max (L.) Merr.] leaves, translocation was limited to an acropetal direction indicating only apoplastic movement. Walter et al. (69) reported when fluorodifen was applied to both roots and leaves of soybean, grain sorghum (Sorghum vulgare Pers.), peanut, and morning glory (Ipomoea spp.), the herbicide was absorbed by the treated tissue, but limited translocation into other plant parts was detected.

With bifenox [methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate], Leather and Foy (38) observed ^{14}C to be in (or on) those areas of the crop plant in contact with the treated soil. With ^{14}C-nutrient solution treatments, velvetleaf (Abutilon theophrasti Medik.), corn (Zea mays L.) and soybean accumulated the ^{14}C-compound(s) in the roots with soybean accumulating the most. There was no difference in the concentration of ^{14}C in the shoots. However, the corn and soybean confined the ^{14}C-compound(s) to the primary and secondary leaf veins, while velvetleaf showed a general distribution throughout the leaf tissue. Velvetleaf absorbed and translocated bifenox from shoot zones to a greater extent

than the crop plants. Some acropetal movement was noted following leaf application, but no movement was detected in soybean (38).

With nitrofen and oxyfluorfen, there was very little movement of the compounds from the roots of pea (Pisum sativum L.) and sorghum, and with foliage application on green bean (Phaseolus vulgaris L.) and soybean almost all of the applied ^{14}C-herbicide remained at the point of application (22). Using fababeans (Vicia faba L.) and green foxtail (Setaria viridis (L.) Beauv.), Vanstone and Stobbe (66) reported uptake of nitrofluorfen [2-chloro-1-(4-nitrophenoxy)-4-(trifluoromethyl) benzene] and oxyfluorfen by the roots from nutrient solution, but translocation was limited.

Mode of Action

The mode of action for diphenyl ethers is not precisly defined. Moreland et al. (48) stated all of the diphenyl ethers acted primarily as inhibitors of chloroplast noncyclic electron transport, and the coupled photophosphorylation, with a site of action close to light reaction II. Gorske and Hopen (24) and Gorske et al. (26) indicated that the ethylene-producing system of Portulaca oleracea L. was influenced within a few hours following applications of nitrofen or oxyfluorfen. Increase in leaf temperature, closure or stomata, membrane disruption, lower water potential, and abscission of leaves also occurred.

Vanstone and Stobbe (67) reported that oxyfluorfen caused membrane disruption in buckwheat (Fagopyrum esculentum Moench). Prendeville and Warren (54) found oxyfluorfen to increase leaf-cell membrane permeability of green bean and soybean in light with a greater increase in leaf-cell permeability of soybean mutant with yellow leaves as compared with

normal green leaves. Vanstone (65) also reported the membrane disruption and light required for activation of nitrofluorfen and oxyfluorfen with applied to fababean and yellow foxtail (Setaria glauca (L.) Beauv.).

Fadayomi and Warren (20) indicate that there is probably a photobiochemical activation, with the products destroying membrane integrity. Pritchard and Warren (56) felt that the activated oxyfluorfen molecule may be altering a biochemical process rather than inducing a direct destructive effect on membranes. They also reported no effect of oxyfluorfen on photosynthetic electron transport with spinach chloroplasts.

The diffusion kinetics of fluorodifen indicated that the herbicide is capable of penetrating the cuticle and epidermis to cause destruction of the tissue. Fluorodifen accumulated in the membranes and light reduced the diffusion of fluorodifen across the membrane (9). Klingman and Ashton (33) point out that fluorodifen and nitrofen appear to cause loss of membrane integrity, but their action applied to the foliage may be different than their action when applied to the soil. Also, exposure of the shoot zone to nitrofen and oxyfluorfen caused much more injury to the plants than root exposure (22).

Orr and Hess (50), working with acifluorfen-methyl [methyl 5-(2-chloro-4-(trifluoromethyl-phenoxy)-2-nitrobenzoate], indicate the primary pigment involved in the light activation mechanism of the herbicide is lutein, and they believe "a light-activated form of the molecule (herbicide) is then involved either directly or indirectly, in the initiation of a free radical chain reaction involving the polyunsaturated fatty acid moieties (e.g., linolenic acid) of the phospholipid molecules making up cellular membranes."

Matsunaka (44) recognized the light reaction and divided the diphenyl ethers into two groups, as mentioned earlier. Prendeville and Warren (54) and Fadayomi and Warren (20) confirmed the light requirement for oxyfluorfen activation. The rate of injury increased as the light intensity increased with the most effective wave length being 565 to 615 mm, suggesting the involvement of a pigment (68). Pritchard and Warren (56) indicated oxyfluorfen was activated by light in the presence of yellow plant pigments. However, not all diphenyl ether herbicides responded this way. With fluorodifen, injury was intensified with exposure of plants to reduced levels of light, occurring the greatest at longer wavelengths of visible light (yellow and red) (53).

Soil Behavior

Oxyfluorfen and nitrofen were readily adsorbed from solution by muck soil and Ca- and H-Al-Bentonite but only slightly by Ca- and H-Al-Kaolinite. Only very small amounts of the herbicides were desorbed after four extractions with distilled water. Using sorghum as an indicator, results showed the herbicides were strongly inactivated by muck soil, but only slightly inactivated by the clays, and there was essentially no movement of either herbicide through 5-cm columns of a silt loam soil and a fine sand soil (19). With fluorodifen, little leaching was detected in a Miller clay or a Lufkin sandy loam and less than 10% of the herbicide remained six months after application (69). May (45) indicated oxyfluorfen looked promising for general broadleaved weed and annual bluegrass control on an organic fine sandy loam and a peat soil.

As for placement of oxyfluorfen, Pritchard and Warren (55) incorporated it and got good weed control with no reduction in yield of muskmelon (Cucumia melo L.) and watermelon (Citrullus vulgaris Schrad.), but

tomato (Lycopersicum esculentum Mill.) yield was reduced. Yih and Swithenbank (71) reported the incorporation of oxyfluorfen into the soil drastically reduces its effectiveness as a herbicide. Fadayomi and Warren (21) and Brickell and Jordan (11) confirmed incorporation reduces oxyfluorfen effectiveness, as well as the effectiveness of other diphenyl ethers.

The diphenyl ether herbicides have often been reported to cause crop injury. On green beans and soybeans, the most critical time for light exposure to result in increased herbicide injury was at the time of emergence of seedlings (53). Fadayomi and Warren (21) observed seedlings of species that emerged most rapidly seemed to be most tolerant to preemergence herbicide applications, and there was no direct relationship between preemergence and postemergence tolerance. Oakes (49) found injury from oxyfluorfen to be greater on wet than dry soils and decreased with increased soil organic matter levels. Injury also increased as day-night temperatures and organic matter levels decreased. McHarry and Kapusta (46) observed oxyfluorfen applied at the full-tillering stage caused injury to wheat (Triticum aestivum L.). Oxyfluorfen caused leaf burn and greatly reduced the production of gladiolus (Gladiolus spp.) corms from cormels (10). Humphrey and Elmore (29) reported the granular formulation of oxyfluorfen caused less damage than the liquid formulation on several of the broadleaved ornamentals, but neither affected conifers. Gorske and Hopen (25) observed cabbage leaves developed white flecked areas which soon became necrotic. Some leaves had a burnt appearance around the edge and leaf curling was common. Some of the described injury resulted from vapors. Johnson (30) reported oxyfluorfen vapors persist in sufficient quantity to cause 90% injury to velvetleaf

grown in untreated pots over a period of three weeks after application on the soil at rates of 1.1-2.2 kg/Ha, and after five weeks no significant injury occurred.

Fate in Plants

Plants differ in their susceptibility to diphenyl ethers. Hawton and Stobbe (27) estimated that green foxtail (Setaria viridis (L.) Beauv.) and redroot pigweed (Amaranthus retroflexus L.) were, respectively, 9 and 99 times more susceptible to nitrofen than was rape. Eastin (17) reported fluorodifen degradation proceeded rapidly in peanut seedling roots and cucumber seedlings degraded fluorodifen via a pathway similar to that reported for peanut, but at a slower rate. Eastin (18) attributes the difference in susceptibility to fluorodifen of cucumber and peanut to the rate of acropetal translocation (cucumber translocates more than peanut) and the rate of degradation (peanut degrades fluorodifen much more rapidly than cucumber). With nitrofluorfen and oxyfluorfen in fababeans and green foxtail, less than 10% of that taken up in vitro was metabolized after 24 hours (66). Pereira et al. (52) indicate selectivity of cabbage to nitrofen is dependent on the amount of cuticular wax on the leaves at the time of application.

As for oxyfluorfen, it is not readily metabolized in plants and microbial degradation is not a major factor (5).

Photodecomposition of oxyfluorfen in water is rapid and on soil is slow. Oxyfluorfen residues do not persist in the environment and have a half-life of about 30 to 40 days (5). When ^{14}C-oxyfluorfen was fed to rats, only trace amounts of radioactivity (2.4%) were recovered in the urine and tissue. The major route of dose elimination was through the feces (95%) and about 75% of the fecal radioactivity was unchanged oxy-

fluorfen (1).

REFERENCES

1. Alder, I. L., B.M. Jones, and J. P. Wargo, Jr. 1977. Fate of 2-chloro-1-(3-ethyoxy-4-nitrophenyoxy)-4-trifluoromethyl) benzene (oxyfluorfen) in rats. J. Agric. Food Chem. 25: 1339-1341.

2. Anderson, W. P. 1977. Weed science: principles. West Publishing Co., New York. 598 pp.

3. Anonymous. 1976. Establishing and managing young apple orchards. Farmers' Bulletin No. 1897. USDA. 26 pp.

4. Anonymous. 1977. Growing cherries east of the Rocky Mountains. Farmers' Bulletin No. 2185. USDA. 30 pp.

5. Anonymous. 1979. 1979 Herbicide handbook of the Weed Science Society of America. 4th ed. Champaign, Ill. 479 pp.

6. Anonymous. 1893. Our native grape. C. Mitzky and Co., Rochester, N.Y. 219 pp.

7. Anonymous. 1969. Weed control, Volume 2. Pub. 1597. Nat. Academy of Sci. 471 pp.

8. Anonymous. 1981. 1981 Weed control manual. Meister Publication Co., Willoughby, Ohio. 326 pp.

9. Ashton, F.M. and A. S. Crafts. 1981. Mode of action of herbicides. John Wiley and Sons, New York. 525 pp.

10. Bing, A. 1979. The effect of preemergence postplant treatments of alachlor, napropamide, oxadiazon, oxyfluorfen and prodiamine on gladiolus. Proc. Northeastern Weed Sci. Soc. 33: 264-269.

11. Brickell, C.M. W. and C. L. Jordan. 1980. Influence of incorporation of diphenyl ether herbicides. Proc. N. Central Weed Conf.: in press.

12. Butler, G. and K. D. Berlin. 1972. Fundamentals of organic chemistry. Ronald Press Co., New York. 1113 pp.

13. Campbell, N., ed. 1955. Organic chemistry. Oliver and Boyd, London. 936 pp.

14. Chandler, W. H. 1925. Fruit growing. Houghton, Mifflin Co., New York. 777 pp.

15. Crafts, A. S. 1975. Modern weed control. Univ. of Calif. Press, Berkley. 440 pp.

16. Eastin, E. F. 1971. Movement and fate of fluorodifen-1'-^{14}C in cucumber seedlings. Weed Res. 11: 63-68.

17. Eastin, E. F. 1971. Degradation of fluorodifen-1'-^{14}C by peanut seedling roots. Weed Res. 11: 120-123.

18. Eastin, E. F. 1972. Fate of fluorodifen in susceptible cucumber seedlings. Weed Sci. 20: 255-260.

19. Fadayomi, O. and G. F. Warren. 1977. Adsorption, desorption, and leaching of nitrofen and oxyfluorfen. Weed Sci. 25: 97-100.

20. Fadayomi, O. and G. F. Warren. 1976. The light requirement for herbicidal activity of diphenyl ethers. Weed Sci. 24: 598-600.

21. Fadayomi, O. and G. F. Warren. 1977. Differential activity of three diphenyl ether herbicides. Weed Sci. 25: 465-468.

22. Fadayomi, O. and G. F. Warren. 1977. Uptake and translocation of nitrofen and oxyfluorfen.. Weed Sci. 25: 111-114.

23. Gardner, V. R., F. C. Bradford, and H. D. Hooker, Jr. 1952. The fundamentals of fruit production, 3rd ed. McGraw-Hill Book Co. , New York. 739 pp.

24. Gorske, S. F. and H. J. Hopen. 1978. Effects of two diphenylether herbicides on common purslane (Portulaca oleracea). Weed Sci. 26: 585-588.

25. Gorske, S. F. and H. J. Hopen. 1978. Selectivity of nitrofen and oxyfluorfen between Portulaca oleracea ecotypes and two cabbage (Brassica oleracea var. capitata) cultivars. Weed Sci. 26: 640-642.

26. Gorske, S. F., H. J. Hopen, and A. M. Rhodes. 1977. Studies of the biology and herbicidal effects on Portulaca oleracea L. HortSci. 12: 385.

27. Hawton, D. and E. H. Stobbe. 1971. Selectivity of nitrofen among rape, redroot pigweed and green foxtail. Weed Sci. 19: 42-44.

28. Hull, J., Jr. 1980. Evolutions in weed control. Amer. Fruit Grower. 100: 22, 66.

29. Humphrey, W. A. and C. L. Elmore. 1978. Plant tolerance and weed control in container-grown plants--progress report. Flower and Nursery Report. Summer, pp. 1-2.

30. Johnson, R. T. 1978. Study of preemergence applied Goal 2E and its residual vapor injury to velvetleaf (Abutilon theophrasti). Res. Farms Report No. 42, Rohm and Haas Co., Philadelphia. Nov.

31. Jones, N. J., Jr., J. E. Moody, and J. H. Lillard. 1969. Effects of tillage, no tillage, and mulch on soil water and plant growth. Agron. J. 61: 719-721.

32. Kenworthy, A. L. 1953. Moisture in orchard soils as influenced by age of sod and clean cultivation. Mich. Agric. Exp. Sta. 35: 454-459.

33. Klingman, G. C. and F. M. Ashton. 1975. Weed science: principles and practices. John Wiley and Sons, New York. 431 pp.

34. Kuehner, C. L. 1934. Farm orchards. Circ. 265. Univ. of Wisc., Madison. 40 pp.

35. Lange, A. H., J. C. Crane, W. B. Fischer, et al. 1969. Pre-emergence weed control in young deciduous fruit trees. J. Amer. Soc. Hort. Sci. 94: 57-60.

36. Lange, A. H. and C. L. Elmore. 1969. Moisture and the use of simazine on Prunus. HortSci. 4: 30-32.

37. Lange, A. H., L. A. Lider, B. B. Fischer, et al. 1969. Weed control studies in young grapevines. AXT-302, Agric. Ext. Serv. Univ. of Calif. 9 pp.

38. Leather, G. R. and C. L. Foy. 1978. Differential absorption and distribution as a basis for the selectivity of bifenox. Weed Sci. 26: 76-81.

39. Lider, L. A., A. H. Lange, and O. A. Leonard. 1966. Susceptibility of grape, Vitis vinifera L., varieties to root application of simazine and diuron. Proc. Amer. Soc. Hort. Sci. 88: 341-345.

40. Linstromberg, W. W. 1966. Organic chemistry, a brief course. D. C. Heath and Co., Boston. 432 pp.

41. Lyons, C. G., Jr. and K. S. Yoder. 1981. Poor anchorage of deeply planted peach trees. HortSci. 16: 48-49.

42. Mathews, C. W. 1901. Grapes. Bull. No. 92. Agric. Exp. Sta. Univ. of Ky., Lexington. 79 pp.

43. Matsunaka, S. 1976. Diphenyl ethers. Pages 709-739 in P. C. Kearney and D. D. Kaufman, eds. Herbicide Chemistry, Degradation, and Mode of Action. Marcel Dekker, New York. 1036 pp.

44. Matsunaka, S. 1969. Acceptor of light energy in photoactivation of diphenylether herbicides. J. Agric. Food Chem. 17: 171-175.

45. May, M. J. 1978. Glasshouse investigation with newer soil-applied herbicides for weed control on organic soils. Proc. 1978 Br. Crop Protection Conf.--Weeds, London. pp. 777-784.

46. McHarry, M. J. and G. Kapusta. 1978. Alternative double-crop soybean weed control. Proc. N. Central Weed Conf. 33: 45.

47. Miller, J. H., P. E. Keeley, R. J. Thullen and C. H. Carter. 1978. Persistence and movement of ten herbicides in soil. Weed Sci. 26: 20-27.

48. Moreland, D.E., W. J. Blackman, H. G. Todd, and F. S. Farmer. 1970. Effects of diphenylether herbicides on reactions of mitochondria and chloroplasts. Weed Sci. 18: 636-642.

49. Oakes. R. L. 1980. Interference and control of two varieties of jimsonweed (Datura stramonium L. var. stramonium and var. tatula (L.) Torr.) in soybean (Glycine max (L.) Merr.) with Oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene) and RH8817 (2-chloro-1-(3-carboyethyl-4-nitrophenoxy)-4-(trifluoromethyl) benzene. Mich. State Univ. doctoral dissertation. 131 pp.

50. Orr, G. L. and F. D. Hess. 1981. Mode of action of acifluorfen-methyl: III. A proposed mechanism. Abstr. Meeting of the Weed Sci. Soc. of Amer.. p. 248.

51. Oskamp, J. 1925. The planting and the early care of the commercial apple orchard. Cornell Univ. Ext. Bull. No. 75. 43 pp.

52. Pereira, J. F., W. E. Splittstoesser, and H. J. Hopen. 1971. Mechanism of intraspecific selectivity of cabbage to nitrofen. Weed Sci. 19: 647-651.

53. Pollak, T. and G. Crabtree. 1976. Effect of light intensity and quality on toxicity of fluorodifen to green bean and soybean seedlings. Weed Sci. 24: 571-573.

54. Prendeville, G. N. and G. F. Warren. 1977. Effect of four herbicides and two oils on leaf-cell membrane permeability. Weed Sci. 30: 251-258.

55. Pritchard, M. K. and G. F. Warren. 1979. Oxyfluorfen for pre-plant incorporated weed control in transplated tomatoes and melons. Abstr. Meeting of the Weed Sci. Soc. of Amer. p. 44.

56. Pritchard, M. K. and G. F. Warren. 1979. Site of action of oxyfluorfen. Abstr. Meeting of the Weed Sci. Soc. of Amer. p. 98.

57. Putnam, A. R. 1975. Chemical weed control in peach orchards. Pages 300-305 in N.F. Childers, ed. The Peach. Horticultural Publ., New Brunswick, N.J. 659 pp.

58. Putnam, A. R. and H. C. Price. 1969. Tolerance of rootstocks and established Malus, Pyrus, and Prunus trees to terbacil. J. Amer. Soc. for Hort. Sci. 94: 655-658.

59. Robinson, D. E. and W. J. Lord. 1970. Response of 'McIntosh' apple trees to soil incorporated simazine. J. Amer. Soc. for Hort. Sci. 95: 195-199.

60. Savage, E. F. 1975. Do peaches need cultivation? Pages 297-300 in N. F. Childers, ed. The Peach. Horticultural Publ., New Brunswick, N.J. 659 pp.

61. Skroch, W. S. 1970. Effects of five herbicides on young apple and peach trees. HortSci. 5: 42-44.

62. Slack, C. H., R. L. Blevins, and C. E. Rieck. 1978. Effect of soil pH and tillage on persistence of simazine. Weed Sci. 26: 145-148.

63. Staude, E.and F. Patat. 1967. Cleavage of the C-O-C Bond. Pages 21-80 in S. Patai, ed. The Chemistry of the Ether Linkage. Interscience Publ., London. 785 pp.

64. Toenjes, W., R. J. Higdon, A. L. Kenworthy. 1956. Soil moisture used by orchard sods. Mich. State Univ. Agric. Exp. Sta. 39: 1-20.

65. Vanstone, D. E. 1978. Physiological aspects of the mode of action of nitrofluorfen and oxyfluorfen. Diss. Abstr. Internatl. B38:2974.

66. Vanstone, D.E. and E. H. Stobbe. 1978. Root uptake, translocation, and metabolism of nitrofluorfen and oxyfluorfen by fababeans (Vicia faba) and green foxtail (Setaria viridis). Weed Sci. 26: 389-392.

67. Vanstone, D.E. and E. H. Stobbe. 1977. Electrolytic conductivity--a rapid measure of herbicide injury. Weed Sci. 25: 352-354.

68. Vanstone, D. E. and E. H. Stobbe. 1979. Light requirement of the diphenylether herbicide oxyfluorfen. Weed Sci. 27: 88-91.

69. Walter, J. P., E. F. Eastin, and M. G. Merkle. 1970. The persistence and movement of fluorodifen in soils and plants. Weed Res. 10: 165-171.

70. Windholz, M., ed. The Merck Index, 9th ed. Merck and Co., Rahway, N.J. 1313 pp.

71. Yih, R. Y. and C. Swithenbank. 1975. New potent diphenyl ether herbicides. J. Agric. Food Chem. 23: 592-593.

CHAPTER 2

EFFICACY OF OXYFLUORFEN IN DECIDUOUS FRUIT PLANTINGS

INTRODUCTION

Previous studies have indicated that, in general, diphenyl ether herbicides control broadleaved weeds better than the grasses (1). Work by Lange and Schlesselman (3) confirmed that oxyfluorfen gave outstanding broad spectrum broadleaf annual weed control in trees and vines in California; however, oxyfluorfen alone did not generally control summer grasses. Fretz and Sheppard (2) reported oxyfluorfen to control the broadleaved weeds but not to control crabgrass (Digitaria spp.) after 35 days.

The safety of oxyfluorfen on trees and vines was excellent; however, there was some injury to newly planted vines where bud swell or leaf break had occurred (3). Schlesselman (8) reported oxyfluorfen applied at 8.8 kg/ha to be safe in deciduous trees and vines. Lange et al. (4) reported oxyfluorfen showed advantages over simazine.

The injury from oxyfluorfen observed on deciduous fruit crops in the field and greenhouse may be related to cuticle development and thickness. Pereira et al. (7) reported cuticle thickness was related to differences in injury of two varieties of cabbage (Brassica oleracea var. capitata L.) to nitrofen.

Cuticle characteristics differ between plants grown under glass and plants in the open. The deposition of cuticle was directly proportional to light intensity and inversely proportional to relative humidity. Also, cuticle in very young leaves was incomplete, while sun and shade leaves and immature and mature leaves had different thickness of

cuticle (5).

Tests were established to observe how oxyfluorfen performed in Michigan on various deciduous fruit crops.

MATERIALS AND METHODS

Field plots, container studies, and greenhouse tests were conducted with oxyfluorfen on deciduous fruit crops (Table 1) in Michigan, using randomized complete block designs. Herbicides were applied with a CO_2 backpack sprayer using a spray volume of 337 l/ha with 2.8 kg/cm^2 pressure.

Dormant rooted cuttings of 'Concord' grape were transplanted into quart containers in February 1980 and grown in the greenhouse until June, at which time they were cut back and placed under lath outdoors. Hardwood cuttings of 'Concord' grape were collected in February 1980 and placed in plastic bags in 1.7°C coolers. In June the cuttings were trimmed to two nodes, rooted in peat: perlite, and potted in 10 cm pots. These plants remained in the greenhouse for approximately 120 days, at which time both sets of plants were treated. The plants in the greenhouse were actively growing, while the plants outside had slowed in rate of growth. Oxyfluorfen, at 2.2 kg/ha, was sprayed over the tops with a CO_2 backpack sprayer at 2.8 kg/cm^2 and 337 l/ha. Treated plants were then placed under metal halide lights (16 hr. photoperiod) in a 21°C greenhouse.

RESULTS AND DISCUSSION

Oxyfluorfen's performance in Michigan was consistent with that previously reported in the literature. The annual broadleaf weeds were controlled much better than were the annual grasses (Table 2). Broadleaf and grass weeds controlled were redroot pigweed, ragweed

Table 1. Field plots and greenhouse tests with oxyfluorfen on deciduous fruit crops in Michigan.

Test Number		Crop	Age of Planting (months)	Location	Soil Type	Date Treated
1		Grape 'Concord'	0.5	Lawton	Sandy Loam	5-28-79 4-17-80
2		Apples[a]	Nursery	Hartford	Loam	11-15-79
3		Peach 'Gerber 477'	0.5	E. Lansing	Sandy Loam	5-24-80
4		Pear[a] Apple[a] Sweet Cherry[a] Tart Cherry[a]	Nursery Nursery Nursery Nursery	Hartford	Sandy Loam	5-4-79
5		Pear 'Bartlett'	12	Hartford	Sandy Loam	5-4-79
6	A	Grape 'Concord'	Propaga-tion bed	Bridgeman	High Organic Sand	5-4-79
	B	Blueberry	Stock plants			
	C	Raspberry 'Latham'	Propaga-tion bed			
7		Apple 'Redchief'	12	Hartford	Sandy Loam	5-4-79 4-17-80
8		Grape 'Concord'	4 & 8	Greenhouse E. Lansing	Greenhouse Mix (2 soil: 1 sand)	10-8-80
9		Cherry 'Montmor-ency'	9	Greenhouse E. Lansing	Composted Leaves and Perlite (2:1)	1-30-81
10		Raspberry 'Heritage	New Planting	Traverse City	Sandy Loam	4-30-80

[a]Newly budded.

Table 2. 1979 Weed ratings at Lawton, Michigan in 'Concord' grapes.

Chemical	kg/ha	Mean Ratings (14 day)		Mean Ratings (21 day)	
		Grass	Broadleaf	Grass	Broadleaf
Control	0.00	0.0	0.0	0.0	0.0
Oxyfluorfen	1.10	7.5	10	6.7	10
Oxyfluorfen	1.65	8.0	9.7	8.0	10
Oxyfluorfen	2.20	9.0	10	8.5	10
Simazine	2.20	5.0	7.5	4.5	8.7
$LSD_{.05}$		1.5	1.4	1.6	0.9
Coefficient of Variation (%)		17	12	19	7

Key: 10 is complete weed control and 7 is acceptable weed control.

(Ambrosia artemisiifolia L.), common lambsquarter (Chenopodium album L.), common yellow woodsorrel (Oxalis stricta L.), common purslane (Portulaca oleracea L.), ladysthumb smartweed (Polygonum persicaria L.), large crabgrass (Digitaria sanguinalis (L.) Scop.), and green foxtail. After 60 to 90 days, large crabgrass would often be the first to appear. When quackgrass [Agropyron repens (L.) Beauv.] was present, oxyfluorfen suppressed it for a few weeks, but did not provide effective control. This was also true for other established perennials such as dandelions (Taraxacum officinale Weber), buckhorn (Plantago lanceolata L.), milkweed (Asclepias syriaca L.), and brambles (Rubus spp.). If weeds had recently germinated, oxyfluorfen at 1 to 2 kg/ha controlled broadleaves that were up to 5 to 8 cm tall; however, grasses initially showed necrosis, and then recovered. At 8.8 kg/ha, acute toxicity occurred on all emerged weeds and the plots remained weed-free for the growing season.

At the Lawton site in 1979, the duration of weed control was approximately 40 days which may have been due to a three-inch rain which occurred one week after herbicide application. In 1980, a more typical duration of weed control was at least 60 days, after which nonacceptable weed control was present due to grass invasion (Table 3).

Crop Tolerance

The crop injury was usually of slight significance, with the exceptions of red raspberries (Rubus idaeus L.) or newly budded material (Table 4). In the former situation, the raspberries were either being grown in nursery beds or were recently planted. At the nursery site, 5 or 8 cm of new growth was present at the time of application of oxyfluorfen. The green raspberry tissues became necrotic approximately 4 days after treatment, and then recovered. However, they did remain

Table 3. 1980 Weed ratings at Lawton, Michigan in 'Concord' grapes.

Chemical	kg/ha	Mean Rating (60 day)	Mean Rating (90 day)
Control	0.00	3.2	0.0
Oxyfluorfen	1.10	8.5	0.7
Oxyfluorfen	1.65	8.2	2.0
Oxyfluorfen	2.20	9.0	4.2
Simazine	2.20	8.7	2.0
$LSD_{.05}$		0.9	2.4
Coefficient of Variation (%)		8	85

Key: 10 is complete weed control and 7 is acceptable weed control.

Table 4. Summary of fruit crop tolerance to oxyfluorfen applied in 1979 or 1980.

Crop	Age of Plantings (months)	Injury 1979	Injury 1980
Peach			
Red Haven	2	N	N
Gerber 477	0.5	NT	N
Cherry			
Montmorency	2	N	N
Montmorency	3	N	NT
Tart & Sweet	Nursery	S	NT
Pear			
Bartlett	12	N	NT
Newly budded	Nursery	S	NT
Grape			
Concord	0.5	N	M
Concord	Nursery	N	NT
Apples			
Redchief	24	N	M
Newly budded	Nursery	S	NT
Plum			
Stanley	Newly planted	N	NT
Raspberry			
Latham	Propagation bed	S	NT
Heritage	Newly planted	NT	S
Blueberry			
Unknown	Stock plants	M	NT

Key: S= Severe, M= Moderate, N = None, NT = Not Treated.

visibly shorter than the control plants for the duration of the season. Newly planted 'Heritage' plants were also severly damaged with rates as low as 1.1 kg/ha.

Pears in the nursery which were sprayed over the top with oxyfluorfen before bud break showed a 'crinkling' on the newly expanding leaves. After approximately 10 days, the plants recovered, yet there appeared to be more lateral bud breaks where oxyfluorfen had been applied. Other pears treated showed no injury.

With newly budded apples and cherries in the nursery, injury was severe. The new leaves appeared "scorched" or "burned" on the edges. The sweet cherries recovered by the end of the growing season to appear similar to the control plants. However, the tart cherries and apples remained shorter at the end of the growing season than were the controls.

On a sand with high organic matter content, propagation beds of 'Concord' grape were treated with oxyfluorfen (Table 1, Test 6A). The cuttings had been stuck the previous year and bud break had not occurred at the time of application. New growth was approximately 30 cm above the soil. No apparent injury was observed. Yet on established blueberries (Vaccinium corymbosum L.) that had been cut back, injury to new emerging leaves occurred. The blueberries showed no long-term effect however (Table 1, Test 6B).

At another location (Table 1, Test 1), planting of 'Concord' grapes was done on May 28, 1979 with herbicides applied three days later; the plants were still dormant with several shoots in direct contact with the soil surface. No injury was visible during 1979. On April 17, 1980 the site was retreated while the vines were still on the ground. During the

latter part of May, limited injury was apparent. Crinkling of leaves with some necrotic edges could be observed in the oxyfluorfen plots. However, later in the growing season, no injury was apparent and the rate of growth seemed unaffected.

In November of 1979, herbicide plots were established on newly budded apple trees in a nursery (Table 1, Test 2). The understock had not been cut back at the time of herbicide application. Later the shoots were cut back just above the desired bud. When observing these plots in May 1980, injury to the lower leaves was apparent. Injury involved slight crinkling of the leaf with some necrosis. Injury was restricted to the leaves within 25 to 30 cm of soil. Also, injury occasionally appeared on plants in adjacent rows that had not been treated with oxyfluorfen. Rows were approximately three feet apart.

In 1979, no injury was observed on newly planted apples (Table 1, Test 7). However, in 1980, after the plots were retreated, injury occasionally appeared if a new shoot developed within 25 to 30 cm of the soil surface. This shoot would later be removed by growers, so is not of concern unless there might be translocation from it. The remainder of the plant showed no injury.

In Test 3 (Table 1), peach bud break had occurred and 3 to 7 cm shoot growth was on the lower trunk of one of the trees at treatment. Oxyfluorfen killed these shoots, and no regrowth occurred during the season. The remainder of the tree showed no other signs of injury from oxyfluorfen (Figures 1 and 2).

Actively growing grape plants in the greenhouse showed severe necrosis where oxyfluorfen came in contact with the plant (Table 1, Test 8). However, if a leaf were shielded by a leaf above it, no injury

Figure 1. Peach sucker necrosis occurring 32 hours after 2.2 kg/ha oxyfluorfen treatment.

12

Figure 2. Peach suckers remained necrotic 43 days after 2.2 kg/ha oxyfluorfen treatment.

II
2

occurred. Terminals were killed back; however, not all of the green stem was injured--only the most recent growth (Figure 3). Within 5 to 10 days, bud break was occurring and normal new growth appeared. Previous injury remained localized.

Older grape plants that were grown outdoors were not as severely damaged. A purple flecking in the leaf was all that was observed.

With oxyfluorfen, injury may be induced in two different ways. There is the contact property which occurred with the actively growing grapes in the greenhouse, and there may also be injury from vaporization.

In 1979, vaporization of oxyfluorfen did not cause injury on grapes (Table 1, Test 1); however, in 1980 at the same site, injury did occur. Also after treating 'Montmorency' cherries in containers (Table 1, Test 9) with 2.2 kg/ha of oxyfluorfen and placing the plants in the greenhouse at approximately 21°C, injury to nontreated plants could occasionally be observed. Meeusen (4) indicated the injury resulting from vaporization was from the parent molecule, oxyfluorfen. The greatest amount of vaporization occurs after a rain if temperature is also favorable.

At grape test sites, the area between the rows was cultivated. If soil from the cultivated area was pushed into the oxyfluorfen plots, weeds germinated and grew in this thin layer of untreated soil. This indicates oxyfluorfen forms a barrier at the soil surface.

Due to the injury observed, applications of oxyfluorfen over the tops of deciduous plants are not recommended. However, there appears to be no problem with use on newly planted sites if the spray is directed at the base of fruit trees or on grapes that have been tied up.

Figure 3. Injury to actively growing grapes when sprayed with 2.2 kg/ha of oxyfluorfen.

REFERENCES

1. Anderson, W. P. 1977. Weed science: principles. West Publishing Co. New York. 598 pp.

2. Fretz, T. A. and W. J. Shepard. 1978. USB-3153 and oxyfluorfen: two new experimental herbicides for container nursery stock. Research circular no. 236. Ornamental Plants 1978, a summary of research. Ohio Agricultural Research and Development Center. pp. 48-50.

3. Lange, A. H. and J. Schlesselman. 1976. Weed control in trees and vines. Weed control notes progress report. Series 76:1. University of California, Parlier, Calif. pp. 22.

4. Lange, A. H., H. J. Schlesselman, L. Nygren, et al. 1977. Control of weed in almonds and pistachios. Proc. West. Soc. of Weed Sci. 30:14.

5. Martin, J. T. and B. E. Juniper. 1970. The cuticle of plants. Edward Arnold Ltd. Edinburgh, Great Britain, 347 pp.

6. Meeusen, R. L. 1980. Personal conversation. Rohm and Haas Co., Philadelphia, Pa.

7. Pereira, J. F., W. E. Splittstoesser, and H. J. Hopen. 1971. Mechanism of intraspecific selectivity of cabbage to nitrofen. Weed Sci. 19: 647-651.

8. Schlesselman, J. 1977. Annual weed control in deciduous trees and vines. Proc. 29th Annual Calif. Weed Conf. pp. 96-99.

CHAPTER 3

OXYFLUORFEN SELECTIVITY ON PEACH (*PRUNUS PERSICA* BATSCH) AND CHERRY (*PRUNUS CERASUS* L.)

ABSTRACT

Three tests were conducted to establish selectivity of oxyfluorfen on peach (*Prunus persica* Batsch/'Halford') and cherry (*Prunus cerasus* L./'Mahaleb'). One test with peaches was conducted in containers with 2.2 and 4.4 kg/ha of oxyfluorfen and 4.4 kg/ha of simazine, either incorporated throughout the media or surface applied. In the second test, 2.2, 4.4, and 8.8 kg/ha oxyfluorfen and 4.4 kg/ha simazine were applied to newly planted peaches in the field. Both tests were conducted with sandy loam soil with 1.5% organic matter. The third test consisted of spraying 2.2 and 4.4 kg/ha of oxyfluorfen to suckering 'Mahaleb' rootstock of 'Montmorency' cherries. Oxyfluorfen did not injure container grown peaches, while simazine caused phytotoxicity 26 days after planting and reduced both top and root growth. With the field planting, there were no tree growth differences attributed to treatment, except weedy controls showed reduced growth from weed interference. No injury was apparent on any trees, even at 8.8 kg/ha oxyfluorfen. Oxyfluorfen at 2.2 kg/ha did dessicate new suckers shortly after application. Application of 2.2 and 4.4 kg/ha oxyfluorfen to actively growing suckers on cherry understocks resulted in necrosis of leaves and killing of terminals of the suckers. However, within two weeks, new bud break and growth had occurred. Tops of the 'Montmorency' cherry showed no damage, indicating oxyfluorfen was not translocated. These tests confirm that a

large safety margin exists for oxyfluorfen on new plantings of peach and cherry on sandy soil.

INTRODUCTION

A 10-year study of 4 vegetation management systems in apple (Malus domestica Borkh.) orchard concluded that a mowed and ground cover resulted in less efficient trees than those with cultivation, residual or non-residual herbicides (6). Raese et al. (20) reported weed control with certain triazole or triazine herbicides on pear (Pyrus communis L.) resulted in increased tree vigor. Yet growers are cautious about using herbicides around new plantings. On coarse textured, sandy soils crop injury has occurred from use of herbicides (4, 5, 15, 18), yet on fine particle soils, no injury was observed on fruit trees with simazine or diuron (9, 12).

Other factors influencing fruit crops response to herbicides were rootstocks and scion varieties (14, 17, 19) and irrigation (13, 15).

Growers were warned not to use various herbicides around young plantings (1, 2). Weaver (23) reported injury to grapevines from simazine and diuron and indicated the herbicides should be applied on bearing vines three or more years old with trunk diameters of 3.8 cm or more. When applied to young grapevines, simazine produced considerable phytotoxicity symptoms on many varieties (14) and combinations of herbicides were found phytotoxic to young grapevines (3). Simazine caused injury to young or newly planted Prunus species (13, 22). Lord et al. (16) reported dichlobenil to cause injury to apple trees (Malus spp.). Diuron and simazine also caused injury to non-bearing apple and pear trees. With sour cherry trees, monuron [3-(p-chlorophenyl)-1,1-dimethylurea] caused injury (8). Blueberries (Vaccinium spp.) were injured by terbacil and simazine (7, 10). Yet, oxyfluorfen was reported safe on

deciduous trees and most vines (15, 21). Kennedy et al. (11) reported oxyfluorfen to be effective as a residual type treatment on Concord grapes. Confirmation of oxyfluorfen's safety on newly planted fruit trees in Michigan was desired.

MATERIALS AND METHODS

Three experiments on newly planted trees were conducted over a two-year period. The first involved dormant peaches (Prunus persica Batsch. 'Harbrite'/'Halford') which were removed from a cooler (2°C) and root and top pruned. The plants were planted in a Spinks sandy loam soil in three gallon poly containers. Herbicides were either incorporated or surface applied. The incorporated treatments had the herbicide thoroughly mixed through the soil using an electric soil mixer. A control incorporated treatment, using just water, was included.

The surface treatments were applied with a CO_2 backpack sprayer (Table 5) at 2.8 kg/cm^2 pressure, 327 l/ha, and 8004 nozzle. The formulated products were used (simazine 80W and oxyfluorfen 2E). After treatment, containers were placed under lath in a randomized complete block design with four replications. Plants were fertilized and watered as needed for 85 days. Ten branches of the current season's growth were harvested from each plant, as well as the roots. Leaf area, branch length, number of internodes, dry weights of branches and leaves, and dry weights of new roots were recorded.

The second study involved a new peach field planting. Bare root 'Gerber 477'/'Halford' peach trees, approximately 2 cm diameter, were root and top pruned and planted in a Spinks sandy loam on May 24, 1980. Approximately 2.5 cm of water was applied by overhead irrigation at the

Table 5. Average dry weights of leaves and branches of current season's growth of 'Harbrite' peaches in containers treated with simazine or oxyfluorfen.

Treatment	Rate (kg/ha)	Placement	Mean Dry Weight (g) Branch & Leaves	Mean Internode Length (cm)
Control	0	Surface	1.98	1.05
Control	0	Incorporated	1.66	0.97
Simazine	4.4	Surface	0.80	0.97
Simazine	4.4	Incorporated	0.67	0.71
Oxyfluorfen	2.2	Surface	1.87	1.00
Oxyfluorfen	2.2	Incorporated	1.95	1.01
Oxyfluorfen	4.4	Surface	2.0	0.98
Oxyfluorfen	4.4	Incorporated	1.82	0.96
$LSD_{.05}$			0.54	0.17

time of planting and trees were irrigated 3 times during the growing season. The planting design was a randomized complete block with three replications and three trees per replication. On June 9, 1980, oxyfluorfen was applied at 2.2, 4.4, and 8.8 kg/ha and simazine was applied at 4.4 kg/ha with a CO_2 backpack sprayer. All treatments were surface applied in bands 0.92 m wide.

To assess growth, the entire trees were sacrificed in late summer. One tree per treatment per replication (15 trees) was harvested August 11, August 25, and September 8, 1980. To retain as much of the root material as possible, a perimeter trench was dug around the root system. Using a garden hose and nozzle, the soil was washed away from the roots by a stream of water. Current season's roots were harvested, dried, and weighed.

Ten branches of current season's growth were measured and internodes counted. (Leaves were not measured due to strong winds removing some leaves during the growing period.)

The third test involved 'Montmorency' cherries on 'Mahaleb' rootstock and was conducted to assess the influence of oxyfluorfen contact on understock sucker growth. Plants were grown in a leaf compost perlite (2:1) mix in two gallon poly containers with 12 to 25 cm of rootstock above the soil level. Plants were grown for four months at which time the leaves were stripped and plants were placed in a cooler at 2°C. Approximately 90 days later the plants were placed in a greenhouse at 25°C under fluorescent lights (16-hr photoperiod). New growth developed with heavily suckered understock growth present after 40 days. The suckers were sprayed at rates equivalent to 2.2 and 4.4 kg oxyfluorfen in 327 l/ha. The plants were placed in the greenhouse in a randomized complete

block design with five replications consisting of one plant per replication. Forty days later, five branches of new growth from each plant were selected. Leaf area, stem length, number of internodes and dry weights were recorded.

RESULTS AND DISCUSSION

After 26 growing days, injury symptoms were already appearing on the peaches that had simazine incorporated in the growing media. At the time of harvest, the surface-applied, simazine-treated plants were also starting to show some phytotoxicity. The oxyfluorfen treated and control plants showed no visual injury.

There was one missing plot for which a value was calculated and a degree of freedom subtracted. Simazine reduced weights of branch and leaves compared to other treatments (Table 5). No significant difference between the control and oxyfluorfen treatments. Oxyfluorfen also had no detrimental effect on terminal growth. Only the incorporated simazine treatment caused significant reduction in internode length (Table 5). However, if this test had been conducted over a longer period of time, the surface-applied simazine treatment may have caused a significant reduction in internode length for phytotoxicity was appearing at harvest time.

There was no significant root injury to 'Harbrite'/'Halford' peaches due to oxyfluorfen (Figure 4). Simazine treatments greatly reduced new root development (Table 6). If oxyfluorfen should get into the root zone of a newly planted peach orchard, injury would not occur; however, if simazine should get into the root zone, not only can top growth be affected, but the roots drastically reduced, causing future growth reductions if not death. The safety of oxyfluorfen on peach was apparent

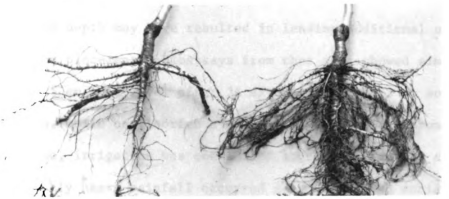
Table 6. Mean dry weights of current season's roots from 'Harbrite'/'Halford' peach after application of oxyfluorfen and simazine.

Treatment	Rate (kg/ha)	Placement	Mean Dry Weight (g)
Control	0	Surface	13.50
Control	0	Incorporated	16.16
Simazine	4.4	Surface	2.45
Simazine	4.4	Incorporated	1.54
Oxyfluorfen	2.2	Surface	16.39
Oxyfluorfen	2.2	Incorporated	11.97
Oxyfluorfen	4.4	Surface	16.85
Oxyfluorfen	4.4	Incorporated	16.69
$LSD_{.05}$			4.65

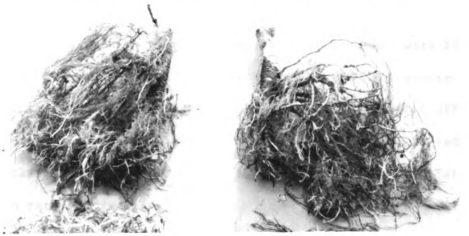
Figure 4. Root systems from 'Harbrite'/'Halford' peach grown in containers (Key: A = Control, B = 4.4 kg/ha simazine incorporated, C = 2.2 kg/ha oxyfluorfen incorporated).

A

B



C



from these test results.

In the field study, peach shoot growth was unaffected by the herbicides (Table 7). The low value obtained for control trees can be attributed to weed interference from high populations in that plot.

Root growth increased as weed control increased. In this field test, however, simazine did not reduce root growth. This was perhaps due to the fact that these plants were planted rather deeply (approximately 45 cm to lower root level) for they had been budded approximately 25 cm above the soil line. At planting the bud union was placed at the soil surface. This depth may have resulted in lending additional simazine selectivity by placement. Bioassays from that area showed simazine to enter the 7-15 cm soil level after 36 days and the 15-23 cm soil level after 60 days, while oxyfluorfen at all rates never moved from the 0-7 cm zone. Also, irrigation was controlled so that it was not a factor and no extremely heavy rainfall occurred at any one time during the test period.

Newly developed suckers (approximately 8 cm at maximum) were killed on peaches with the 2.2 kg/ha of oxyfluorfen, and new sucker growth did not occur for the remainder of the season. Also, no detrimental effect appeared due to this. However, oxyfluorfen should not be considered as a peach desuckering agent until more detailed timing work is completed.

The high rate of oxyfluorfen (8.8 kg) did not hamper root development. Safety of oxyfluorfen on peach was excellent, which confirms reports from the western United States.

In the third test, none of the parameters measured, cm per internode, leaf area, leaf dry weight, and stem dry weight were influenced by oxyfluorfen sprayed on 'Mahaleb' suckers (Table 8). The suckers, however,

Table 7. Current season's growth of 'Gerber 477'/'Halford' peach after application of oxyfluorfen or simazine.

Treatment	Rate (kg/ha)	Mean Length per Internode (cm)	Mean Dry Weight of Roots (g)
Control	0	1.03	6.21
Oxyfluorfen	2.2	1.13	9.82
Oxyfluorfen	4.4	1.15	13.95
Oxyfluorfen	8.8	1.18	19.34
Simazine	4.4	1.18	14.44
$LSD_{.05}$		0.17	7.61

Table 8. 'Montmorency' cherry growth after oxyfluorfen application to actively growing 'Mahaleb' cherry understock.

Treatment	Mean (cm/ internode)	Mean leaf area (sq. cm)	Mean dry leaf weight (g)	Mean dry stem weight (g)
Control	2.67	394.5	2.47	1.19
2.2 kg Oxyfluorfen	2.41	370.6	2.42	1.07
4.4 kg Oxyfluorfen	2.56	423.9	2.54	1.08
$LSD_{.05}$	0.45	77.9	0.50	0.34

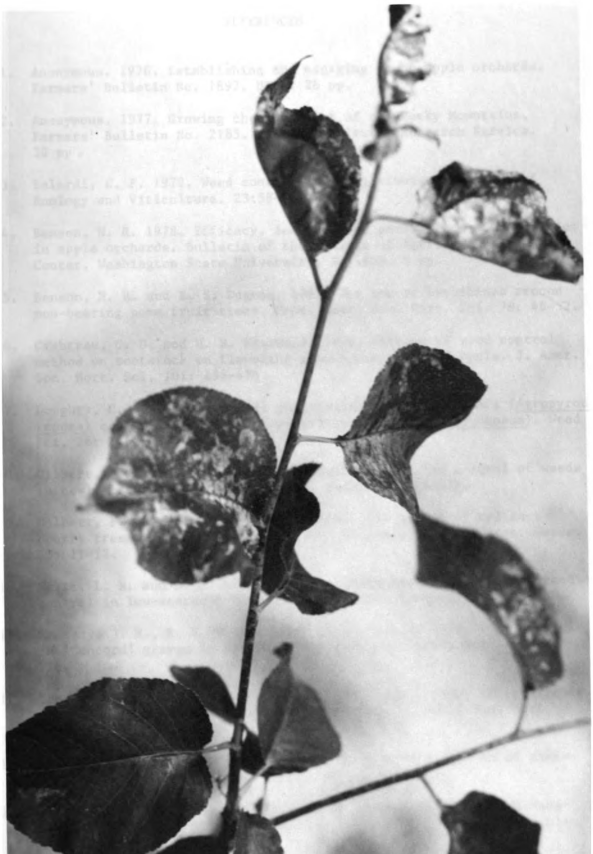
were injured in the form of leaf and tip necrosis, with the youngest tissue being killed (Figure 5). Within two weeks, bud break had occurred and new growth developed. If a sucker was past the four or five leaf stage, oxyfluorfen did not kill it back, therefore oxyfluorfen's contact properties are not 100% effective for desuckering cherries.

Top growth of treated plants was not influenced by oxyfluorfen, indicating little or no translocation occurred. No visual symptoms were apparent on any tops of treated plants. Again, the safety of oxyfluorfen to young plants was apparent.

CONCLUSIONS

Oxyfluorfen did not significantly reduce peach tree growth even when placed in the root zone, nor when applied at high rates to the soil surface or when contacting low leaves. When oxyfluorfen was placed on suckering rootstock of cherry, no significant difference was apparent in cherry top growth. It appears that oxyfluorfen may be safely used on newly planted peach or cherry on sandy soils with an excellent margin of safety of at least 4X.

Figure 5. 'Mahaleb' cherry sucker injury 67 hours after 2.2 kg/ha oxyfluorfen treatment.



REFERENCES

1. Anonymous. 1976. Establishing and managing young apple orchards. Farmers' Bulletin No. 1897. USDA. 26 pp.

2. Anonymous. 1977. Growing cherries east of the Rocky Mountains. Farmers' Bulletin No. 2185. USDA Agricultural Research Service. 30 pp.

3. Balerdi, C. F. 1972. Weed control in young vineyards. Am. J. of Enology and Viticulture. 23:58-60.

4. Benson, N. R. 1978. Efficacy, leaching and persistence of herbicides in apple orchards. Bulletin of the College of Agriculture Research Center, Washington State University, No. 863. 5 pp.

5. Benson, N. R. and E. S. Degman. 1961. The use of herbicides around non-bearing pome fruit trees. Proc. Amer. Soc. Hort. Sci. 78: 46-52.

6. Crabtree, G. D. and M. N. Westwood. 1976. Effects of weed control method on rootstock on flowering growth and yield of apple. J. Amer. Soc. Hort. Sci. 101: 454-456.

7. Doughty, C. C. 1978. Terbacil phytotoxicity and quackgrass (Agropyron repens) control in highbush blueberries (Vaccinium corymbosum). Weed Sci. 26: 488-492.

8. Gilbert, F. A., L. Holm, and E. Haltvick. 1959. The control of weeds in newly established sour cherries. Weeds. 7: 223-229.

9. Gilbert, F., L. Holm, and L. Rake. 1965. The growth of red tart cherry trees with annual applications of simazine and diuron. Weeds. 13: 11-12.

10. Hertz, L. B. and D. K. Wilding. 1978. Quackgrass and broadleaf weed control in low-statured hybrid blueberries. HortSci. 13: 699-700.

11. Kennedy, J. M., R. E. Talbert, and J. R. Morris. 1979. Weed control in 'Concord' grapes in Arkansas. J. Amer. Soc. Hort. Sci. 104: 713-716.

12. Lange, A. H., J. C. Crane, W. B. Fischer, et al, 1969. Pre-emergence weed control in young deciduous fruit trees. J. Amer. Soc. Hort. Sci. 94: 57-60.

13. Lange, A. H. and C. L. Elmore. 1969. Moisture and the use of simazine on Prunus. HortSci. 4: 30-32, 49.

14. Lange, A.,L. Lider, B. Fischer, and H. Agamalian. 1970. Herbicide-variety studies of young grapevines. Amer. J. Enology and Viticulture. 21: 85-93.

15. Lange, A. H. and J. Schlesselman. 1976. Weed control in trees and vines. Weed Control Notes Progress Report. Series 76:1. Univ. of Calif. Parlier, Calif. 22 pp.

16. Lord, W. J., R. A. Damon, Jr., and D. W. Greene. 1973. Response of 'McIntosh' apple trees to annual applications of 2,6-dichlorobenzonitrile (dichlobenil). J. Amer. Soc. Hort. Sci. 98: 596-598.

17. Lord, W. J., R. A. Damon, Jr., and D. E. Robinson. 1970. Comparative responses of three apple rootstocks to soil-incorporated simazine. J. Amer. Soc. Hort. Sci. 95: 737-739.

18. Putnam, A. R. 1975. Chemical weed control in peach orchards. Pages 300-305 in N. F. Childers, ed. The Peach . Horticultural Publ., New Brunswick, N.J., 659 pp.

19. Putnam, A. R. and H. C. Price. 1969. Tolerance of rootstocks and established Malus, Pyrus, and Prunus trees to terbacil. J. Amer. Soc. Hort. Sci. 94: 655-658.

20. Raese, J. T., M. W. Williams, and H. Schomer. 1974. Yield and vigor of 'd'Anjou' pears with early application of triazole and triazine herbicides. HortSci. 9: 32-33.

21. Schlesselman, J. 1977. Annual weed control in deciduous trees and vines. Proc. 29th Ann. Calif. Weed Conf. pp. 96-99.

22. Tweedy, J. A. and S. K. Ries. 1966. Fruit tree tolerance to two triazines. Weeds. 14: 268-269.

23. Weaver, R. J. 1976. Grape growing. John Wiley and Sons. New York. 371 pp.

CHAPTER 4

MOVEMENT AND PERSISTENCE OF OXYFLUORFEN IN MICHIGAN SOILS

ABSTRACT

Randomized complete block field experiments were established in 1979 and 1980 to establish soil behavior of oxyfluorfen in coarse textured soils. Soil samples at 0-7.6, 7.6-15.2, and 15.2-22.9 cm depths were collected at several intervals after treatment and bioassayed with tomato seedlings as the indicator species. Results showed oxyfluorfen not to move out of the 0-7.6 cm level after 130 days at rates up to 8.8 kg/ha, while simazine at 4.4 kg/ha moved into the 7.6-15.2 cm level after only 36 days. For the 2.2 kg/ha of oxyfluorfen, dissipation had occurred within 60 days and for the 4.4 kg/ha of oxyfluorfen, dissipation had occurred within 90 days. The data indicate that a fruit grower need not be concerned about leaching or persistence of oxyfluorfen. This lends additional support for safe use of this herbicide on new fruit plantings in coarse textured soils.

INTRODUCTION

Crop injury may result from leaching herbicides into the root area of the crop, and leaching is enhanced by sandy soil (1). Soil organic matter, cation exchange capacity, exchangeable calcium, moisture equivalent, free drainage value and total exchangeable bases influenced toxicity (25). Cultural practices, such as liming, increased persistence and uptake of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine]; however, absorption differed with species (4). Persistence of simazine in the soil increased with increasing pH and the persistence of simazine was less under no-tillage culture than under conventionally-tilled conditions (22). Heavy sprinkler irrigation has increased leaching and toxicity of simazine to young Prunus rootstocks (12). The rate of disappearance of triazines may vary from year to year, depending on rainfall (12). If sprinkler irrigation follows an application of 2,4-D [2,4-dichlorophenoxy) acetic acid] under apple and pear trees, soil concentration may be high enough to damage the trees (3).

No injury to cherry was observed with simazine or diuron on fine particle soils (10). But Harris (11) reported some substituted urea herbicides and some s-triazine herbicides moved in the soil. On a Monona silty clay loam, cyanazine [2-[4-chloro-6-(ethylamino)-s-triazine-2-yl] amino]-2-methylpropionitrile] and diuron only moved 5 cm (16). In a peach orchard, simazine and linuron moved to a depth of 15 cm (17). Tucker (24) found low levels of bromacil and diuron to soil depths of 60 cm in Florida citrus soils. Benson (2) reported simazine, propyzamide, and terbacil plus diuron to leach to a depth of 61 cm in apple orchards.

The number of years of consecutive applications could be an influ-

encing factor on depth of penetration. In peach orchards, terbacil and dichlobenil did not accumulate in the 0-15 cm soil layer, but low concentrations of terbacil were detected in the 15 to 30 cm soil depth and dichlobenil was detected in the 30 to 60 cm soil depth one year after the third annual application (21). Elmore et al. (7) reported that dichlobenil and simazine caused phytotoxicity symptoms on young prune trees; however, diphenamid (N,N-dimethyl-2,2-diphenylacetamide) may have had a more subtle effect on the trees. After seven consecutive annual applications of simazine and linuron in a peach orchard, varying quantities of herbicides were detected in the following spring and autumn of the last two years of treatment, yet the downward movement did not appear to exceed 15 cm (17). A depth of 15 cm may not seem significant, however the highest concentration of feeder roots was reported to be in the top 10 cm of soil (15). An advantage of the diphenyl ether herbicides has been shown that they did not leach (8, 26).

In Florida citrus soils, a small amount of bromacil (5-bromo-3-sec-butyl-6-methyl-uracil) was detectable one year following application and diuron levels were higher, but residue levels were not accumulative (24). Doughty (5) reported that terbacil did carry-over in the soil from year to year. The carry-over of linuron was 30-40% of the annual treatment rate, while carry-over of simazine was less than 10% (17). Miller et al. (18) reported carry-over of linuron, diuron, and fluometuron [1,1-dimethyl-3-(a,a,a,-trifluoro-m-tolyl) urea] in the tilled zone. Horowitz (11) found diuron and simazine to be highly persistent. Roadhouse and Birk (19) indicated that 2.5% of 2.2 kg/ha simazine application could be found after 2 years and 6.5% after one year. Smith and Hayden (23) also reported that simazine remained active after two

growing seasons.

To detect herbicide presence in soil, bioassays have been used. The main advantage of the bioassay techniques to measure herbicide persistence over chemical methods of estimation is that the bioassay measures directly the residues which are capable of affecting plant growth (12). Fryer and Kirkland (9) found that one year after application of 1.1 kg/ha, simazine could be detected by bioassay. Dowler (6) described a bioassay test using cucumber as the indicator plant for certain herbicide residue in soils. An overview of bioassays for herbicide detection has been presented by Santelmann (20).

The objective of this work was to confirm whether or not oxyfluorfen leached in sandy soils and how long it persisted under Michigan conditions by use of bioassays.

MATERIALS AND METHODS

During 1979 and 1980, randomized complete block experiments were established with many of the sites being treated both years (Table 9). The soil types were predominantly sandy loams with organic matter contents of less than 3% (Table 10). Soil samples were then collected at random using a soil probe obtaining approximately 20 subsamples per plot from three depths: 0-7.6, 7.6-15.2, and 15.2-22.9 cm. In the fall of 1979, soils were also collected from the 0-20.3, 20.3-40.6, and 40.6-61.0 cm levels, using a truck mounted soil core sampler. Samples were placed in plastic bags and either frozen until bioassayed in the greenhouse or planted the day of collecting.

Tomato (Lycopersicon esculentum Mill.) proved to be a very satisfactory indicator for both oxyfluorfen and simazine (Appendix 1). The to-

Table 9. Soil samples collected for bioassays.

Location	Date Treated	Date Collected
Lawton	5-31-79	8-8-79
		11-27-79
	4-17-80	6-18-80
		7-17-80
Hartford	4-17-80	6-18-80
		7-17-80
Watervliet	5-4-79	7-13-79
		11-27-79
	4-17-80	6-18-80
		7-18-80
Traverse City	5-9-79	6-28-79
East Lansing	6-9-80	7-15-80
		8-8-80
		9-8-80
		10-17-80

Table 10. Soil Characteristics for Lawton, Michigan site.

Depth (cm)	Percent Sand	Percent Silt	Percent Clay	Texture	pH
0-7.6	41	34	24	Loam	4.4
7.6-15.2	76	11	13	Sandy loam	4.8
15.2-22.9	80	3	17	Sandy loam	5.1

tomato VF 134, from Petoseed Co., was used for the bioassays which were done in four-inch styrofoam pots placed in aluminum pie dishes so that watering could be alternated between top and bottom.

A filter paper was placed in the bottom of the pot. Each soil sample was volumetrically (400 ml) added to the pots and the surface smoothed. Twenty tomato seeds were distributed over the soil surface and covered with an additional 100 ml of soil. Pots were placed under metal halide lamps (16-hr photoperiod) in a 21°C greenhouse in a randomized complete block design. Plants were watered as needed and fertilized once with Peter's 20-20-20 soluble fertilizer during each of the second and third weeks. After three weeks, tomato shoots were harvested, dried, and weighed.

RESULTS AND DISCUSSION

Data from the Lawton and East Lansing sites are selected for presentation since they accurately represent the results of the entire study.

After 70 days, the 2.2 kg/ha rate of oxyfluorfen remained active in the 0-7.6 cm layer, at a level of about 0.65 ppm (Appendix 1), while the lower rate of oxyfluorfen had dissipated (Table 11, Figure 6). Simazine at the 2.2 kg/ha rate also persisted in the 0-7.6 cm layer. Otherwise, there were no significant differences at the 5% level with either rate of oxyfluorfen at any depth and the control at any depth. Leaching had not occurred. The fall samples (130 days) confirmed that oxyfluorfen was not at a greater depth and that dissipation of oxyfluorfen had occurred.

When tomatoes are grown in oxyfluorfen-treated soils, the germinating seedlings become twisted and later die. If a tomato seedling did survive in soil from an oxyfluorfen-treated plot, a depressed or sunken area was observed on the tomato stem at the soil surface area.

The 1980 results for Lawton indicated a more rapid dissipation of oxyfluorfen than in 1979, for after 60 days the 2.2 kg/ha of oxyfluorfen (approximately 0.57 ppm) was equivalent to control samples. This was also apparent in the weed ratings (Chapter 2, Table 3), for the 60 day evaluation indicated weed presence was developing and growers could not expect grass control past 60 days at the 2.2 kg/ha rate. Again, leaching did not occur and after 90 days, oxyfluorfen had totally dissipated.

The 1980 tests from the East Lansing site (Table 12, Figure 7) provided an explicit picture of leaching and dissipation of oxyfluorfen and simazine. After 36 days, simazine at 4.4 kg/ha had moved into the 7.6-15.2 cm soil level while oxyfluorfen at 8.8 kg/ha remained in the 0-7.6 cm depth. At 60 days, the 2.2 kg/ha of oxyfluorfen had dissipated. While at 90 days, the 4.4 kg/ha of oxyfluorfen had dissipated. At 130 days, the 8.8 kg/ha of oxyfluorfen was still active in the 0-7.6 cm depth, as was the 4.4 kg/ha of simazine. The simazine was also active in the 7.6-15.2 cm level while oxyfluorfen never leached to that depth.

For new plantings, oxyfluorfen safety may be excellent because the herbicide remains in the surface area of the soil. Excessive persistence does not occur with 2.2 and 4.4 kg/ha of oxyfluorfen. Higher rates would not need to be recommended to growers. The soil data confirm the usefulness of this compound for weed control in new deciduous fruit plantings.

Figure 6. Tomato bioassay results of soils collected at the Lawton site during 1979 and 1980.

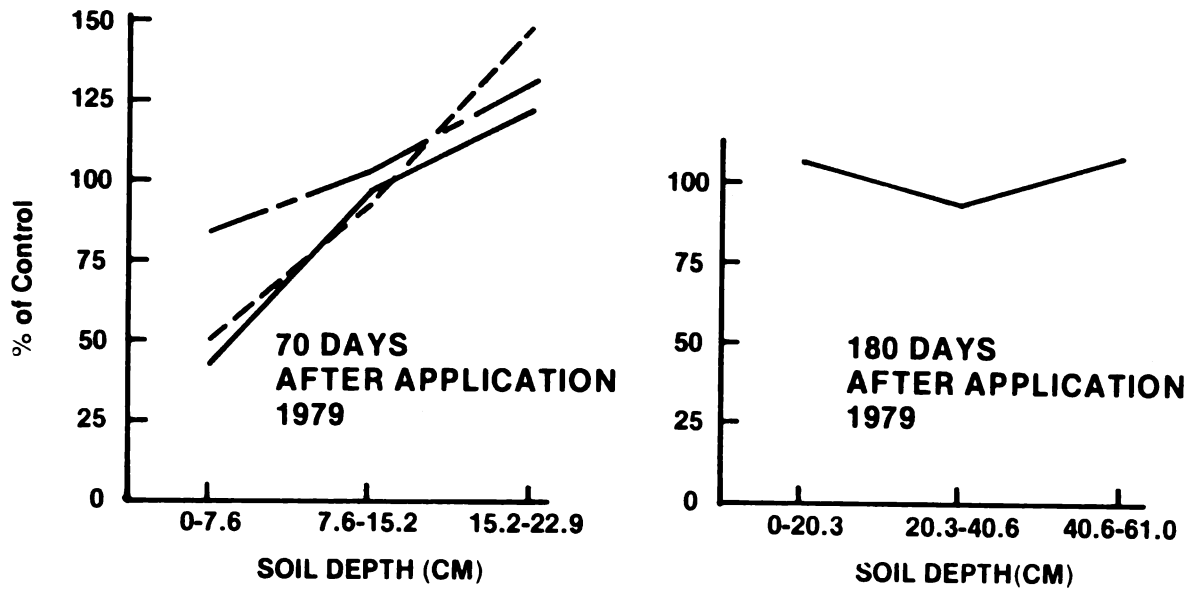

150
125
100
75
50
25
0
% of Control
70 DAYS
AFTER APPLICATION
1979
0-7.6
7.6-15.2
15.2-22.9
SOIL DEPTH (CM)
100
75
50
25
0
180 DAYS
AFTER APPLICATION
1979
0-20.3
20.3-40.6
40.6-61.0
SOIL DEPTH(CM)
OXYFLUORFEN 1.1 kg/HA
SIMAZINE 2.2 kg/HA
OXYFLUORFEN 2.2 kg/HA
100
75
50
25
0
% of Control
60 DAYS
AFTER APPLICATION
1980
0-7.6
7.6-15.2
15.2-22.9
SOIL DEPTH(CM)
100
75
50
25
0
90 DAYS
AFTER APPLICATION
1980
0-7.6
7.6-15.2
15.2-22.9
SOIL DEPTH (CM)

Table 11. Mean dry weights of tomato bioassay for soils from the Lawton, Michigan site during 1979 and 1980.

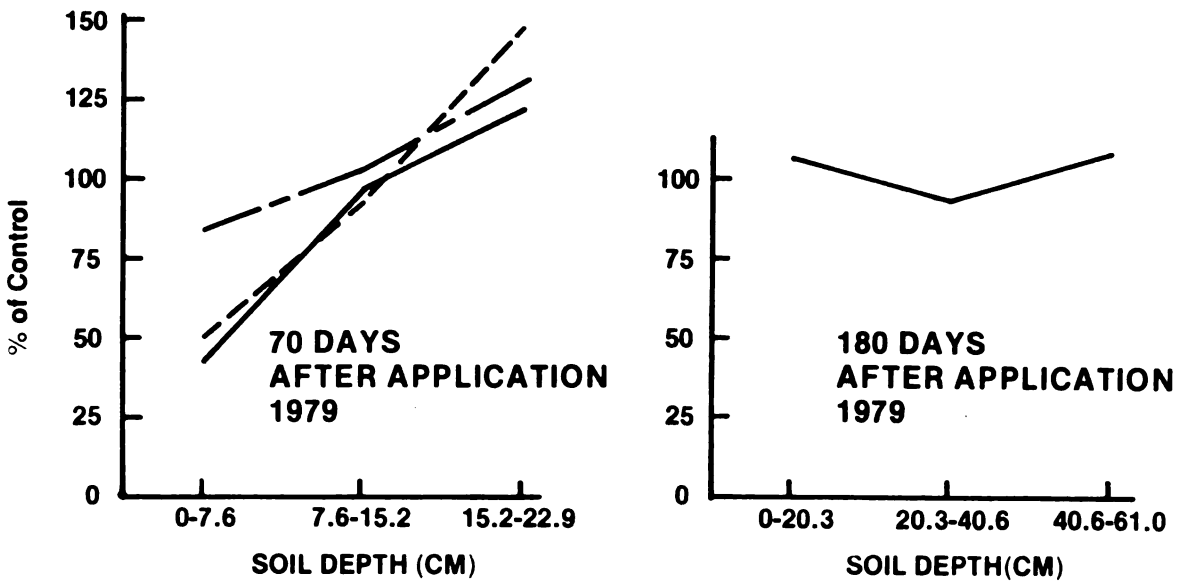
Treatment	Soil Depth (cm)	Mean dry weights (g) Days after treatment			
		1979		1980	
		70 days	180 days*	60 days	90 days
Control	0-7.6	1.09	0.72	0.66	1.43
	7.6-15.2	1.02	0.85	0.67	1.22
	15.2-22.9	0.78	0.78	0.69	1.38
Oxyfluorfen 1.1 kg/ha	0-7.6	0.92		0.54	1.23
	7.6-15.2	1.05		0.60	1.47
	15.2-22.9	1.02		0.70	1.47
Oxyfluorfen 2.2 kg/ha	0-7.6	0.46	0.76	0.54	1.26
	7.6-15.2	0.99	0.79	0.64	1.36
	15.2-22.9	0.95	0.84	0.81	1.49
Simazine 2.2 kg/ha	0-7.6	0.54		0.23	1.34
	7.6-15.2	0.96		0.54	1.34
	15.2-22.9	1.16		0.75	1.53
$LSD_{.05}$		0.30		0.22	0.34

*Soil samples were taken every 20.3 cm.

Table 12. Mean dry weights of tomato bioassay for soils from East Lansing, Michigan location during 1980.

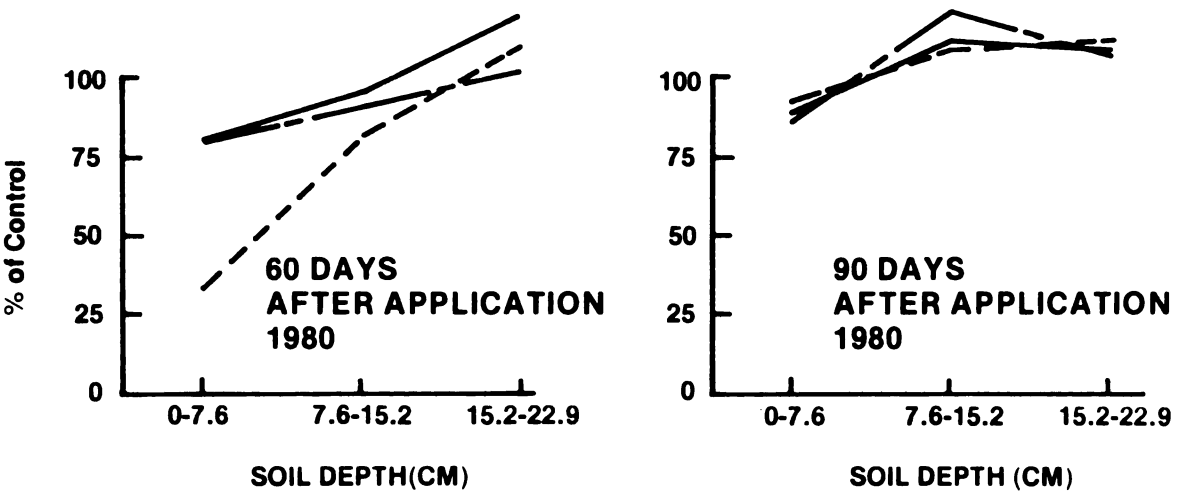
Treatment	Soil depth	Mean dry weight (g) Days after treatment			
		36 days	60 days	90 days	130 days
Control	0-7.6	0.71	1.63	1.15	1.27
	7.6-15.2	0.60	1.50	1.07	1.33
	15.2-22.9	0.67	1.62	1.20	1.29
Oxyfluorfen 2.2 kg/ha	0-7.6	0.31	1.58	1.08	1.24
	7.6-15.2	0.76	1.56	1.14	1.46
	15.2-22.9	0.76	1.74	1.09	1.46
Oxyfluorfen 4.4 kg/ha	0-7.6	0.30	0.44	1.05	1.30
	7.6-15.2	0.82	1.55	1.10	1.51
	15.2-22.9	0.88	1.55	1.19	1.38
Oxyfluorfen 8.8 kg/ha	0-7.6	0	0.05	0.36	0.39
	7.6-15.2	0.73	1.56	1.05	1.49
	15.2-22.9	0.91	1.78	1.09	1.43
Simazine 4.4 kg/ha	9-7.6	0	0.03	0.47	0.42
	7.6-15.2	0.08	0.65	0.76	0.73
	15.2-22.9	0.58	1.19	1.01	1.26
$LSD_{.05}$		0.29	0.52	0.24	0.33

Figure 7. Tomato bioassay results of soils collected at the East Lansing site during 1980.



——— OXYFLUORFEN 1.1 kg/HA — — — — SIMAZINE 2.2 kg/HA

——— OXYFLUORFEN 2.2 kg/HA



REFERENCES

1. Anderson, W. P. 1977. Weed science: principles. West Publishing Co. New York. 598 pp.

2. Benson, N. R. 1978. Efficacy, leaching and persistence of herbicides in apple orchards. Bulletin of the Coll. of Agric. Res. Ctr. Washington State Univ. No. 863. 5 pp.

3. Benson, N. R. and R. P. Covey, Jr. 1974. Soil toxicity of 2,4-D to pome fruit trees from herbicide application. J. Amer. Soc. Hort. Sci. 99: 79-83.

4. Best, J. A., J. B. Weber, and T. J. Monaco. 1975. Influence of soil pH on s-triazine availability to plants. Weed Sci. 23: 378-382.

5. Doughty, C. C. 1978. Terbacil phytotoxicity and quackgrass (Agropyron repens) control in highbush blueberries (Vaccinium corymbosum). Weed Sci. 26: 488-492.

6. Dowler, C. C. 1969. A cucumber bioassay test for the soil residues of certain herbicides. Weed Sci. 17: 309-310.

7. Elmore, C. L., A. H. Lange, L. L. Buschman, and D. H. Chaney. 1970. Annual weed control in young prunes. HortSci. 5: 263-264.

8. Fadayomi, O. and G. F. Warren. 1977. Adsorption, desorption and leaching of nitrofen and oxyfluorfen. Weed Sci. 25: 97-100.

9. Fryer, J. D. and K. Kirkland. 1970. Field experiments to investigate long-term effects of repeated applications of MCPA, tri-allate, simazine, and linuron: report after 6 years. Weed Res. 10:133-158.

10. Gilbert, F., L. Holm, and L. Rake. 1965. The growth of red tart cherry trees with annual applications of simazine and diuron. Weeds. 13:11-12.

11. Harris, C. I. 1967. Movement of herbicides. Weeds. 15: 214-216.

12. Holly, K. and H. A. Roberts. 1963. Persistence of phytotoxic residues of triazine herbicides in soil. eeds Res. 3: 1-10.

13. Horowitz, M. 1969. Evaluation of herbicide persistence in soil. Weed Res. 9: 314-321.

14. Lange, A. H. and C. L. Elmore. 1969. Moisture and the use of simazine on Prunus. HortSci. 4: 30-32, 49.

15. Lyons, C. G., Jr. and K. S. Yoder. 1981. Poor anchorage of deeply planted peach trees. HortSci. 16: 48-49.

16. Majka, J. T. and T. L. Lavy. 1977. Adsorption, mobility and degradation of cyanazine and diuron in soils. Weed Sci. 25: 401-406.

17. Marriage, P. B. and W. J. Saidak. 1976. Simazine and linuron residues in peach orchard soil after repeated annual applications. Can. J. of Soil Sci. 56: 111-114.

18. Miller, J. H., P. E. Keeley, R. J. Thullen, and C. H. Carter. 1978. Persistence and movement of ten herbicides in soil. Weed Sci. 26: 20-27.

19. Roadhouse,F. E. B. and L. A. Birk. 1961. Penetration of and persistence in soil of the herbicide 2-chloro-4,6-bis (ethylamino)-s-triazine (simazine). Can. J. Plant Sci. 41: 252-260.

20. Santelmann, P. W. 1977. Herbicide bioassay. Pages 79-87 in Bryan Truelove, ed. Research Methods in Weed Science, 2nd ed. Auburn Printing, Auburn, Ala. 221 pp.

21. Skroch, W. A., T. J. Sheets, and J. W. Smith. 1971. Herbicide effectiveness, soil residues, and phytotoxicity to peach trees. Weed Sci. 19: 257-260.

22. Slack, C. H., R. L. Blevins, and C. E. Rieck. 1978. Effect of soil pH and tillage on persistence of simazine. Weed Sci. 26: 145-148.

23. Smith, A. E. and B. J. Hayden. 1976. Field persistence studies with eight herbicides commonly used in Saskatchewan. Can. J. of Plant Sc. 56: 769-771.

24. Tucker, D. P. H. 1978. Bromacil and diuron residue levels in Florida citrus soils. HortSci. 13: 346.

25, Upchurch, R. P. and D. D. Mason. 1962. The influence of soil organic matter on the phytotoxicity of herbicides. Weeds. 10: 9-14.

26. Walter, J. P., E. F. Eastin, and M. G. Merkle. 1962. The persistence and movement of fluorodifen in soils and plants. Weed Res. 10: 165-171.

CHAPTER 5

ABSORPTION AND TRANSLOCATION OF ^{14}C-OXYFLUORFEN IN *PRUNUS CERASUS* L. 'MONTMORENCY' AND *VITIS LABRUSCA* L. 'CONCORD'

ABSTRACT

Studies were conducted with ^{14}C-oxyfluorfen in nutrient solution, on green stems, and on leaves to determine absorption and translocation in 'Concord' grape and 'Montmorency'/'Mahaleb' cherry. Roots readily absorbed ^{14}C-oxyfluorfen during the first 24 hr. but then slowed in rate of absorption. Of the ^{14}C absorbed by the roots, less than 2% was translocated. When green stems were treated with ^{14}C-oxyfluorfen, localized treated areas became necrotic. Absorption increased up to 96 hr where it leveled off. Absorption was less than 2% of the ^{14}C recovered after 216 hr, and no significant amount was translocated. With leaf treatments, absorption of ^{14}C also appeared to level off. There was no significant difference in uptake between young and old leaves. Translocation from the treated leaf was not significant. The safety of oxyfluorfen to deciduous fruit crops is such that growers would not need to be concerned if oxyfluorfen got into the root zone, on the green stem, or on the leaves of the crop for translocation does not occur.

INTRODUCTION

The movement of herbicides within plants is a factor of concern because of possible residues and adverse effects at distant sites of action. This is of particular concern with perennial crops where effects can be long term. When 2,4-D was applied to filbert (Corylus avellana L.) suckers, translocation occurred (10). Crafts (1) reported 2,4-D, monuron, and amitrole (3-amino-s-triazole) to move in plants. Monuron moved from the roots to leaves (8), and translocation upward was very rapid (6). Rogers (11) had also shown that translocation occurred with amitrole. Glyphosate [N-(phosphonomethyl) glycine] was reported to readily move to active meristems (12). Putnam (9) indicated that glyphosate applications to the basal trunk and lower branches of peach resulted in trunk splitting and death of the tree. Kennedy et al. (7) observed injury to 'Concord' grapes during May and June resulting from glyphosate getting on suckers and low branches the previous September.

With the diphenyl ether herbicides, movement within plants has varied. Eastin (3,4) reported rapid absorption and acropetal translocation of ^{14}C-fluorodifen in cucumber seedlings while peanuts just absorbed ^{14}C-fluorodifen (2). Vanstone (13) reported ^{14}C-nitrofluorfen to be translocated more extensively than ^{14}C-oxyfluorfen with neither compound being metabolized rapidly by faba bean or yellow foxtail. With sorghum and pea, Fadayomi and Warren (5) found little movement of nitrofen or oxyfluorfen from the roots, and when either herbicide was applied to the foliage, almost all of the applied herbicide remained at the point of application. The objective of this work was to confirm if oxyfluorfen was absorbed and translocated in selected fruit species.

MATERIALS AND METHODS

Root Uptake

Studies were conducted with ^{14}C-oxyfluorfen (2.6 µCi/mg) which was uniformly labeled in the nitrophenyl ring. The ^{14}C-oxyfluorfen was dispersed in 10 ml of acetone making a 1.97 mg/ml acetone solution. When root uptake was investigated, 20 µl of ^{14}C-oxyfluorfen and acetone were added to each cup by using a 100 µl syringe.

A separate study was conducted to determine if the plastic cups retained any oxyfluorfen. Hoagland's solution (150 ml) was placed in four foil-covered plastic cups and 20 µl of ^{14}C-oxyfluorfen plus acetone was added to each cup. One ml samples were taken after 15, 30, 45, and 60 minutes and added to 15 ml of ACS[1] cocktail. All samples were quantified for radioactivity by liquid scintillation spectrometry and corrected for quenching by external standardization.

'Montmorency' cherry seed was collected and stratified at 1.7°C for 180 days. The seed was sown and germinated. After the seedlings reached the two true leaf stage, the plant was removed from the germinating media and the roots were washed under tap water to remove any media that may have adhered to the roots. The plants were then placed in foil-covered plastic cups, with 150 ml of Hoagland's solution. The plant was supported by a slit foam rubber disc cut to fit the top of the cup. After 24 hours the plants were transferred to another cup of Hoagland's solution and ^{14}C-oxyfluorfen. Plants were harvested after 12, 24, and 48 hours. Roots were washed in a 10x oxyfluorfen solution to remove any ^{14}C-oxyfluorfen adhering to the root surface. Plants were separated into root, stem, or leaf sections and frozen. The samples were later

---

[1] Manufactured by Amersham Corporation

freeze-dried and oxidized with a biological oxidizer (Harvey OX-200). Carbosorb II and Permaflour V (2:1, v/v) were the CO_2 trapping and fluor cocktail solutions used. Samples taken from the root wash and nutrient solution were placed in ACS cocktail. All samples were quantified for radioactivity by liquid scintillation spectrometry and corrected for quenching by external standardization.

Hardwood 'Concord' grape cuttings were rooted for 30 days. After the initiation of roots and top growth, the roots were washed under tap water and the plants were treated like the cherry seedlings. However, with the grapes, only new growth was oxidized and not the section of original cutting due to its size.

Foliage and Stem Treatments

Studies were also conducted where ^{14}C-oxyfluorfen was applied to cherry or grape leaves and green stems. Treatments were allowed to remain on the plant up to nine days. The ^{14}C-oxyfluorfen treatments consisted of 20 µl of ^{14}C-oxyfluorfen plus acetone combined with 80 µl of formulated 2E oxyfluorfen plus water (1:35, v/v) to duplicate field treatments as much as possible. With 'Montmorency' cherry, treatments to be continued longer than five days had to be reduced to 20 µl ^{14}C-oxyfluorfen and 30 µl formulation plus water (1:35, v/v) or otherwise leaf abscission would occur. Other studies of five days or more were conducted on cherries with ^{14}C-oxyfluorfen plus methanol (200 µg/µl) plus the 2E oxyfluorfen plus water (1:35, v/v). At harvest, 50 ml of methanol was used to wash the treated site. Samples were collected from the wash and assayed. Plant parts were harvested and frozen, and lyophilized prior to oxidation.

All treatments had a minimum of two replications for each sampling

time. Where the grape leaf was treated, two leaves above and below the treated leaf were harvested (Figure 8). Due to size, leaf petioles were handled separately. Also, a stem section, which included the node of the treated leaf, and terminal section was harvested.

With the grape stem treatment, two leaves, above and below the treated area were harvested (Figure 9). The treated stem section, stem sections above and below the treated section, and a terminal section were harvested. Again, the leaf petiole was detached from the leaf blade.

Nine treated leaves and a stem section of cherry branches which included the node of one treated leaf were harvested (Figure 10). Terminal leaves were harvested if development had occurred after treatment but before harvest.

With cherry stem treatments, two internode sections were treated (Figure 11). The leaf from the center of the treated section was harvested along with two leaves above and below the treated area, stem sections above and below the treated area, and a terminal section. The stem of cherry was too thin and glabrous to retain the quantity of the desired treatment; therefore, filter paper was placed around the stem on three sides. This allowed the treatment to be placed in direct contact with the stem and yet prevented runoff. The filter paper was oxidized when the plant tissues were harvested.

RESULTS AND DISCUSSION

Root Uptake

The plastic cups were found to retain approximately 75% of the ^{14}C-oxyfluorfen and this was taken into account when making data calculations. Data from cherry seedlings grown in ^{14}C-oxyfluorfen nutrient

Figure 8. Distribution of ^{14}C 216 hours after treating grape leaves with ^{14}C-oxyfluorfen.

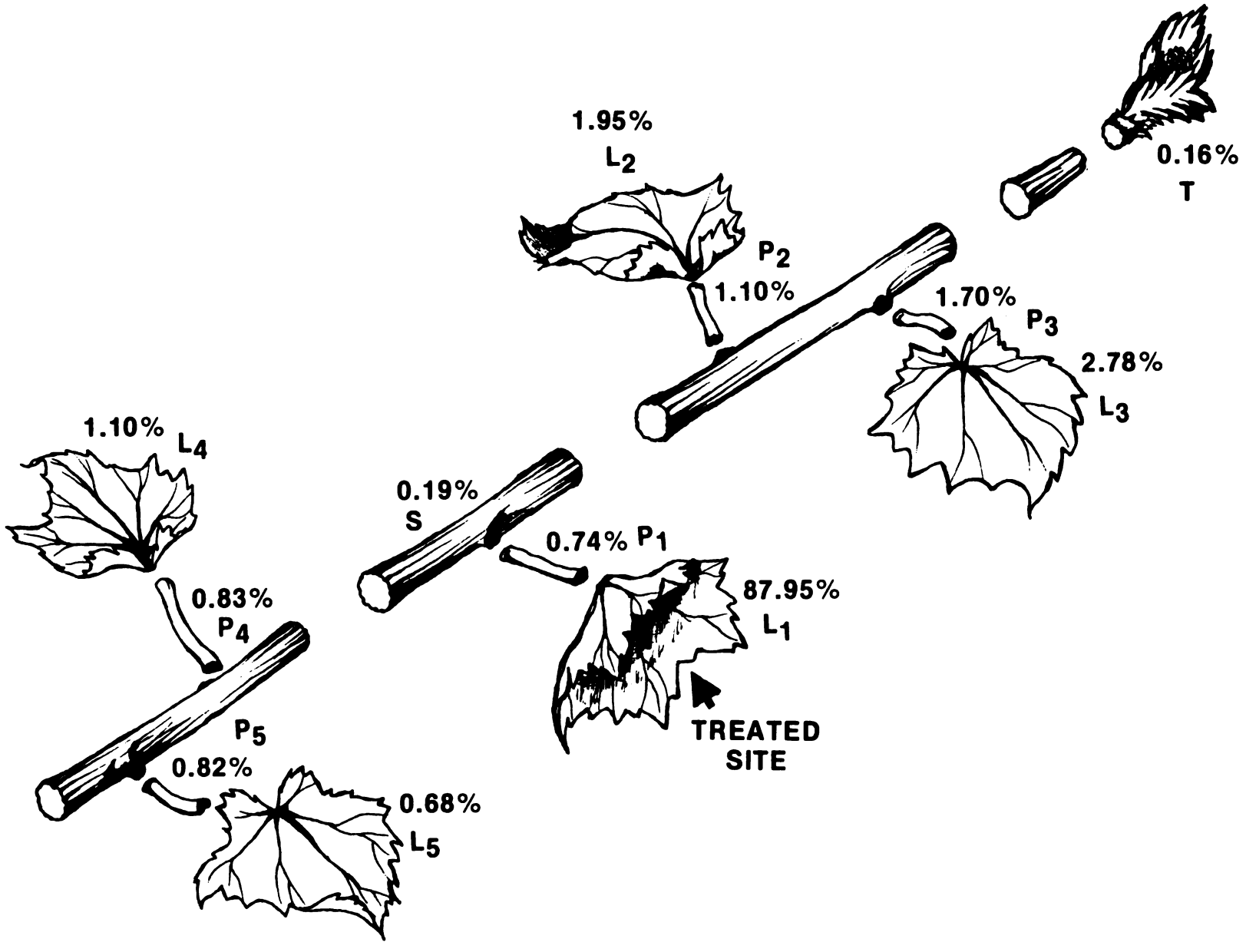

1.95%
L2
P2
1.10%
0.16%
T
1.70%
P3
2.78%
L3
1.10%
L4
0.19%
S
0.74%
P1
87.95%
L1
0.83%
P4
P5
0.82%
0.68%
L5
TREATED
SITE

Figure 9. Percent of total ^{14}C recovered in plant parts, the percent mean distribution of the 216-hour treatment is presented, based on six replications.

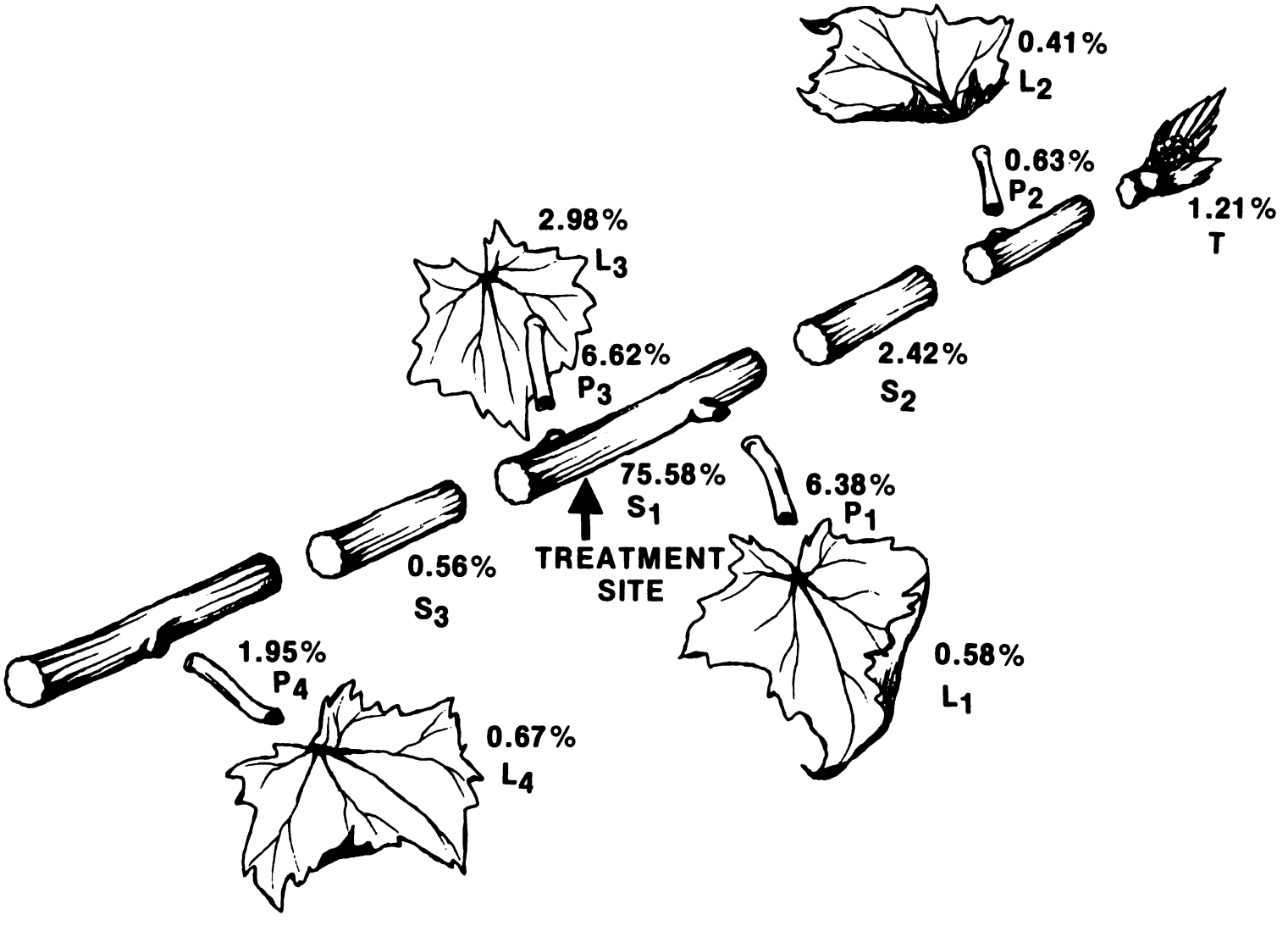

0.41%
L2
0.63%
P2
1.21%
T
2.98%
L3
6.62%
P3
2.42%
S2
75.58%
S1
6.38%
P1
TREATMENT
SITE
0.56%
S3
1.95%
P4
0.67%
L4
0.58%
L1

Figure 10. Mean distribution of percent ^{14}C remaining in the cherry plant after ^{14}C-oxyfluorfen treatment for 216 hours.

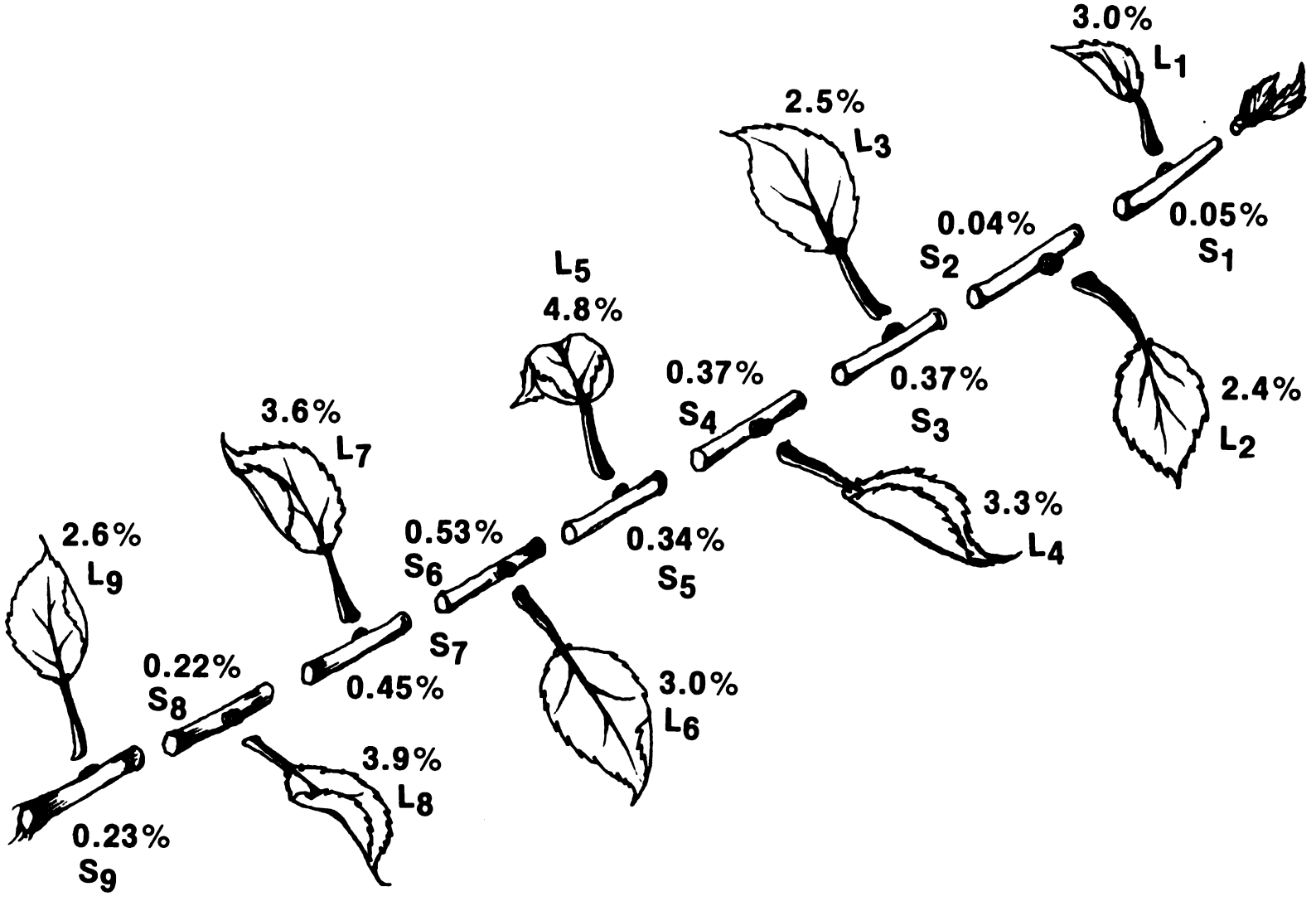
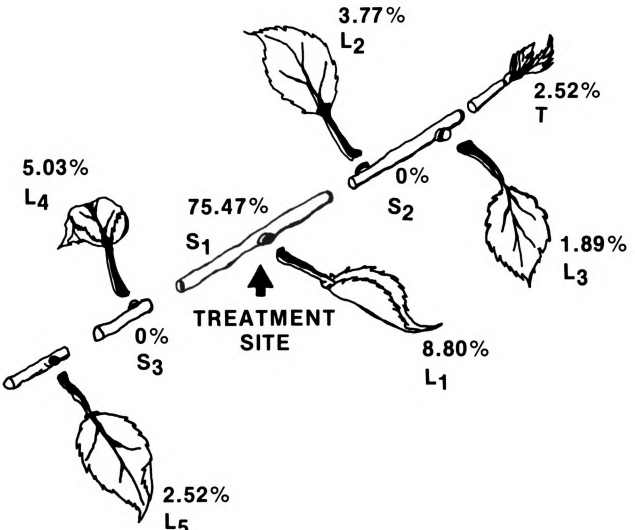

3.0%
L1
2.5%
L3
0.04%
S2
0.05%
S1
L5
4.8%
0.37%
S4
0.37%
S3
2.4%
L2
3.6%
L7
3.3%
L4
2.6%
L9
0.53%
S6
0.34%
S5
S7
0.22%
S8
0.45%
3.0%
L6
3.9%
L8
0.23%
S9

Figure 11. Mean percent distribution of ^{14}C in plant parts after ^{14}C-oxyfluorfen was applied to green stem and allowed to remain for 216 hours.


3.77%
L2
2.52%
T
5.03%
L4
0%
S2
75.47%
S1
1.89%
L3
TREATMENT
SITE
0%
S3
8.80%
L1
2.52%
L5

solution were based on 16 plants per harvest period. The results were averaged into groups of 4 so that statistical analysis could be performed with available computer programs (Table 13).

Using a two-way factorial analysis, the main effects of plant parts were highly significantly different whereas the time X plant parts interaction was also significantly different (Table 14, Figure 12). Uptake increased up to 24 hr., with no significant increase after that time. After 48 hr, only 10% of the recovered ^{14}C was in the roots and no significant amount in the stems or leaves. The majority (89%) remained in the nutrient solution (Table 15). Although root absorption occurred, there was no translocation.

The rooted grape cuttings were harvested after 24 and 48 hr of treatment. The results were similar to those from the cherry seedlings, but the data represented 9 replications. The grape roots absorbed more ^{14}C-oxyfluorfen; however, the root mass was ten times greater with the grapes than the cherry seedlings (Table 16, Figure 13). After 24 hr, there was no increase in the amount of ^{14}C absorbed; however, there were higher numerical values in the 48 hr stems and leaves than in the 24 hr stems and leaves (Table 16). These increased concentrations only account for 0.43% and 0.08% respectively of the total ^{14}C recovered (Table 17). There was no significant translocation from the roots of grapes to leaves or new stems.

If oxyfluorfen should get into the root zone of cherries or grapes grown in the field, movement into the roots may occur; however, translocation to any other plant part would not occur. For growers, this should mean top injury to a crop would probably not result after root uptake. From previous test (Chapter 3) there is no apparent injury to

Table 13. Total ^{14}C (corrected dpm's) in cherry seedlings after uptake of ^{14}C-oxyfluorfen from nutrient solutions.

Time After Treatment (hr)	DPM [1]		
	Roots	Stem	Leaves
12	5593	66	32
	9892	142	37
	9973	137	30
	9264	41	23
MEAN	8630.5[b]	96.5[a]	30.5[a]
24	20597	122	36
	17372	54	33
	12053	111	15
	7047	45	9
MEAN	14267[c]	83[a]	23[a]
48	20438	197	54
	15704	80	46
	19202	289	44
	11248	53	17
MEAN	16648[c]	155[a]	40[a]

[1]Means with uncommon letters are significantly different by Duncan's Multiple Range Test at 5% level.

Table 14. Two-way factorial analysis of variance of cherry seedlings grown in ^{14}C-oxyfluorfen nutrient solution.

Source	D.F.	Mean Square	F-Ratio
Replication	3	.796546E 7	1.3
Time	2	.228918E 8	3.75*
Plant Part	2	.687565E 9	112.75**
Time X Part	4	.224642E 8	3.7*
Error	24	.609819E 7	
Total	35		

** Significant at 1%

* Significant at 5%.

Figure 12. Relative distribution of ^{14}C recovered in various parts of cherry seedlings.

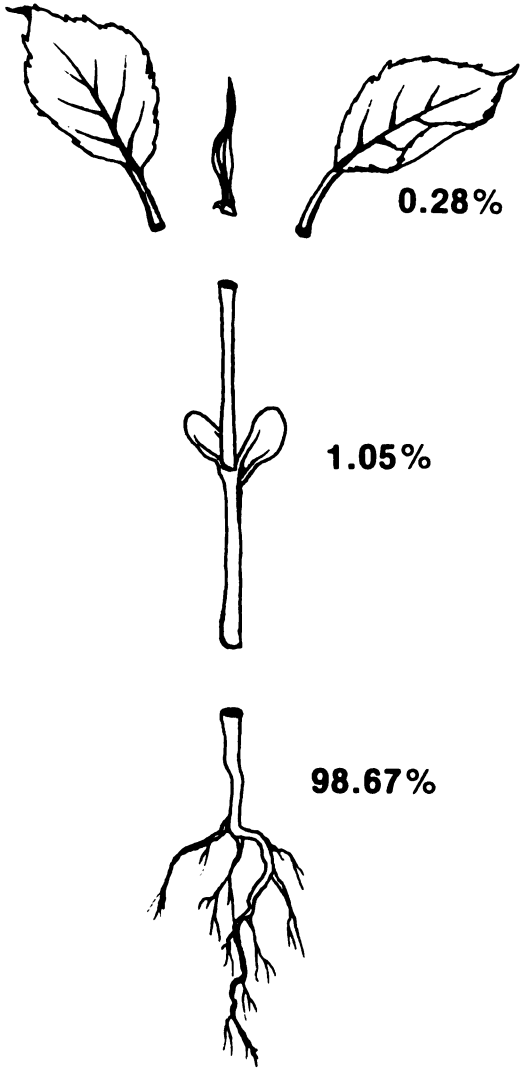

0.28%
1.05%
98.67%

Table 15. Mean distribution of total ^{14}C recovered from cherry seedlings grown in ^{14}C-oxyfluorfen nutrient solution.

Time of Treatment (hrs.)	Percent				
	Roots	Leaves	Stems	Root Wash	Nutrient Solution
12	5.67	0.03	0.1	0.67	93.52
24	8.96	0.01	0.05	0.83	90.14
48	10.04	0.02	0.09	0.7	89.14

Table 16. Means of corrected dpm's for grapes grown in ^{14}C-oxyfluorfen nutrient solution.

Time after Treatment (hrs)	Time	Roots [1]	Leaves [1]	Stem [1]
24	20208	60467[b]	124[a]	33[a]
48	18839	56122[b]	316[a]	78[a]

[1]Means with uncommon letters are significantly different by Duncan's Multiple Range Test at 5% level.

Figure 13. Relative distribution of the ^{14}C recovered in various grape plant parts after 48 hours.

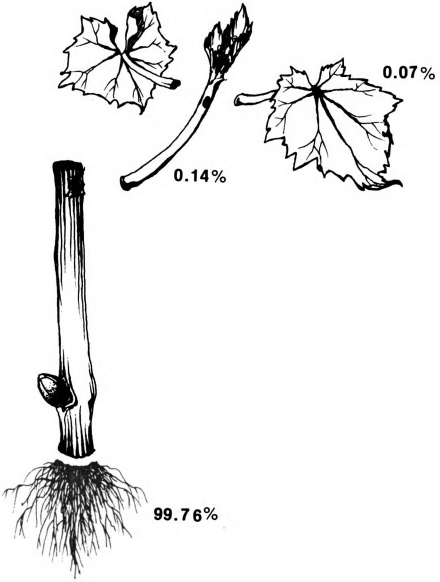

0.07%
0.14%
99.76%

Table 17. Mean distribution of total ^{14}C recovered from grapes and nutrient solution containing ^{14}C-oxyfluorfen.

Time after Treatment (hrs)	Percent				
	Roots	Leaves	Stems	Root Wash	Nutrient Solution
24	41.21	0.09	0.03	3.19	55.48
48	39.12	0.43	0.08	4.64	55.73

root systems from oxyfluorfen.

Stem Absorption

Within 48 hr after treatment, grape green stem sections turned purple and then brownish black, but growth in the other areas was not influenced. The results of the grape stem treatment revealed 1.44% of the herbicide entered the plant (Table 18). After 216 hr, 76% of the amount absorbed remained at the point of application (Figure 9).

To observe if green stems of 'Montmorency' cherry would respond similarly to green stems of 'Concord' grape, the 192 and 216 hr treatments were selected for comparison with three replications per time. Less than 2% of the ^{14}C remained with the plant after washing the treated area with 50 ml of methanol (Table 19). The majority of ^{14}C in the plant remained at the site of application (Table 20, Figure 6). Of the 1.2% of ^{14}C retained by the cherry plant after 216 hours, 75% remained at the site of application, which was significantly different from other harvested portions of the plant.

There was very little absorption of ^{14}C-oxyfluorfen by the green stems of grape or cherry. Of the ^{14}C absorbed, no significant quantity was translocated. If oxyfluorfen should contact green stems of grape or cherry in the field, there would be no reason for concern. Unless the 2.5-5 cm terminal end of a stem is covered with oxyfluorfen, no serious injury would result. Otherwise, tip necrosis would occur, if the plant is actively growing, followed by lateral bud break. If active growth is not occurring, discoloration may occur with no other indication of injury.

Leaf Absorption

When applications of ^{14}C-oxyfluorfen were made to the leaves of

Table 18. Mean percents of ^{14}C recovered after ^{14}C-oxyfluorfen application to green grape stems.

Plant Part (see Fig. 4)	Time after Treatment (hrs)			
	24	48	96	216
S_1	0.75	0.65	1.57	1.09
S_2	0.01	0	0.01	0.02
S_3	0.02	0	0.02	0.01
L_1	0.03	0.04	0.07	0.02
P_1	0.01	0	0.01	0.03
L_2	0.02	0.01	0.01	0.02
P_2	0	0	0	0
L_3	0.08	0.03	0.07	0.16
P_3	0.01	0	0.02	0.04
L_4	0.05	0.03	0.15	0.04
P_4	0.04	0.05	0.04	0
T	0.02	0.01	0.01	0.01
Wash	98.97	99.15	98.03	98.56

Table 19. Mean percent of ^{14}C recovered after treating green cherry stem with ^{14}C-oxyfluorfen and waiting 192 or 216 hours before harvesting.

Observed Portion (see Fig. 6)	Time (hrs) 192	216
L_1	0.06	0.14
L_2	0.04	0.06
L_3	0.07	0.03
L_4	0.04	0.08
L_5	0.09	0.04
T_1	0.02	0.04
S_1	0.75	1.20
S_2	0.02	0
S_3	0.05	0
Paper	2.59	3.31
Wash	96.28	95.10

Table 20. Mean corrected dpm's for the plant parts of the cherry stem treatments at 192 and 216 hours .

Plant Part (see Fig. 3)	Time after Treatment (hrs) 192	216
S_1 (treated)	965	1261
S_2	22	6
S_3	58	2
L_1	68	152
L_2	57	71
L_3	83	31
L_4	47	80
L_5	121	46
T	28	43
$LSD_{.05}$	189	351

grape, very small amounts of the material were absorbed or translocated (Table 21). There was little difference in the amount absorbed after 96 hours. Of the less than 2% absorbed after 216 hours, 88% remained in the treated leaf (Figure 3). Where spot applications were made on the leaf, the area became necrotic but injury remained localized.

With cherry leaf treatment, information concerning the influence of leaf age on uptake was desired. Of the nine leaves treated per branch, the youngest leaves showed the greatest amount of leaf necrosis after treatment.

Absorption increased with time through 6 days when it appeared to level off (Table 22). Using a randomized complete block design, with each branch representing a block, there was no significant difference between the leaves (young vs. old), the stem sections, or the leaf wash of 192 hr harvest time (Table 23). Cuticle thickness appeared not to influence ^{14}C absorption.

After 216 hours, the average percent of absorbed ^{14}C by cherry leaves was 3.2%, with the fifth leaf from the terminal averaging 4.8% for the maximum absorbed (Figure 10). Of the ^{14}C absorbed, very little moved into the stem sections.

The leaf studies showed localized necrosis developed when oxyfluorfen was placed on the leaves, with the youngest leaves injured the most. No significant translocation occurred. Growers need not be concerned if oxyfluorfen got on lower leaves of grapes or cherries, for death of the plants would not occur. Oxyfluorfen's slight absorption and little translocation add to its safety for use on new plantings of deciduous fruit crops.

Table 21. Mean percent of the ^{14}C recovered after grape leaf treatment with ^{14}C-oxyfluorfen.

Plant Part (see Fig. 3)	Time After Treatment (hrs)			
	24	48	96	216
L_1	0.62	1.04	1.36	1.33
P_1	0.02	0	0	0.01
L_2	0.07	0.02	0.05	0.02
P_2	0.02	0.01	0	0.02
L_3	0.06	0.07	0.02	0.04
P_3	0.03	0	0.02	0.02
L_4	0.01	0.07	0.02	0.10
P_4	0.02	0	0	0.01
L_5	0.06	0	0.02	0.06
P_5	0.01	0.01	0.04	0.01
S	0.03	0	0	0.04
T	0	0	0.03	0
Wash	99.02	98.74	98.43	98.32

Table 22. Mean percent distribution of uptake of ^{14}C when ^{14}C-oxyfluorfen was applied to nine leaves per branch of 'Montmorency' cherry.

Leaf	Time After Treatment (hrs)							
	24	48	96	120	144	168	192	216
L_1 (youngest)	0.6	0.6	1.6	4.7	3.8	5.8	1.7	3.0
L_2	0.9	0.7	1.9	6.2	6.3	6.0	3.2	2.4
L_3	0.6	0.4	1.2	4.9	2.6	2.6	3.4	2.5
L_4	0.4	0.4	1.3	2.6	3.8	1.6	1.3	3.3
L_5	0.4	0.4	1.6	1.9	4.6	1.4	4.8	4.8
L_6	0.9	1.0	1.4	2.5	1.6	1.8	2.4	3.1
L_7	1.5	0.8	1.8	1.7	3.7	1.9	2.0	3.7
L_8	0.4	1.4	1.8	1.2	1.5	1.8	4.4	3.9
L_9 (oldest)	0.7	0.8	1.9	1.8	1.7	2.8	3.2	2.6
Mean	0.71	0.72	1.61	3.06	3.29	2.86	2.93	3.26

Table 23. Mean corrected dpm's from 'Montmorency' cherry leaf treatment

Leaf (see Fig. 5)	Time after Treatment (192 hrs)		
	Leaf	Stem	Wash
L_1	1806	152	106475
L_2	4070	60	116358
L_3	4121	7	110875
L_4	1686	36	125804
L_5	9393	839	122880
L_6	6300	252	120282
L_7	6668	77	118245
L_8	5730	978	124882
L_9	3985	107	121703
$LSD_{.05}$	6638	1069	23969

REFERENCES

1. Crafts, A. S. 1967. Bidirectional movement of labeled tracers in soybean seedlings. Hilgerdia, Calif. Agric. Exp. Sta. 37: 625-638.

2. Eastin, E. F. 1971. Degradation of fluorodifen-1'-^{14}C by peanut seedling roots. Weed Res. 11: 120-123.

3. Eastin, E. F. 1972. Fate of fluorodifen in susceptible cucumber seedlings. Weed Sci. 20: 255-260.

4. Eastin, E. F. 1971. Movement and fate of fluorodifen-1'-^{14}C in cucumber seedlings. Weed Res. 11: 63-68.

5. Fadayomi, O. and G. F. Warren. 1977. Uptake and translocation of nitrofen and oxyfluorfen. Weed Sci. 25: 111-114.

6. Haun, J. R. and J. H. Peterson. 1954. Translocation of 3-(p-chlorophenyl)-1,1-dimethylurea in plants. Weeds. 3: 177-187.

7. Kennedy, J. M., R. E. Talbert and J. R. Morris. 1979. Weed control in 'Concord' grapes in Arkansas. J. Amer. Soc. Hort. Sci. 104: 713-716.

8. Muzik, T. J., H. J. Cruzado, and M. P. Morris. 1957. A note on the translocation and metabolism on monuron in velvetbeans. Weeds. 5: 132-133.

9. Putnam, A. R. 1976. Fate of glyphosate in deciduous fruit trees. Weed Sci. 24: 425-430.

10. Reich, J. E. and H. B. Lagerstedt. 1971. The effect of paraquat, dinoseb and 2,4-D on filbert (Corylus avellana L.) suckers. J. Amer. Soc. Hort. Sci. 96: 554-556.

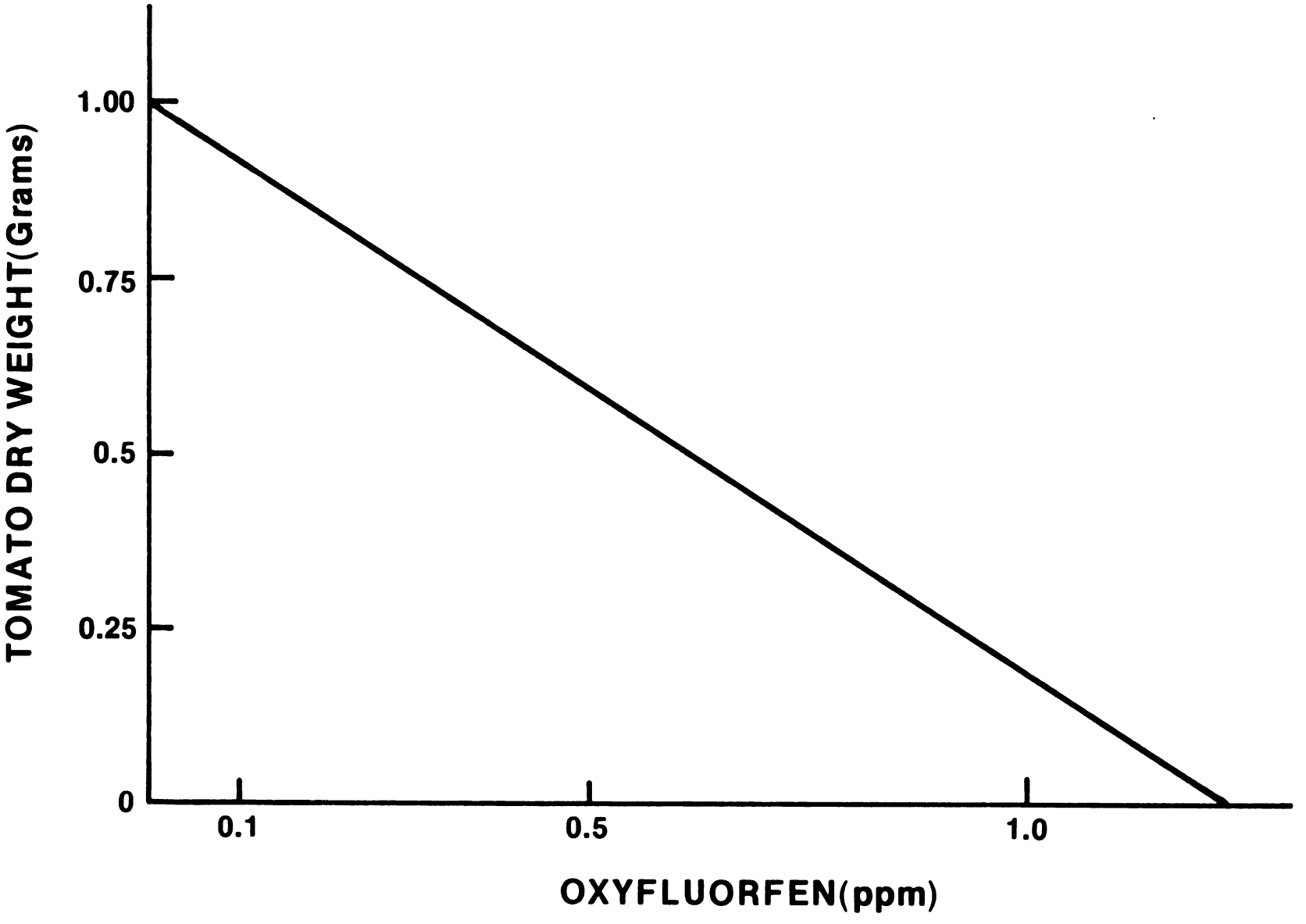
11. Rogers, B. J. 1957. Translocation and fate of amino triazole in plants. Weeds 5: 5-11.

12. Sprankle, P., W. F. Meggitt, and D. Penner. 1975. Absorption, action, and translocation of glyphosate. Weed Sci. 23: 235-240.

13. Vanstone, D.E. 1978. Physiological aspects of the mode of action of nitrofluorfen and oxyfluorfen. Diss. Abst. Intern. B 38: 2974.

APPENDIX

Appendix 1. Standard curve for oxyfluorfen based on a tomato bioassay with oxyfluorfen mixed in soil with four replications per treatment. Twenty seeds per treatment were sown and plant tops were harvested after three weeks. Data were: slope -0.815, intercept 0.997, correlation coefficient 0.87, and standard deviation 0.336. The regression equation is $y=-0.82x + 1$.


TOMATO DRY WEIGHT(Grams)
1.00
0.75
0.5
0.25
0
0.1
0.5
1.0
OXYFLUORFEN(ppm)

BIBLIOGRAPHY

BIBLIOGRAPHY

Alder, I. L., B. M. Jones, and J. P. Wargo, Jr. 1977. Fate of 2-chloro-1-(3-ethyoxy-4-nitrophenyoxy)-4-trifluoromethyl) benzene (oxyfluorfen) in rats. J. Agric. Food Chem. 25: 1339-1341.

Anderson, W. P. 1977. Weed science: principles. West Publishing Co., New York. 598 pp.

Anonymous. 1976. Establishing and managing young apple orchards. Farmers' Bulletin No. 1897. USDA. 26 pp.

Anonymous. 1977. Growing cherries east of the Rocky Mountains. Farmers' Bulletin No. 2185. USDA. 30 pp.

Anonymous. 1979. 1979 Herbicide handbook of the Weed Science Society of America. 4th ed. Champaign, Ill. 479 pp.

Anonymous. 1893. Our native grape. C. Mitzky and Co., Rochester, N.Y. 219 pp.

Anonymous. 1969. Weed control, volume 2. Pub. 1597. Nat. Academy of Sci. 471 pp.

Anonymous. 1981. 1981 Weed control manual. Meister Publ. Co., Willoughby, Ohio. 326 pp.

Ashton, F. M. and A. S. Crafts. 1981. Mode of action of herbicides. John Wiley and Sons, New York. 525 pp.

Balerdi, C. F. 1972. Weed control in young vineyards. Am. J. of Enology and Viticulture. 23: 58-60.

Benson, N. R. 1978. Efficacy, leaching and persistence of herbicides in apple orchards. Bulletin of the Coll. of Agric. Res. Center. Wash. State Univ. No. 863. 5 pp.

Benson, N. R. and R. P. Covey, Jr. 1974. Soil toxicity of 2,4-D to pome fruit trees from herbicide application. J. Amer. Soc. Hort. Sci. 99: 79-83.

Benson, N. R. and E. S. Degman. 1961. The use of herbicides around non-bearing pome fruit trees. Proc. Amer. Soc. Hort. Sci. 78: 46-52.

Best, J. A., J. B. Weber, and T. J. Monaco. 1975. Influence of soil pH on s-triazine availability to plants. Weed Sci. 23: 378-382.

Bing, A. 1979. The effect of preemergence postplant treatments of alachlor, napropamide, oxadiazon, oxyfluorfen and prodiamine on gladiolus. Proc. Northeastern Weed Sci. Soc. 33: 264-269.

Brickell, C. M. W. and G. L. Jordan. 1980. Influence of incorporation of diphenyl ether herbicides. Proc. N. Central Weed Conf.: in press.

Butler, G. and K. D. Berlin. 1972. Fundamentals of organic chemistry. Ronald Press Co., New York. 1113 pp.

Campbell, N., ed. 1955. Organic chemistry. Oliver and Boyd, London. 936 pp.

Chandler, W. H. 1925. Fruit growing. Houghton, Mifflin Co., New York. 777 pp.

Crabtree, G. D. and M. N. Westwood. 1976. Effects of weed control method on rootstock on flowering growth and yield of apple. J. Amer. Soc. Hort. Sci. 101: 454-456.

Crafts, A. S. 1967. Bidirectional movement of labeled tracers in soybean seedlings. Hilgerdia. Calif. Agric. Exp. Sta. 37: 625-638.

Crafts, A. S. 1975. Modern weed control. Univ. of Calif. Press, Berkley. 440 pp.

Doughty, C. C. 1978. Terbacil phytotoxicity and quackgrass (Agropyron repens) control in highbush blueberries (Vaccinium corymbosum). Weed Sci. 26: 488-492.

Dowler, C. C. 1969. A cucumber bioassay test for the soil residues of certain herbicides. Weed Sci. 17: 309-310.

Eastin, E. F. 1971. Degradation of fluorodifen-1'-^{14}C by peanut seedling roots. Weed Res. 11: 120-123.

Eastin, E. F. 1971. Movement and fate of fluorodifen-1'-^{14}C in cucumber seedlings. Weed Res. 11: 63-68.

Eastin, E. F. 1972. Fate of fluorodifen in susceptible cucumber seedlings. Weed Sci. 20: 255-260.

Elmore, C. L., A. H. Lange, L. L. Buschman, and D. H. Chaney. 1970. Annual weed control in young prunes. HortSci. 5: 263-264.

Fadayomi, O. and G. F. Warren. 1976. The light requirement for herbicidal activity of diphenyl ethers. Weed Sci. 24: 598-600.

Fadayomi, O. and G. F. Warren. 1977. Adsorption, desorption, and leaching of nitrofen and oxyfluorfen. Weed Sci. 25: 97-100.

Fadayomi, O. and G. F. Warren. 1977. Differential activity of three diphenyl ether herbicides. Weed Sci. 25: 465-468.

Fadayomi, O. and G. F. Warren. 1977. Uptake and translocation of nitrofen and oxyfluorfen. Weed Sci. 25: 111-114.

Fretz, T. A. and W. J. Shepard. 1978. USB-3153 and oxyfluorfen: two new experimental herbicides for container nursery stock. Res. Circ. No. 236. Ornamental Plants 1978, a summary of research. Ohio Agric. Res. and Dev. Center. pp. 48-50.

Fryer, J. D. and K. Kirkland. 1970. Field experiments ot investigate long term effects of repeated applications of MCPA, tri-allate, simazine, and linuron: report after 6 years. Weed Res. 10: 133-158.

Gardner, V. R., F. C. Bradford, and H. D. Hooker, Jr. 1952. The fundamentals of fruit production, 3rd ed. McGraw-Hill Book Co., New York. 739 pp.

Gilbert, F. A., L. Holm, and E. Haltvick. 1959. The control of weeds in newly established sour cherries. Weeds. 7: 223-229.

Gilbert, F., L. Holm, and L. Rake. 1965. The growth of red tart cherry trees with annual applications of simazine and diuron. Weeds. 13: 11-12.

Gorske, S. F. and H. J. Hopen. 1978. Effects of two diphenylether herbicides on common purslane (Portulaca oleracea). Weed Sci. 26: 585-588.

Gorske, S. F. and H. J. Hopen. 1978. Selectivity of nitrofen and oxyfluorfen between Portulaca oleracea ecotypes and two cabbage (Brassica oleracea var. capitata) cultivars. Weed Sci. 26: 640-642.

Gorske, S. F., H. J. Hopen, and A. M. Rhodes. 1977. Studies of the biology and herbicidal effects on Portulaca oleracea L. HortSci. 12: 385.

Harris, C. I. 1967. Movement of herbicides. Weeds. 15: 214-216.

Haun, J. R. and J. H. Peterson. 1954. Translocation of 3-(p-chlorophenyl) -1,1-dimethylurea in plants. Weeds. 3: 177-187.

Hawton, D. and E. H. Stobbe. 1971. Selectivity of nitrofen among rape, redroot pigweed and green foxtail. Weed Sci. 19: 42-44.

Hertz, L. B. and D. K. Wilding. 1978. Quackgrass and broadleaf weed control in low-statured hybrid blueberries. HortSci. 13: 699-700.

Holly, K. and H. A. Roberts. 1963. Persistence of phytotoxic residues of triazine herbicides in soil. Weeds Res. 3: 1-10.

Horowitz, M. 1969. Evaluation of herbicide persistence in soil. Weed Res. 9: 314-321.

Hull, J., Jr. 1980. Evolutions in weed control. Amer. Fruit Grower. 100: 22, 66.

Humphrey, W. A. and C. L. Elmore. 1978. Plant tolerance and weed control in container-grown plants--progress report. Flower and Nursery Report. Summer, pp. 1-2.

Johnson, R. T. 1978. Study of preemergence applied Goal 2E and its residual vapor injury to velvetleaf (Abutilon theophrasti). Res. Farms Report No. 42, Rohm and Haas Co., Philadelphia. November.

Jones, N. J., Jr., J. E. Moody, and J. H. Lillard. 1969. Effects of tillage, no tillage, and mulch on soil water and plant growth. Agron. J. 61: 719-721.

Kennedy, J. M., R. E. Talbert, and J. R. Morris. 1979. Weed control in 'Concord' grapes in Arkansas. J. Amer. Soc. Hort. Sci. 104: 713-716.

Kenworthy, A. L. 1953. Moisture in orchard soils as influenced by age of sod and clean cultivation. Mich. Agric. Exp. Sta. 35: 454-459.

Klingman, G. C. and F. M. Ashton. 1975. Weed science: principles and practices. John Wiley and Sons, New York. 431 pp.

Kuehner, C. L. 1934. Farm orchards. Circ. 265. Univ. of Wisc., Madison. 40 pp.

Lange, A. H., J. C. Crane, W. B. Fischer, et al. 1969. Pre-emergence weed control in young deciduous fruit trees. J. Amer. Soc. Hort. Sci. 94: 57-60.

Lange, A. H. and C. L. Elmore. 1969. Moisture and the use of simazine on Prunus. HortSci. 4: 30-32.

Lange, A., L. Lider, B. Fischer, and H. Agamalian. 1970. Herbicide variety studies of young grapevines. Amer. J. Enology and Viticulture. 21: 85-93.

Lange, A. H., L. A. Lider, B. B. Fischer, et al. 1969. Weed control studies in young grapevines. AXT-302, Agric. Ext. Serv. Univ. of Calif. 9 pp.

Lange, A. H. and J. Schlesselman. 1976. Weed control in trees and vines. Weed Control Notes Progress Report. Series 76: 1. Univ. of Calif. Parlier, Calif. 22 pp.

Lange, A. H., H. J. Schlesselman, L. Nygren, et al. 1977 Control of weed in almonds and pistachios. Proc. West. Soc. of Weed Sci. 30: 14.

Leather, G. R. and C. L. Foy. 1978. Differential absorption and distribution as a basis for the selectivity of bifenox. Weed Sci. 26: 76-81.

Lider, L. A., A. H. Lange, and O. A. Leonard. 1966. Susceptibility of grape, Vitis vinifera L., varieties to root application of simazine and diuron. Proc. Amer. Soc. Hort. Sci. 88: 341-345.

Linstromberg, W. W. 1966. Organic chemistry, a brief course. D. C. Heath and Co., Boston. 432 pp.

Lord, W. J., R. A. Damon, Jr., and D. W. Greene. 1973. Response of 'McIntosh' apple trees to annual applications of 2,6-dichlorobenzonitrile (dichlobenil). J. Amer. Soc. Hort. Sci. 98: 596-598.

Lord, W. J., R. A. Damon, Jr., and D. E. Robinson. 1970. Comparative responses of three apple rootstocks to soil-incorporated simazine. J. Amer. Soc. Hort. Sci. 95: 737-739.

Lyons, C. G., Jr. and K. S. Yoder. 1981. Poor anchorage of deeply planted peach trees. HortSci. 16: 48-49.

Majka, J. T. and T. L. Lavy. 1977. Adsorption, mobility and degradation of cyanazine and diuron in soils. Weed Sci. 25: 401-406.

Marriage, P. B. and W. J. Saidak. 1976. Simazine and linuron residues in peach orchard soil after repeated annual applications. Can. J. of Soil Sci. 56: 111-114.

Martin, J. T. and B. E. Juniper. 1970. The cuticle of plants. Edward Arnold Ltd., Edinburgh, Great Britain, 347 pp.

Mathews, C. W. 1901. Grapes, Bull. No. 92. Agric. Exp. Sta. Univ. of Kentucky, Lexington. 79 pp.

Matsunaka, S. 1976. Diphenyl ethers. Pages 709-739 in P. C. Kearney and D. D. Kaufman, eds. Herbicide Chemistry, Degradation, and Mode of Action. Marcel Dekker, New York. 1036 pp.

Matsunaka, S. 1969. Acceptor of light energy in photoactivation of diphenylether herbicides. J. Agric. Food Chem. 17: 171-175.

May, M. J. 1978. Glasshouse investigation with newer soil-applied herbicides for weed control on organic soils. Proc. 1978 Br. Crop Protection Conf.--Weeds, London. pp. 777-784.

McHarry, M. J. and G. Kapusta. 1978. Alternative double-crop soybean weed control. Proc. N. Central Weed Conf. 33: 45.

Meeusen, R. L. 1980. Personal conversation. Rohm and Haas Co., Philadelphia.

Miller, J. H., P. E. Keeley, R. J. Thullen, and C. H. Carter. 1978. Persistence and movement of ten herbicides in soil. Weed Sci. 26: 20-27.

Moreland, D. E., W. J. Blackman, H. G. Todd, and F. S. Farmer. 1970. Effects of diphenylether herbicides on reactions of mitochondria and chloroplasts. Weed Sci. 18: 636-642.

Muzik, T. J., H. J. Cruzado, and M. P. Morris. 1957. A note on the translocation and metabolism on monuron in velvetbeans. Weeds. 5: 132-133.

Oakes, R. L. 1980. Interference and control of two varieties of jimsonweed (Datura stramonium L. var. stramonium and var. tatula (L.) Torr.) in soybean (Glycine max (L.) Merr.) with oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene) and

RH8817 (2-chloro-1-(3-carboyethyl-4-nitrophenoxy)-4-(trifluoromethyl) benzene. Mich. State Univ. doctoral dissertation. 131 pp.

Orr, G. L. and F. D. Hess. 1981. Mode of action of acifluorfen-methyl: III. A proposed mechanism. Abstr. Meeting of the Weed Sci. Soc. of Amer. p. 248.

Oskamp, J. 1925. The planting and the early care of the commercial apple orchard. Cornell Univ. Ext. Bull. No. 75. 43 pp.

Pereira, J. F., W. E. Splittstoesser, and H. J. Hopen. 1971. Mechanism of intraspecific selectivity of cabbage to nitrofen. Weed Sci. 19: 647-651.

Pollak, T. and G. Crabtree. 1976. Effect of light intensity and quality on toxicity of fluorodifen to green bean and soybean seedlings. Weed Sci. 24: 571-573.

Prendeville, G. N. and G. F. Warren. 1977. Effect of four herbicides and two oils on leaf-cell membrane permeability. Weed Sci. 30: 251-258.

Pritchard, M. K. and G. F. Warren. 1979. Oxyfluorfen for pre-plant incorporated weed control in transplanted tomatoes and melons. Abstr. Meeting of the Weed Sci. Soc. of Amer. p. 44.

Pritchard, M. K. and G. F. Warren. 1979. Site of action of oxyfluorfen. Abstr. Meeting of the Weed Sci. Soc. of Amer. p. 98.

Putnam, A. R. 1975. Chemical weed control in peach orchards. Pages 300-305 in N. F. Childers, ed. The Peach. Horticultural Publ., New Brunswick, N. J. 659 pp.

Putnam, A. R. 1976. Fate of glyphosate in deciduous fruit trees. Weed Sci. 24: 425-430.

Putnam, A. R. and H. C. Price. 1969. Tolerance of rootstocks and established Malus, Pyrus, and Prunus trees to terbacil. J. Amer. Soc. Hort. Sci. 94: 655-658.

Raese, J. T., M. W. Williams, and H. Schomer. 1974. Yield and vigor of 'd'Anjou' pears with early application of triazole and triazine herbicides. HortSci. 9: 32-33.

Reich, J. E. and H. B. Lagerstedt. 1971. The effect of paraquat, dinoseb and 2,4-D on filbert (Corylus avellana L.) suckers. J. Amer. Soc. Hort. Sci. 96: 554-556.

Roadhouse, F. E. B. and L. A. Birk. 1961. Penetration of and persistence in soil of the herbicide 2-chloro-4,6-bis (ethylamino)-s-triazine (simazine). Can. J. Plant Sci. 41: 252-260.

Robinson, D. E. and W. J. Lord. 1970. Response of 'McIntosh' apple trees to soil incorporated simazine. J. Amer. Soc. Hort. Sci. 95: 195-199.

Rogers, B. J. 1957. Translocation and fate of amino triazole in plants. Weeds. 5: 5-11.

Santelmann, P. W. 1977. Herbicide bioassay. Pages 79-87 in Bryan Truelove, ed. Research Methods in Weed Science, 2nd ed. Auburn Printing, Auburn, Ala. 221 pp.

Savage, E. F. 1975. Do peaches need cultivation? Pages 297-300 in N. F. Childers, ed. The Peach. Horticultural Publi., New Brunswick, N. J. 659 pp.

Schlesselman, J. 1977. Annual weed control in deciduous trees and vines. Proc. 29th Annual Calif. Weed Conf. pp. 96-99.

Skroch, W. A. 1970. Effects of five herbicides on young apple and peach trees. HortSci. 5: 42-44.

Skroch, W. A., T. J. Sheets, and J. W. Smith. 1971. Herbicide effectiveness, soil residues, and phytotoxicity to peach trees. Weed Sci. 10: 257-260.

Slack, C. H., R. L. Blevins, and C. E. Rieck. 1978. Effect of soil pH and tillage on persistence of simazine. Weed Sci. 26: 145-148.

Smith, A. E. and B. J. Hayden. 1976. Field persistence studies with eight herbicides commonly used in Saskatchewan. Can. J. of Plant Sci. 56: 769-771.

Sprankle, P., W. F. Meggit, and D. Penner. 1975. Absorption, action, and translocation of glyphosate. Weed Sci. 23: 235-240.

Staude, E. and F. Patat. 1967. Cleavage of the C-O-C Bond. Pages 21-80 in S. Patai, ed. The Chemistry of the Ether Linkage. Interscience Publ., London. 785 pp.

Toenjes, W., R. J. Higdon, A. L. Kenworthy. 1956. Soil moisture used by orchard sods. Mich. State Univ. Agric. Exp. Sta. 39: 1-20.

Tucker, D. P. H. 1978. Bromacil and diuron residue levels in Florida citrus soils. HortSci. 13: 346.

Tweedy, J. A. and S. K. Ries. 1966. Fruit tree tolerance to two triazines. Weeds. 14: 268-269.

Upchurch, R. P. and D. D. Mason. 1962. The influence of soil organic matter on the phytotoxicity of herbicides. Weeds. 10: 9-14.

Vanstone, D. E. 1978. Physiological aspects of the mode of action of nitrofluorfen and oxyfluorfen. Diss. Abstr. Internatl. B38: 2974.

Vanstone, D. E. and E. H. Stobbe. 1978. Root uptake, translocation, and metabolism of nitrofluorfen and oxyfluorfen by fababeans (Vicia faba) and green foxtail (Setaria viridis). Weed Sci. 26: 389-392.

Vanstone, D. E. and E. H. Stobbe. 1977. Electrolytic conductivity--a rapid measure of herbicide injury. Weed Sci. 25: 352-354.

Vanstone, D. E. and E. H. Stobbe. 1979. Light requirement of the diphenyl ether herbicide oxyfluorfen. Weed Sci. 27: 88-91.

Walter, J. P., E. F. Eastin, and M G. Merkle. 1970. The persistence and movement of fluorodifen in soils and plants. Weed Res. 10: 165-171.

Weaver, R. J. 1976. Grape growing. John Wiley and Sons, New York. 371 pp.

Windholz, M., ed. The Merck index, 9th ed. Merck and Co., Rahway, N. J. 1313 pp.

Yih, R. Y. and C. Swithenbank. 1975. New potent diphenyl ether herbicides. J. Agric. Food Chem. 23: 592-593.