WEED CONTROL IN FIELD GROWN NURSERY STOCK

By

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Bachelor of Science in Agriculture

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1978

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December 1981

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Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express my deepest appreciation to my wife, Margaret, for her constant support, understanding and many sacrifices made throughout the course of this study. Only with her help did this paper become a reality.

A special apology is expressed to my little girl Jamie, who could not quite comprehend why daddy was gone so much but when I was home, she was determined to help me write.

Sincere appreciation is also expressed to Dr. Carl E. Whitcomb for being a friend and for his timeless guidance throughout the duration of this research project.

A very special note of thanks is given to Steve Shoup, Bonnie Dillon, Mike Carney and Susan Henderson for their companionship and many hours of help taking data during a typical hot and humid Oklahoma summer.

I would also like to acknowledge "Honorary professors of Horticulture Research and Technology," Charlie Gray and Billy Cavanaugh.

Sincere appreciation is given to Dr. Ronald McNew for his help on the statistical analysis of the data.

Special gratitude is extended to Dr. H. Grant Vest and Dr. Don Murray for serving as advisory committee members.

I would also like to thank my parents for their many years of support.

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CHAPTER I

INTRODUCTION

Commercial field nursery production of trees and shrubs requires a unique management system for weed control. A normal field nursery operation generally has many different species and cultivars growing in the same area. Moreover, most field nurseries harvest plants using the "balled-in-burlap" and bare root methods. These systems of harvesting require different soil types. Bare root nursery stock is generally grown in a sandy loam soil to facilitate digging and soil removal from the roots while balled-in-burlap harvesting requires a clay loam soil which will hold together as a ball of earth when wrapped in burlap or similar material. Therefore, a weed control system must be consolidated into these broad ranges of soil types.

In the production of field grown nursery stock, many factors influence plant growth and quality. Factors such as soil, light, space, water and nutrition have a direct influence on productivity. Weeds strongly compete with the crop plants (33). Increases in crop diseases and insect infestations have also been observed when weeds are present (25). The competition commonly observed between weeds and crop plants was dramatically illustrated by Fretz (15), who found that one pigweed (*Amaranthus* spp.) growing in a one gallon (3.78 liters) container reduced the top growth of Japanese holly (*Ilex crenata*) by 47%. Many weeds belong to plant families noted for their extensive fibrous root system, high reproductive capacity, phenomenal growth rates and advanced means of seed dispersal (42). Nurserymen realize weeds are cosmopolitan and they must employ all reasonable measures to check weed populations and ensure high quality and maximum growth of nursery stock.

For many years mechanical cultivation and hand weeding were the only techniques available to control weeds in field nurseries. It is now generally believed that frequent and especially deep cultivation decreases soil organic matter content and increases soil moisture loss (25). Mechanical cultivation is believed to prune the roots of field nursery plants (36). The residual effect of constant root pruning, decreased organic matter and increased soil moisture loss ultimately stunts the plants. Today, with increased machinery prices, higher fuel bills and labor costs, coupled with the adverse effects of cultivation, nurserymen are looking for alternative means of controlling weeds.

Herbicides are part of the alternative weed control system. There are several herbicides that have been registered for use on field nursery stock. However, not all of these herbicides meet the requirements that the unique field nursery circumstances dictate. The ideal herbicide would meet the following criteria: (1) would not require incorporation since incorporation will enhance root/herbicide contact and cannot be done in the rows; (2) should be safe and effective in conjunction with a broad spectrum of nursery stock; (3) should be effective all season (since frequent and repeated applications are costly); (4) should not carry over from year to year (since frequent random removal of field nursery stock is common); and (5) needs to be effective on a wide range of weed species.

Although many field nurseries throughout the United States are using various herbicides in weed control programs, no single herbicide is effective in controlling all weeds and many have significant adverse effects on field nursery stock. Therefore, the search for new and better herbicides is never ending. In recent years, research conducted on the following four herbicides have stimulated much interest and investigation: oxadiazon (Ronstar) [2-tert-butyl-4-(2,4 dichloro-5-isopropoxyphenyl) - Δ^2-1,3,4-oxadiazolin-5-one]; trifluralin (Treflan) α,α,α-trifluro-2,6-dinitro-N, N-dipropyl-p-toluidine; napropamide (Devrinol) 2-(α-naphtoxy)-N,N-diethylpropionamide and oxyfluorfen (Goal) 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene. Therefore, these four herbicides were used in this study with the following objectives: (a) to determine what latitude of safety can be expected from these herbicides, alone and in combination on field nursery stock; (b) to compare the effectiveness of each herbicide in field use; (c) to determine if combinations of these herbicides would give a broader spectrum of weed control, with equal or greater crop safety, than each herbicide used alone.

CHAPTER II

LITERATURE REVIEW

Agrichemical companies place low priority on developing herbicides for use in nursery crops because of high crop value compared to the low acreage and sales potential (48). Therefore, only a few herbicides are available to the nursery industry today. Unfortunately, several of these herbicides have only marginal crop tolerance, control a narrow spectrum of weeds or need to be incorporated to be effective. Bean and Whitcomb (5) reported that progress has been made, but consistent chemical weed control in field nursery stock with little or no crop damage is not yet possible.

For almost two decades, simazine (Princep) 2-chloro-4,6-bis (ethylamino)-s-triazone, has been the most widely used preemergence applied herbicide for nursery stock (2). Simazine is labeled for more than 42 ornamental species. It is relatively insoluble in water, thus, downward leaching in field soil is limited. Tests have shown that for several months after application, the greatest portion of simazine will be found in the upper two inches of soil (20). Like other members of the triazine herbicide family, simazine is relatively persistent in most soils (25). With optimum field conditions, simazine should not persist more than one year. However, under conditions not conducive to decomposition, such as dry, cold or low fertility soils, it may persist longer (20, 46). There have been numerous undocumented reports of field nursery stock damage by chemical carryover from one year to the next. Several researchers have found simazine to be especially phytotoxic to species of: Euonymus, Buxus, Berberis and Pyracantha (2).

Another preemergence applied herbicide which has also been available for several years is dichlobenil (Casoron) 2,6-dichlorobenzonitrile. Like simazine, it also has a low solubility in water (18 ppm). However, due to the relatively high volatility, losses from the surface can be rapid (20), making several applications necessary during the growing season. This complicates management and increases the costs of producing field nursery stock. Another major disadvantage with dichlobenil is that field applications should not be made until four weeks after transplanting nursery stock (46). During that period, weed populations may become extensive and additional cultivation or other weed control measures may be required. Although, it has some undesirable chemical properties, nurserymen find dichlobenil efficient and effective during the late fall and early winter.

In general, both simazine and dichlobenil have distinct disadvantages, which has prompted much testing of new herbicides. Weatherspoon and Currey (48) noted that much research was being conducted to test and evaluate weed control production and maintenance of woody ornamentals. The search continues to find an herbicide which is effective in controlling a broad spectrum of weeds, has good crop tolerance and is effective in various soil types. Moreover, this herbicide should not require incorporation into the soil to be effective and have little, if any, carryover between seasons.

Most of the available preemergence applied herbicides on the market today are most efficient in controlling either grassy weeds or broadleaf weeds. Reavis and Whitcomb (37) theorized that the greatest potential of controlling a broad spectrum of weeds was in combining trifluralin type herbicides (dinitroaniline) which are stronger on grasses, yet safe and easy to use with other herbicides which will control broadleaf weeds. Ahrens (2) found that combinations or subsequent applications of two herbicides controlled a broader spectrum of weeds than single applications. It may also be possible to attain a synergistic weed control effect with the combination of two herbicides (37). Cohen (11) found that by combining oxadiazon and napropamide, each at 4.0 lbs./A (4.48 kg/ha), fair-to-good weed control of grasses was achieved with excellent control of broadleaf weeds and no damage to newly transplanted birch (Betula spp.) trees. However, at 3 lbs./A (3.36 kg/ha) rate of napropamide and oxadiazon, the control of the grassy weeds was much poorer, while the broadleaf control remained excellent. Barr and Merkle (4) found that no single herbicide treatment in a pine seedling nursery was effective against all weeds, but season-long control was attained by using two herbicides. Smith, et al (41) reported that herbicide combinations in general, control weeds for longer periods of time. Additional studies by Reavis and Whitcomb (37, 38), showed that oxyfluorfen rates of 0.5, 1 and 2 lbs./A (.56, 1.12 and 2.24 kg/ha) and oxadiazon rates of 1, 2 and 3 lbs./A (1.12, 2.24 and 3.36 kg/ha) surface applied without incorporation appeared promising. An herbicide handbook (20) suggests that oxyfluorfen has a good potential in increased weed control when used in combination with other herbicides.

Oxyfluorfen

Oxyfluorfen is a relatively new preemergent and postemergent diphenyl ether compound formerly known by the code number RH-2915 (20, 46). It has a water solubility of less than 0.1 ppm coupled with a strong affinity for soil colloidal particles. Oxyfluorfen is very resistant to leaching either by rain or irrigation and is relatively stable (20, 46). However, oxyfluorfen is subject to decomposition by U.V. irradiation and is sensitive to photodecomposition in water. Unlike many other herbicides, microbial degradation is not a major factor in breakdown (20). A unique feature of oxyfluorfen and many other diphenyl ether herbicides is that light is needed to activate the weed control properties of the compound (35). In general oxyfluorfen appears to be more effective in controlling broadleaf weeds than grasses (46).

Several researchers have found excellent crop tolerance with many nursery species (7, 8, 14, 27, 37, 38, 43, 45). South (43) found oxyfluorfen at 0.5 lbs./A (.56 kg/ha) gave good weed control and was safe on several pine species in seedbeds. Research by Smith (40) conducted on five species (Euonymus, Ligustrum, Forsythia, Taxus and Viburnum) determined that oxyfluorfen at 2, 8 and 16 lbs./A (2.24, 8.96 and 17.92 kg/ha) gave excellent weed control after 11 weeks in a silt-loam soil. Euonymus, Taxus, Forsythia and Ligustrum were injured at the 8 lb./A rate but there was no crop damage at the 2 lb./A rate. Frank and Beste (14) conducted four separate field experiments to evaluate and determine the weed control effectiveness and possible phytotoxicity of several preemergence herbicide treatments on two Rhododendron spp. cultivars grown in ground beds. They found oxyfluorfen at 2 and

4 lbs./A (2.24 or 4.48 kg/ha) reduced the weeds by 58% and 80%, respectively. Further studies by Bing (7) revealed oxyfluorfen was effective against weeds and safe to fourteen species of nursery liners at both 4 and 8 lbs./A (4.48 and 8.96 kg/ha). Additional research conducted by Kuhns and Haramaki (27) on a silt-loam soil with a pH of 5.2 found that oxyfluorfen applied at 1, 2, 4 or 8 lbs./A (1.12, 2.24, 4.48 or 8.96 kg/ha) gave excellent weed control in areas that were weed-free at the time of herbicide application. They also noted that oxyfluorfen was safe on Thuja occidentalis 'Elegantissima' and Taxus media 'Hicks' and "Hatfieldi' at the four rates tested. However, oxyfluorfen was especially phytotoxic to Rhododendron spp., Cotoneaster dammeri 'Loufasti', Pyracantha coccinea 'Lalandi' and Pieris japonica at the 4 and 8 lb./A (4.48 and 8.96 kg/ha) rate. Euonymus fortunei 'Coloratus', Juniperus chinesis 'Hetzi' and Juniperus horizontalis 'Plumosa' showed varying degrees of phytotoxicity depending on rate of application. Talbert et al (45) working with field grown nursery stock, found oxyfluorfen at 1 to 8 lbs./A (1.12 to 8.96 kg/ha) gave good pigweed (Amaranthus spp.) and fall panicum (Panicum spp.) weed control but poor goosegrass (Eleusine indica) control with no crop injury to euonymus (Euonymus spp.), forsythia (Forsythia spp.), English ivy (Hedera helix) and Golden Raintree (Koelreuteria paniculata). Any rate of oxyfluorfen gave consistent weed control of pigweed, lambsquarters (Chemopodium album) and some grasses while goosegrass was not consistently controlled.

Napropamide

Napropamide is a preemergent herbicide with registration for several species. Water solubility of napropamide is about 73 ppm but it is quite resistant to leaching in most mineral soils (20, 25, 39). Romanowski and Borowy (39) noted that surface-applied napropamide did not move deeper than approximately 6 cm (2.4 inches) in Tiller sandy loam and 14 cm (15.5 inches) in a sandy soil when leached with 10.2 cm (4.0 inches) of water. Napropamide is a long lasting compound and under some conditions, more than nine months of soil persistence can be expected (20, 39). When incorporated into a moist loam soil at 70 to 90°F (21 to 32°C), the half-life of napropamide is 8 to 12 weeks (25). Several researchers have noted that napropamide is more active on grassy weeds than on many broadleaf weeds (25, 39). However, napropamide is more active on specific pigweed species, such as red-root pigweed (Amaranthus retroflexus) than prostrate pigweed (Amaranthus blitoides) (24).

Numerous studies have shown napropamide to be safe to many nursery species (2, 14, 17, 18, 22, 43, 44, 45). Cohen (11) found napropamide safe at 6.0 and 8.0 lbs./A (6.72 and 8.96 kg/ha) on Burford holly (Ilex cornuta 'Burfordi'), white pine (Pinus strobus) and Douglas fir (Tsuga canadensis) and gave excellent control of goosegrass and pigweed. Talbert et al. (45) reported napropamide at 2 to 4 lbs./A (2.24 to 4.48 kg/ha) was safe on euonymus (Euonymus spp.), English Ivy (Hedera helix), sugar maple (Acer saccharum) and Golden Raintree (Koelreuteria paniculata) and gave good weed control. Holt et al. (22) working on weed control in Indiana forest nurseries noted napropamide at 3 lb./A (3.36 kg/ha) provided good weed control. Further studies by South et al. (44) on southern pine species showed excellent full season weed control with napropamide at 1.5, 3.0 or 6.0 lbs./A (1.68, 3.36 or 6.72 kg/ha). However stunting of pine seedlings at the higher rates of napropamide was observed. Additional studies by Frank and Beste (14) working with weed control on azaleas (*Rhododendron* spp.) found that napropamide at 4 and 8 lbs./A (4.48 and 8.96 kg/ha) reduced the percent of weed cover by 70% and 80%, respectively. Haramaki et al. (18) sprayed napropamide at 1, 2, 4 and 8 lbs./A (1.12, 2.24, 4.48 and 8.96 kg/ha) on the following nursery liners with little or no herbicide damage: wintergreen barberry (*Berberis julianae*), mentor barberry (*Berberis* x *mentorensis*), warty barberry (*Berberis veraculosa*), rockspray cotoneaster (*Cotoneaster horizontalis*), American holly (*Ilex opaca*), winter jasmine (*Jasminum nudifluorum*) and choinaides rhododendron (*Rhododendron chionaides*). They also noted that napropamide controlled grassy weeds much better than the broadleaf weeds. South (43) also found napropamide to be selective on pines in the Southeastern states. At 1.5 lbs./A (1.68 kg/ha), it was injurious to shortleaf pine (*Pinus echinata*) at one specific site. In a study on a Taiwan sandy soil type, Ksu and Kuo (26), found that napropamide at 1 lb./A (1.12 kg/ha) was safe to *Pinus luchuensis* but on a clay-loam soil *Pinus luchuensis* was not tolerant of napropamide at the 1 lb./A (1.12 kg/ha) rate. Ahrens (1) reported napropamide safe at 4 to 8 lbs./A (4.48 to 8.96 kg/ha) to newly planted periwinkle (*Vinca minor*), pachysandra (*Pachysandra terminalis*), English ivy (*Hedera helix*) and evergreen wintercreeper (*Euonymus fortunei*). However, at the end of the year of testing, napropamide at 8 lbs./A caused some injury to common periwinkle and pachysandra.

Oxadiazon

Oxadiazon, a preemergent oxadiazole compound has just recently attained registration for use on several field nursery crops (46). Oxadiazon is very insoluble in water (0.7 ppm) and is non-volatile

(20, 46). It is strongly adsorbed by soil colloidal particles and soil humus. Thus, very little migration or leaching can occur. Young shoots of susceptible weed species are affected by oxadiazon as they grow through the treated zone (20). Due to the moderate persistence in soil of oxadiazon, season long weed control can be expected. It seems that oxadiazon is more active in moist soil than in dry soil (46). Therefore, irrigation or rainfall after field application, creates an environment more conducive to efficient weed control.

In general, oxadiazon appears to be more active on broadleaf weeds than on grasses (11, 16, 38, 41, 45, 46).

Oxadiazon has shown crop tolerance on numerous field nursery species with fair to excellent weed control (3, 8, 11, 29, 31, 40, 41, 45). Cohen (11), experimenting with several herbicides on birch trees (Betula spp.), Burford holly (Ilex cornuta 'Burfordi'), white pine (Pinus strobus) and Douglus fir (Tsuga canadensis), found oxadiazon gave excellent control of goosegrass, pigweed and other broadleaf weeds but poor control of other grassy weeds with no crop injury. Bailey and Simmons (3) studied oxadiazon selectivity to numerous field nursery species and weed control effectiveness throughout the United States. During 1975 and 1976, more than 100 plant species were tested. Of the 100 different species tested, Chineses privet (Ligustrum sinense) and scarlet firethorn (Pyracantha coccinea) displayed moderate toxicity symptoms when treated with 5 and 10 lbs./A (5.6 and 11.2 kg/ha) of oxadiazon. In both years (1975 and 1976) oxadiazon gave good to excellent weed control at rates of 3, 4, 5 and 10 lbs./A (3.36, 4.48, 5.6 and 11.2 kg/ha). However, all rates of oxadiazon were ineffective on common chickweed (Stelloria media). In an additional study, Long and

Geyer (29) found cottonwood (*Populus* spp.) and silver maple (*Acer saccharinum*) tolerant of oxadiazon at 3 or 5 lbs./A (3.36 or 5.6 kg/ha) applied immediately after planting. Smith et al. (41) found on a Brookston silty clay loam soil, several deciduous shrubs relatively tolerant of oxadiazon at 2 lbs./A (2.24 kg/ha) with Day lilies (*Lilium* spp.) being injured slightly. Oxadiazon was more effective on broadleaf weeds than on grasses. Weatherspoon and Currey (48) reported oxadiazon at 3 lbs./A (3.36 kg/ha) gave effective weed control with no phytotoxicity to Andorra juniper (*Juniperus horizontalis* 'Plumosa'), ligustrum (*Ligustrum* spp.), dogwood (*Cornus florida*) and arborvitae (*Thuja orientalis*). Smith (40) also observed that oxadiazon at 4 lbs./A (4.48 kg/ha) gave 85% weed control after seven weeks and 58% after 11 weeks. Of the several nursery bedded liners tested, only forsythia (*Forsythia viridissima*) displayed signs of phytotoxicity. Frank and Beste (14) found that azaleas (*Rhododendron* spp.) grown in raised soil beds tolerant of oxadiazon at 4 lbs./A (4.48 kg/ha) which gave 65% weed control. Bing (8) showed that oxadiazon at 2 lbs./A (2.24 kg/ha) was effective against weeds with no crop damage in a retail sale nursery yard holding area. Of the several balled-in-burlap plants tested (hetzi juniper, *Juniperus chinensis* 'Hetzi'; Hicks yew, *Taxus cuspidata* 'Hicks'; azalea, *Rhododendron obtusum japonicum*; Japanese holly, *Ilex crenata* and Japanese andromeda, *Pieris japonica*) none displayed signs of injury. Talbert et al. (45) found oxadiazon at 4 lbs./A (4.48 kg/ha) gave good control of pigweed (*Amaranthus* spp.) and ragweed (*Ambrosia* spp.) but consistently failed to control goosegrass (*Eleusine indica*). They observed no injury to euonymus (*Euonymus* spp.), forsythia (*Forsythia*, spp.), or Golden Raintree

(*Koelreuteria paniculata*) at any rates tested. Holt et al. (22) reported oxadiazon at 3 lbs./A (3.36 kg/ha) provided 70 to 100% weed control on forest nurseries in Indiana.

Although much research has shown oxadiazon to be safe and effective on a broad array of field nursery stock, there have been some reports of crop injury (5, 23, 38). Bean and Whitcomb (5) found that oxadiazon at 2 or 4 lbs./A (2.24 or 4.48 kg/ha) was injurious to silver maple (*Acer saccharinum*). Holt et al. (23) experimenting with several herbicides on forest nurseries found that oxadiazon at 1 and 2 lbs./A (1.12 and 2.24 kg/ha) damaged tulip poplar (*Liriodendron tulipifera*) when applied about one month after germination. Reavis and Whitcomb (38) reported that oxadiazon at 2, 3 or 4 lbs./A (2.24, 3.36 or 4.48 kg/ha) was effective against several broadleaf weeds, however, pin oak (*Quercus palustris*) and monarch birch (*Betula maximowicziana*) seedlings were damaged at all three rates.

Trifluralin

Trifluralin is a selective dinitroaniline herbicide (19, 20, 25, 46). Water solubility is very low (<1 ppm) and soil absorption is strong (20, 25, 46) thus, little if any leaching occurs. Klingman and Ashton (25) noted that even after a heavy rainfall, trifluralin was not leached beyond the weed seed germination zone. Numerous studies have shown that microbial decomposition, volatilization, photodecomposition and chemical decomposition are the main factors responsible for the disappearance of trifluralin from the soil (21, 25). Volatilization and photodecomposition are probably the most important causes of losses from the soil surface (25). Hollingsworth (21) found that rainfall and the resulting soil moisture effects during the first 20 days markedly influenced the volatilization of trifluralin.

However, rainfall later in the growing season had little effect on the vaporization of trifluralin. Klingman and Ashton (25) report that flooding of the soil surface stimulated the rapid degradation of trifluralin (7 days at 76^{o}F) (24^{o}C). It appears that anaerobic degradation of trifluralin can occur by microbial and/or chemical action. The recommended practice is to incorporate trifluralin into the upper few inches of the soil (20, 32, 34, 46, 47). However, Bean and Whitcomb (5) found that trifluralin was more injurious to crop species when incorporated into the soil than when left undisturbed on the surface. Additional studies by Reavis and Whitcomb (38) revealed that if trifluralin was used at higher rates, unincorporated, but applied early in the season when the soil is cool and some shallow rainfall incorporation occurs, good-to-moderate weed control could be expected. Trifluralin, when surface applied and not incorporated, appears to be more effective for grassy weeds and consistently misses certain broadleaf weeds, especially pigweed.

Research with trifluralin on field nursery stock has shown it has excellent crop tolerance and acceptable weed control on susceptible weed species (6, 9, 10, 12, 13, 28, 30, 38, 49, 50). Dorsser (13) found that trifluralin is very effective against crabgrass (Digitaria sanguinalis). Research by Cellerino (10) on a newly planted poplar nursery in northern Italy found that trifluralin at 2 lbs./A (2.24 kg/ha) was highly efficient in controlling weeds with no injury to the trees. Bengtson et al. (6) found that trifluralin applied to newly transplanted slash pine (Pinus taeda) proved safe, with effective control of the predominant weeds. Wilkinson and Davis (49) working with several herbicides on southern pine seedlings found trifluralin gave effective control of grassy weeds but poor control of broadleaf weeds, yet it was safe to most pine species tested. Studies conducted on hardwood seedlings in Taiwan by Kuo and Wang (28) found trifluralin gave good control of crabgrass (Digitaria spp.) with no crop injury. McDonald et al. (30) studied trifluralin on a conifer seed bed with a sandy soil. They found no injury to six species of conifers when trifluralin applications were made one week after conifer germination. A similar study by Dill and Carter (12), working with several pre-emergence applied herbicides, found that trifluralin at 1 and 2 lbs./A (1.12 and 2.24 kg/ha) was safe on slash and loblolly seedlings and at the same time provided good weed control. Woessner (50) found trifluralin safe and effective on cottonwood (Populus deltoides) cuttings. Results showed that the average height growth was greatest at 4 lbs./A (4.48 kg/ha), however, higher rates of trifluralin reduced growth. Reavis and Whitcomb (38) reported that trifluralin unincorporated at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha) on a sandy loam soil controlled grassy weeds but many broadleaf weeds were not effectively controlled.

CHAPTER III

MATERIALS AND METHODS

On April 20, 1980 an experiment was begun to evaluate the performance of oxadiazon 2%G at 1, 2 and 3 lbs./A (1.12, 2.24 and 3.36 kg/ha); oxyfluorfen 2%G at 0.5, 1 and 2 lbs./A (0.56, 1.12, and 2.24 kg/ha); napropamide 10%G at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha); and trifluralin 5%G at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha) for weed control in field nursery stock. In addition, herbicide combinations of oxadiazon and trifluralin; oxadiazon and napropamide; oxyfluorfen and trifluralin and oxyfluorfen and napropamide were used at all rate combinations. Also, there were two controls: (a) hand weeded and (b) weeds allowed to develop. Herbicides, rates and combinations are listed in Table 1. Three woody ornamental species were chosen as indicator plants; *Populus deltoides*, Male "Cottonless" Cottonwood, *Euonymus japonica*, Japanese Euonymus, *Pyracantha coccinea* "Wateri", Wateri pyracantha. The cottonwood, euonymus and pyracantha were propagated from cuttings to ensure genetic uniformity.

The study was conducted at the Oklahoma State University Nursery Research Station, Stillwater, Oklahoma on a sandy clay loam soil with a soil composition of 21.5% clay, 38.0% sand and 40.5% silt, 0.6% organic matter and a soil pH of 6.1. During the previous growing season (1979) hybrid sudan (*Sorghum bicolor sudanensis*) was grown on the study site and incorporated into the soil with a moldboard plow in

TABLE I

HERBICIDE TREATMENTS[1] USED[E]

Oxadiazon[A]	Oxyfluorfen[B]	Trifluralin[C]	Napropamide[D]
1 (1.12)	0	0	0
2 (2.24)	0	0	0
3 (3.36)	0	0	0
0	.5 (.56)	0	0
0	1 (1.12)	0	0
0	2 (2.24)	0	0
0	0	2 (2.24)	0
0	0	3 (3.36)	0
0	0	4 (4.48)	0
0	0	0	2 (2.24)
0	0	0	3 (3.36)
0	0	0	4 (4.48)
1 (1.12)	0	2 (2.24)	0
1 (1.12)	0	3 (3.36)	0
1 (1.12)	0	4 (4.48)	0
2 (2.24)	0	2 (2.24)	0
2 (2.24)	0	3 (3.36)	0
2 (2.24)	0	4 (4.48)	0
3 (3.36)	0	2 (2.24)	0
3 (3.36)	0	3 (3.36)	0
3 (3.36)	0	4 (4.48)	0
1 (1.12)	0	0	2 (2.24)
1 (1.12)	0	0	3 (3.36)
1 (1.12)	0	0	4 (4.48)
2 (2.24)	0	0	2 (2.24)
2 (2.24)	0	0	3 (3.36)
2 (2.24)	0	0	4 (4.48)
3 (3.36)	0	0	2 (2.24)
3 (3.36)	0	0	3 (3.36)
3 (3.36)	0	0	4 (4.48)
0	.5 (.56)	2 (2.24)	0
0	1 (1.12)	3 (3.36)	0
0	2 (2.24)	4 (4.48)	0

TABLE I (Continued)

Oxadiazon[A]	Oxyfluorfen[B]	Trifluralin[C]	Napropamide[D]
0	.5 (.56)	2 (2.24)	0
0	1 (1.12)	3 (3.36)	0
0	2 (2.24)	4 (4.48)	0
0	.5 (.56)	2 (2.24)	0
0	1 (1.12)	3 (3.36)	0
0	2 (2.24)	4 (4.48)	0
0	.5 (.56)	0	2 (2.24)
0	1 (1.12)	0	3 (3.36)
0	2 (2.24)	0	4 (4.48)
0	.5 (.56)	0	2 (2.24)
0	1 (1.12)	0	3 (3.36)
0	2 (2.24)	0	4 (4.48)
0	.5 (.56)	0	2 (2.24)
0	1 (1.12)	0	3 (3.36)
0	2 (2.24)	0	4 (4.48)
0	0	0	0 H.W.L.[2]
0	0	0	0 H.W.L.[3]

[1]Rates and herbicides in a horizontal row represent one treatment.

[2]Hand-weeded control; maintained weed free throughout the study and without herbicides.

[3]Non-weeded control; weeds were allowed to germinate and grow in this treatment and were removed at intervals as in the treated plots.

[A]Mfg. for Rhodia Inc., Agriculture Division Monmouth Junction, NJ08852, A subsidiary of Rhone-Poulenc, France.

[B]Mfg. by the Rohm and Haas Company, Philadelphia, PA 19105.

[C]Mfg. by the Elanco Products Company, A Division of Eli Lilly and Company, P.O. Box 1750, Indianapolis, Indiana 46206.

[D]Mfg. by the Stauffer Chemical Company, Agricultural Chemical Division, Westport, CT 06880.

[E]Lbs./A and Kg/ha respectively.

October. There had been a heavy infestation of weeds at the site during the 1978 growing season. Dominant weed species present the previous years were: cutleaf eveningprimrose (Oenothera laciniata), giant ragweed (Ambrosia trifida), Pennsylvania smartweed (Polygonum pensylvanicum), redroot pigweed (Amaranthus retroflexus), crabgrass (Digitaria spp.), barnyardgrass (Echinochloa crusgalli), stinkgrass (Eragrostis celianensis), common lambsquarters (Chenopodium album) and prostrate spurge (Euphorbia supina). The broad spectrum of weeds provided reasonable assurance of a representative weed population in the field study area.

Several days prior to planting, a springtooth harrow and a rototiller were used to loosen the soil at the study site. Immediately after planting on April 20, 1980, a portable overhead sprinkler irrigation system was set up and approximately two acre inches (5 cm/ha) were applied. Irrigation was used throughout the study to maintain adequate soil moisture. Each of the three test species were arranged in a fixed position within a 5 ft. x 5 ft. (1.5 m x 1.5 m) plot. Plants were approximately 2 ft. (.6 m) from the outside plot boundary with 1.5 ft. (.5 m) between each species.

Each of the herbicide treatments was applied by hand with a modified salt shaker on April 23, 1980. Immediately following herbicide applications, approximately one-half acre inch (1.3 cu/ha) of water was applied by sprinkler irrigation to incorporate the herbicides.

The 50 herbicide treatments were replicated six times and arranged in a randomized complete block design. Test plants were blocked by size in order to reduce the variation within a block. Data analysis was by analysis of variance and least squares difference for mean separation.

On May 5, 1980 initial plant height and stem caliper 6 cm. above the soil line were recorded from all test plants.

On June 2, 1980 approximately five weeks after herbicide treatment applications, the first weed evaluation was made by number and species. Later evaluation showed no differences in weed control between any weed species in either the number or the fresh weight. For purposes of evaluation, all grassy weeds were grouped together and all broadleaf weeds were grouped together. There was a significant difference in weed control between these two groups. The weeds were left undisturbed to allow further weed growth and germination of additional weeds. On June 23, 1980 the population and fresh weight of each weed species was recorded. Only those weeds developed beyond the juvenile foliage stage were considered. The weeds which were observed to only have been recently germinated were left undisturbed.

There was a slight infestation of perennial weeds such as yellow nutsedge (Cyperus escultentus) and common bermudagrass (Cynodon dactylon). On June 25, 1980 Glyphosphate (Roundup) N-(phosphonomethyl)-glycine was carefully spot sprayed to eliminate all perennial weeds.

A final weed count was made July 24, 1980. Once more the weed species were determined and the number of weeds were recorded.

Final evaluation of the study began on August 24, 1980. Nursery test plant height and stem caliper at 6 cm. above soil ground line were determined for all test plants on September 1, 1980. The number of branches on cottonwood was recorded. Top weight of all nursery test plants was taken on September 3, 1980.

CHAPTER IV

RESULTS AND DISCUSSION

Weed Control

General Weed Population

Each herbicide alone significantly reduced the total number of weeds as compared to the control where no herbicide was applied (Table II). Mean treatment values differ greatly, although there were few significant differences among herbicides or rates. This was probably due to the variation in the natural weed population between plots.

Oxadiazon at 3 lbs./A (3.36 kg/ha) significantly suppressed weights of the general weed population better than trifluralin at 2, 3 or 4 lbs./A (2.24, 3.36 or 4.48 kg/ha) (Table II). This is of interest since trifluralin and oxadiazon did not differ significantly in the number of weeds, but oxadiazon reduced the weight of the weeds (Table II). Any herbicide at any rate reduced the weight of weeds present in each plot when compared to the non-weeded control (Table II).

Each herbicide alone at certain rates caused a distinct reduction in the broadleaf weed population (Table II). Oxadiazon at 2 and 3 lbs./A (2.24 and 3.36 kg/ha) or oxyfluorfen at 1 or 2 lbs./A (1.12 and 2.24 kg/ha) significantly reduced the number of broadleaf weeds when

TABLE II

EFFECTS OF HERBICIDES ON WEED CONTROL

		Oxadiazon Lbs. aia (kg/ha)			Oxyfluorfen Lbs. aia (kg/ha)			Trifluralin Lbs. aia (kg/ha)			Napropamide Lbs. aia (kg/ha)		
	Control	1 (1.1)	2 (2.2)	3 (3.4)	.5 (.56)	1 (1.1)	2 (2.2)	2 (2.2)	3 (3.4)	4 (4.5)	2 (2.2)	3 (3.4)	4 (4.5)
All Weeds (Count)	74*a	17bc	7c	3c	39b	20bc	13c	23bc	21bc	22bc	15bc	12bc	17bc
All Weeds Fresh Weight (g)	1901a	603bc	218cd	33d	554bcd	335bcd	369bcd	642bc	803b	815b	340bcd	338bcd	330bcd
Broadleaf Weeds (Count)	25a	3bc	1c	0c	5bc	2c	0c	14ab	14ab	10bc	14ab	10bc	13b
Broadleaf Weeds Fresh Weight (g)	493a	23b	2b	0b	29b	1b	0b	363a	313a	258ab	336a	259ab	269ab
Grassy Weeds (Count)	48a	14cd	6de	3e	34b	18c	12cd	9de	6de	11cde	0e	2e	3e
Grassy Weeds Fresh Weight (g)	1402a	567b	216bcd	33d	525b	341bcd	369bcd	279bcd	489bc	555b	4d	78cd	61cd

*Means within a row followed by the same letter are not significantly different at the 5% level using least squares analysis.

contrasted to trifluralin at 2 and 3 lbs./A (2.24 and 3.36 kg/ha) or napropamide at 2 or 4 lbs./A (2.24 and 4.48 kg/ha). When contrasting the performance of weed control on the broadleaf weed population, oxadiazon and oxyfluorfen significantly suppressed the weight of the weeds missed initially. This is unique since trifluralin and napropamide likewise reduced the number of broadleaf weeds, but the remaining weeds grew to be much larger than the broadleaf weeds in the oxyfluorfen or oxadiazon plots.

Napropamide at 2, 3 or 4 lbs./A (2.24, 3.36 or 4.48 kg/ha) significantly reduced grassy weed counts more than oxadiazon at 1 lb./A (1.12 kg/ha) or oxyfluorfen at 0.5, 1 or 2 lbs./A (.56, 1.12 or 2.24 kg/ha) (Table II). However, oxadiazon at 2 or 3 lbs./A (2.24 or 3.36 kg/ha) and trifluralin at 2, 3 or 4 lbs./A (2.24, 3.36 or 4.48 kg/ha) resulted in the same excellent grassy weed control as napropamide when contrasted to the non-weeded control where no herbicide was applied.

Oxadiazon alone at 3 lbs./A (3.36 kg/ha) was superior to trifluralin at 3 or 4 lbs./A (3.36 and 4.48 kg/ha), oxyfluorfen at 0.5 lbs./A (.56 kg/ha) and oxadiazon at 1 lb./A (1.12 kg/ha) in reducing grassy weed weights. Napropamide at 2 lbs./A (2.24 kg/ha) suppressed grassy weed weights better than trifluralin at 3 and 4 lbs./A (3.36 and 4.48 kg/ha), oxyfluorfen at 0.5 lbs./A (.56 kg/ha) or oxadiazon at 1 lb./A (1.12 kg/ha) (Table II).

There was no observed benefit from combining herbicides based on weed counts or weed weights when compared to the same herbicide used alone except oxyfluorfen at 1 or 2 lbs./A (1.12 or 2.24 kg/ha) combined with napropamide at 2 and 3 lbs./A (2.24 and 3.36 kg/ha) which resulted in a significant interaction between the two herbicides in reducing weed weight (Table III). The combination of oxyfluorfen at

TABLE III

INTERACTION OF OXYFLUORFEN AND NAPROPAMIDE ON CONTROL OF ALL WEEDS

NAPROPAMIDE lbs./A (kg/ha)		OXYFLUORFEN lbs./A (kg/ha)			
		0*	0.5 (.56)	1 (1.12)	2 (2.24)
			(1901)'	(1901)'	(1901)'
*0		1901^{1}_{a}	554^{2}_{b}	355^{2}_{b}	369^{2}_{b}
2 (2.24)	(1901)a	340^{2}_{b}	222^{3}_{b}	195^{23}_{b}	60^{23}_{b}
3 (3.36)	(1901)a	338^{2}_{b}	215^{3}_{bc}	19^{3}_{c}	16^{3}_{c}
4 (4.48)	(1901)a	330^{2}_{b}	65^{3}_{bc}	24^{3}_{bc}	7^{3}_{c}

*Control

NOTE: Means within a row followed by the same letter or means within a column followed by the same number are not significantly different at the 5% level using least squares analysis.

1 and 2 lbs./A (1.12 and 2.24 kg/ha) and napropamide at 3 and 4 lbs./A (3.36 and 4.48 kg/ha) significantly reduced the fresh weight of weeds compared to other combinations or either herbicide used alone and should be studied further over several growing seasons.

In summary, combinations of oxyfluorfen, oxadiazon, napropamide and trifluralin proved ineffective in enhancing weed control applications over that of each herbicide alone (Table III). This is contradictory to the research reported by Cohen (11), Reavis and Whitcomb (37, 38) and Barr and Merkle (4). In general, these reports specified the significance of combining two herbicides to attain improved weed control, especially combining dinitroanaline type herbicides to control the grassy weeds with other herbicides which are more effective in controlling broadleaf weeds (37). However, oxyfluorfen at 1 and 2 lbs./A (1.12 and 2.24 kg/ha) combined with napropamide at 2 and 3 lbs./A (2.24 and 3.36 kg/ha) was an exception, significantly reducing the weights of the general weed population. The synergism found with oxyfluorfen is in agreement with other research (20, 37).

Oxadiazon at 2 and 3 lbs./A (2.24 and 3.36 kg/ha) or oxyfluorfen at 1 and 2 lbs./A (1.12 and 2.24 kg/ha) provided good to excellent control of grassy weeds, equal to or only slightly poorer than either napropamide or trifluralin. This relation is unique, since numerous studies have consistently noted the weakness of oxyfluorfen and oxadiazon on grassy weeds (11, 16, 38, 41, 45, 46).

Crop Response

Cottonwood

Cottonwood top weight increased when oxadiazon at 2 and 3 lbs./A (2.24 and 3.36 kg/ha), oxyfluorfen at 1 and 2 lbs./A (1.12 and 2.24

kg/ha), napropamide at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha) and trifluralin at 2 lbs./A (2.24 kg/ha) were used, compared to the weedy control where no herbicide was applied (Table IV). This increase in top weight is directly correlated with the improved weed control as displayed in Table II. Only trifluralin at 3 and 4 lbs./A (3.36 and 4.48 kg/ha), oxadiazon at 1 lb./A (1.12 kg/ha) and oxyfluorfen at 0.5 lbs./A (.56 kg/ha) did not result in a significantly greater cottonwood top weight.

No significant differences were observed between the height and caliper growth in the weedy control and the hand-weeded control (Table IV). This suggests that cottonwood can tolerate considerable competition (Table IV). Separate applications of oxadiazon at 1, 2 and 3 lbs./A (1.12, 2.24 and 3.36 kg/ha), oxyfluorfen at 2 lbs./A (2.24 kg/ha) and trifluralin at 2 lbs./A (2.24 kg/ha) significantly improved height growth of cottonwood above the weedy control where no herbicide was applied (Table IV). It is particularly striking that these specific treatments also significantly increased weed control and thus reduced competition, but failed to increase height growth above the hand-weeded control where no herbicide was applied and the plots were maintained nearly weed-free. This unique situation suggests that these herbicide treatments may have a slight stimulatory effect on cottonwood height growth.

There was a benefit from the improved weed control resulting in larger stem caliper growth observed when oxadiazon at 1, 2 and 3 lbs./A (1.12, 2.24 and 3.36 kg/ha), oxyfluorfen at 0.5, 1 and 2 lbs./A (.56, 1.12 and 2.24 kg/ha), trifluralin at 3 and 4 lbs./A (3.36 and 4.48 kg/ha) and napropamide at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha) were used alone as compared to the weedy control (Table IV). When considering

TABLE IV

EFFECTS OF HERBICIDES ON GROWTH OF COTTONWOOD

	Herbicide Rate	Top Fresh Weight (g)	Height Growth (cm)	Caliper Growth (cm)	Branch Number
Weedy Control		760a	107a	1.6a	7a
Hand-weeded Control		1354b	113ab	2.0ab	13b
Oxadiazon	1 (1.12)	1050ab	131ab	2.1b	8ab
lbs./A	2 (2.24)	1319b	135b	2.4b	10ab
(kg/ha)	3 (3.36)	1518b	138b	2.5b	7a
Oxyfluorfen	0.5 (.56)	1298ab	114b	2.3b	9.5ab
lbs./A	1 (1.12)	1415b	122ab	2.4b	11ab
(kg/ha)	2 (2.24)	1416b	143b	2.5b	12ab
Trifluralin	2 (2.24)	1438b	136b	2.0ab	7a
lbs./A	3 (3.36)	1275ab	124ab	2.3b	11ab
(kg/ha)	4 (4.48)	1299ab	103a	2.2b	8ab
Napropamide	2 (2.24)	1334b	130ab	2.4b	10ab
lbs./A	3 (3.36)	1538b	130ab	2.4b	13b
(kg/ha)	4 (4.48)	1419b	129ab	2.5b	8ab

*Means within a column followed by the same letter are not significantly different at the 5% level using least squares analysis.

all of the herbicide treatments, only trifluralin at 2 lbs./A (2.24 kg/ha) failed to increase cottonwood stem caliper growth above the weedy control. However, trifluralin at the 2 lbs./A (2.24 kg/ha) rate was observed not to be significantly different from any of the other herbicide treatments when used alone (Table IV).

The reduced competition of the hand-weeded control increased the number of branches of cottonwood (Table IV). When each herbicide was used alone, only napropamide at 3 lbs./A (3.36 kg/ha) resulted in greater branch numbers than the hand weeded control, although none of the other herbicide treatments had any suggestion of a detrimental effect on branch numbers.

In general, combinations of herbicides had no detrimental nor stimulatory effects on cottonwood stem caliper growth, height growth, top weight or branch numbers. Moreover, herbicide combinations did not prove to be superior to separate applications of individual herbicides. It is interesting to note however that combinations of oxadiazon at 3 lbs./A (3.36 kg/ha) with trifluralin at 3 lbs./A (3.36 kg/ha), oxyfluorfen at 1 lb./A (1.12 kg/ha) with napropamide at 2 lbs./A (2.24 kg/ha) or oxadiazon at 3 lbs./A (3.36 kg/ha) with napropamide at 3 lbs./A (3.36 kg/ha) significantly increased the branch number of cottonwood over the weedy control, whereas the same herbicides and rates applied alone did not (Tables V, VI, VII). Although the herbicide combinations improved branch number when contrasted to the weedy control, there were no significant differences between the combinations and the herbicides when used alone. Since weed control was found not to be significantly improved by herbicide combinations (Table II), a slight stimulation of branch count might be at play and thus an

TABLE V

INTERACTION OF OXADIAZON AND TRIFLURALIN ON COTTONWOOD, BRANCH NUMBER

TRIFLURALIN lbs./A (kg/ha)	OXADIAZON lbs./A: 0*	0**	1 (1.12)	2 (2.24)	3 (3.36)
*0	7	$(7)^{1}$	$(7)^{1}$	$(7)^{1}$	$(7)^{1}$
**0	(7)a	13^{2}_{ab}	8^{1}_{ab}	10^{1}_{ab}	7^{1}_{a}
2 (2.24)	(7)a	7^{1}_{a}	8^{1}_{a}	11^{1}_{a}	7^{1}_{a}
3 (3.36)	(7)a	11^{12}_{ab}	9^{1}_{ab}	12^{1}_{ab}	13^{2}_{b}
4 (4.48)	(7)a	8^{12}_{a}	11^{1}_{a}	11^{1}_{a}	7^{1}_{a}

*Non-weeded control
**Hand-weeded control

NOTE: Means within a row followed by the same letter or means within a column followed by the same number are not significantly different at the 5% level using least squares analysis.

TABLE VI

INTERACTION OF OXYFLUORFEN AND NAPROPAMIDE ON COTTONWOOD, BRANCH NUMBER

NAPROPAMIDE lbs./A (kg/ha)	OXYFLUORFEN lbs./A (kg/ha) 0*	0**	0.5 (.56)	1 (1.12)	2 (2.24)
*0	7	$(7)^{1}$	$(7)^{1}$	$(7)^{1}$	$(7)^{12}$
**0	(7)a	13^{2}_{b}	9.5^{12}_{ab}	11^{12}_{ab}	12^{2}_{ab}
2 (2.24)	(7)a	10^{12}_{ab}	12^{12}_{ab}	15^{2}_{b}	11^{2}_{ab}
3 (3.36)	(7)a	13^{2}_{b}	14^{2}_{b}	11^{12}_{ab}	9^{2}_{ab}
4 (4.48)	(7)ab	8^{12}_{ab}	11^{12}_{b}	8^{12}_{ab}	2.5^{1}_{a}

*Non-weeded control
**Hand-weeded control

NOTE: Means within a row followed by the same letter or means within a column followed by the same number are not significantly different at the 5% level using least squares analysis.

TABLE VII

INTERACTION OF OXADIAZON AND NAPROPAMIDE ON
COTTONWOOD, BRANCH NUMBER

NAPROPAMIDE lbs./A (kg/ha)	OXADIAZON lbs./A (kg/ha) 0*	0**	1 (1.12)	2 (2.24)	3 (3.36)
*0	7	$(7)^{1}$	$(7)^{1}$	$(7)^{1}$	$(7)^{1}$
**0	(7)a	13^{2}_{b}	8^{1}_{ab}	10^{1}_{ab}	7^{1}_{a}
2 (2.24)	(7)a	10^{12}_{ab}	11^{1}_{ab}	10^{1}_{ab}	14^{2}_{b}
3 (3.36)	(7)a	13^{2}_{b}	8^{1}_{ab}	7^{1}_{ab}	12^{12}_{ab}
4 (4.48)	(7)a	8^{12}_{a}	11^{1}_{a}	8^{1}_{a}	7^{1}_{a}

*Non-weeded control
**Hand-weeded control

NOTE: Means within a row followed by the same letter or means within a column followed by the same number are not significantly different at the 5% level using least squares analysis.

interacting effect between herbicide combinations and improved cottonwood branch numbers.

There is one exception to the observed no effect of herbicide combinations on cottonwood top weight. Significant reductions on top weight were detected when oxyfluorfen at 2 lbs./A (2.24 kg/ha) was combined with napropamide at 4 lbs./A (4.48 kg/ha) compared to separate applications of oxyfluorfen at 2 lbs./A (2.24 kg/ha) and napropamide at 4 lbs./A (4.48 kg/ha) (Table VIII).

Evergreen Euonymus

Neither oxyfluorfen, oxadiazon, trifluralin nor napropamide alone or in combination resulted in any detrimental or stimulatory effects to the height growth or top weight of everygreen euonymus. The fact that the weedy control, hand-weeded control and all herbicide treatments were similar in top weight and height growth affirms the vigorous growth and durability of evergreen euonymus.

Wateri Pyracantha

The intense competition believed to exist between weeds and field nursery stock plants was not reflected by the top weight or height growth of wateri pyracantha as there were no significant differences between the weedy control and the hand-weeded control (Table IX). There were, however, several significant increases in pyracantha top weight above the hand-weeded control, oxadiazon at 1 and 2 lbs./A (1.12 and 2.24 kg/ha), oxyfluorfen at 1 and 2 lbs./A (1.12 and 2.24 kg/ha), trifluralin at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha) and napropamide at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha). Thus, a

TABLE VIII

INTERACTION OF OXYFLUORFEN AND NAPROPAMIDE ON COTTONWOOD FRESH TOP WEIGHT

			OXYFLUORFEN lbs./A (kg/ha)			
		0*	0**	0.5 (.56)	1 (1.12)	2 (2.24)
NAPROPAMIDE lbs./A (kg/ha)	*0	760	$(760)^{1}$	$(760)^{1}$	$(760)^{1}$	$(760)^{1}$
	**0	(760)a	1354^{2}_{b}	1798^{2}_{b}	1415^{2}_{b}	1416^{2}_{b}
	2 (2.24)	(760)a	1334^{2}_{ab}	1798^{2}_{b}	1761^{2}_{b}	1836^{2}_{b}
	3 (3.36)	(760)a	1538^{2}_{b}	1449^{2}_{b}	1570^{2}_{b}	1777^{2}_{b}
	4 (4.48)	(760)a	1419^{2}_{b}	1848^{2}_{b}	1562^{2}_{b}	899^{1}_{a}

*Non-weeded control
**Hand-weeded control

NOTE: Means within a row followed by the same letter or means within a column followed by the same number are not significantly different at the 5% level using least squares analysis.

TABLE IX

EFFECTS OF HERBICIDES ON GROWTH OF WATERI PYRACANTHA

	Herbicide Rate	Top Fresh Weight (g)	Height Growth (cm)	Caliper Growth (cm)
Weedy Control		51a	29a	0.2a
Hand-weeded Control		63a	34ab	0.5bc
Oxadiazon	1 (1.12)	102bc	38abc	0.4b
lbs./A	2 (2.24)	88ab	34ab	0.5bc
(kg/ha)	3 (3.36)	126bc	38abc	0.4b
Oxyfluorfen	0.5 (.56)	96abc	40bc	0.4b
lbs./A	1 (1.12)	118bc	40bc	0.6c
(kg/ha)	2 (2.24)	121bc	38abc	0.5bc
Trifluralin	2 (2.24)	119bc	46c	0.5bc
lbs./A	3 (3.36)	103bc	42bc	0.5bc
(kg/ha)	4 (4.48)	110bc	37abc	0.5bc
Napropamide	2 (2.24)	114bc	35ab	0.5bc
lbs./A	3 (3.36)	133bc	43bc	0.5bc
(kg/ha)	4 (4.48)	145c	40bc	0.5bc

*Means within a column followed by the same letter are not significantly different at the 5% level using least squares analysis.

stimulation of top weight by the herbicides at specific rates is suggested. Moreover, these plants were more branched and of superior visual appearance than either control treatment.

Wateri pyracantha stem caliper was significantly greater with applications of any herbicide as well as the hand-weeded control when compared to the non-weeded control (Table IX).

Significant increases in height growth were detected above the weedy control with oxyfluorfen at 0.5 and 1 lbs./A (.56 and 1.12 kg/ha), trifluralin at 2 and 3 lbs./A (2.24 and 3.36 kg/ha) and napropamide at 3 and 4 lbs./A (3.36 and 4.48 kg/ha). Only trifluralin at 2 lbs./A (2.24 kg/ha) was observed to be significantly greater than the hand-weeded control (Table IX).

When considering all the herbicide combinations, only oxyfluorfen at 2 lbs./A (2.24 kg/ha) combined with napropamide at 4 lbs./A (4.48 kg/ha) was possibly stunting wateri pyracantha top weight (Table X). This specific treatment combination is not significantly different from most other treatments. The treatment combination of oxadiazon at 2 lbs./A (2.24 kg/ha) with trifluralin at 3 lbs./A (3.36 kg/ha) resulted in a significant increase of height growth of wateri pyracantha above separate applications of either trifluralin at 3 lbs./A (3.36 kg/ha) or oxadiazon at 2 lbs./A (2.24 kg/ha) (Table XI).

In general, excellent crop compatibility was observed when applications of oxadiazon, oxyfluorfen, napropamide or trifluralin were used alone. This observation coincides with other studies conducted with the same herbicides on field nursery stock.

Kuhns and Haramaki (27) found oxyfluorfen to be especially phytotoxic to pyracantha (<u>Pyracantha coccinea</u> 'Lalandii') and evergreen

TABLE X

INTERACTION OF OXYFLUORFEN AND NAPROPAMIDE ON
WATERI PYRACANTHA, FRESH TOP WEIGHT

		OXYFLUORFEN lbs./A (kg/ha)				
NAPROPAMIDE lbs./A (kg/ha)		0*	0**	0.5 (.56)	1 (1.12)	2 (2.24)
	0	51	51	$(51)^{1}$	$(51)^{1}$	$(51)^{1}$
	0	(51)a	63^{1}_{ab}	96^{12}_{ab}	118^{2}_{b}	121^{2}_{b}
	2 (2.24)	(51)a	114^{2}_{b}	111^{2}_{b}	114^{2}_{b}	106^{2}_{b}
	3 (3.36)	(51)a	133^{2}_{b}	101^{2}_{ab}	89^{12}_{ab}	116^{2}_{b}
	4 (4.48)	(51)a	145^{2}_{c}	109^{2}_{bc}	104^{2}_{bc}	73^{12}_{ab}

*Non-weeded control
**Hand-weeded control

NOTE: Means within a row followed by the same letter or means within a column followed by the same number are not significantly different at the 5% level using least squares analysis.

TABLE XI

INTERACTION OF OXADIAZON AND TRIFLURALIN ON WATERI PYRACANTHA, HEIGHT GROWTH

TRIFLURALIN lbs./A (kg/ha)		OXADIAZON lbs./A (kg/ha) 0*	0**	1 (1.12)	2 (2.24)	3 (3.36)
	*0	29	$(29)^{1}$	$(29)^{1}$	$(29)^{1}$	$(29)^{1}$
	**0	(29)a	34^{12}_{a}	38^{12}_{a}	34^{12}_{a}	38^{12}_{a}
	2 (2.24)	(29)a	46^{3}_{b}	40^{2}_{b}	43^{23}_{b}	47^{2}_{b}
	3 (3.36)	(29)a	42^{23}_{b}	34^{12}_{ab}	47^{3}_{c}	40^{2}_{b}
	4 (4.48)	(29)a	37^{23}_{b}	40^{2}_{b}	39^{23}_{b}	44^{2}_{b}

*Non-weeded control
**Hand-weeded control

NOTE: Means within a row followed by the same letter or means within a column followed by the same number are not significantly different at the 5% level using least squares analysis.

winter creeper (Euonymus fortunei 'Coloratus'), however, this study did not find oxyfluorfen detrimental to any field stock tested. By contrast, a slight stimulation of either caliper growth, top weight or height growth was oppressed due to applications of oxyfluorfen at specific rates to wateri pyracantha and cottonwood. The general increases in growth of the field nursery stock compared to no herbicide used can best be attributed to reduced weed competition.

Napropamide was observed to be safe on cottonwood, wateri pyracantha and evergreen euonymus. This coincides with studies by Talbert et al. (45) and Ahrens (1). They found napropamide to be safe on euonymus (Euonymus spp.) and everygreen winter creeper (Euonymus fortunei). Moreover, this study has found napropamide to have a slight stimulatory effect on the growth of wateri pyracantha and cottonwood at some specific rates.

Several studies with oxadiazon have shown a wide range of crop safety (3, 8, 11, 29, 31, 33, 40, 41, 45). However, some research has shown oxadiazon to be phytotoxic to certain field stock (5, 23, 38). Bailey and Simmons (3) found oxadiazon safe on numerous field species, but observed moderate signs of phytotoxicity on scarlet firethorn (Pyracantha coccinia). Also, Bean and Whitcomb (5) and Reavis and Whitcomb (38) noted oxadiazon damage to silver maple (Acer saccharinum), pin oak (Quercus palustris) and Monarch birch (Betula maximowicziana). Data from this study did not show any detrimental effects of separate applications of oxadiazon. In fact, at specific rates, it had a slight stimulatory effect on cottonwood and wateri pyracantha.

Due to the volatilization and photodecomposition of trifluralin, the recommended practice has been to incorporate the herbicide into the upper few inches of the soil (20, 32, 34, 46, 47). However, this study confirmed the findings by Bean and Whitcomb (5) and Reavis and Whitcomb (38) who noted that if trifluralin is used at higher rates, unincorporated, but applied early in the season good to moderate weed control can be expected with good crop safety. Woessner's (50) study of improved height growth on cottonwood (Populus deltoides) with applications of trifluralin at 4 lbs./A (4.48 kg/ha), coincides with findings in this study on cottonwood based on increases in top weight, caliper growth and height growth.

Cellerino (10) reported that trifluralin at 2 lbs./A (2.24 kg/ha) resulted in no injury when applied to newly planted poplar trees. These results confirm that data taken from cottonwood when trifluralin was found to be safe at 2 lbs./A (2.24 kg/ha).

Combinations of herbicides did not generally result in improved crop growth, nor were combinations found to be consistently detrimental to field nursery stock as reported by Cohen (11). However, the combination of oxyfluorfen at 2 lbs./A (2.24 kg/ha) with napropamide at 4 lbs./A (4.48 kg/ha) did significantly reduce the top weight of wateri pyracantha and cottonwood. This is contradictory to the findings of Reavis and Whitcomb (37) where oxyfluorfen was used in several combinations and did not result in a harmful effect on the field stock tested. There was a side benefit of increased crop growth when other specific rate combinations were used. This finding is unique since an extensive literature search did not locate other studies with a similar stimulatory growth response from herbicide combinations.

CHAPTER V

CONCLUSIONS

Separate applications of oxyfluorfen, oxadiazon, napropamide and trifluralin gave acceptable to excellent weed control with no significant field stock damage. Combinations of herbicides did not consistently improve the spectrum of weed control or have much influence on the field stock tested.

The objectives of this study were: (1) to determine what latitudes of safety can be expected from these herbicides, alone and in combination on field grown nursery stock; (2) to compare the effectiveness of each herbicide on weed control in field use; and (3) to determine if combinations of the herbicides will give a broader spectrum of weed control with equal or greater crop safety than each herbicide used alone.

The four herbicides alone or in combination were found to have an acceptable latitude of safety on evergreen euonymus, cottonwood and wateri pyracantha. In addition, a stimulation of height growth was observed on cottonwood by oxadiazon at 1, 2 and 3 lbs./A (1.12, 2.24 and 3.36 kg/ha), oxyfluorfen at 2 lbs./A (2.24 kg/ha) and trifluraline at 2 lbs./A (2.24 kg/ha) and a stimulation of top weight on wateri pyracantha by oxadiazon at 1 and 2 lbs./A (1.12 and 2.24 kg/ha), oxyfluorfen at 1 and 2 lbs./A (1.12 and 2.24 kg/ha), trifluralin at 2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha) and napropamide at

2, 3 and 4 lbs./A (2.24, 3.36 and 4.48 kg/ha). The combination of oxyfluorfen at 2 lbs./A (2.24 kg/ha) with napropamide at 4 lbs./A (4.48 kg/ha) consistently reduced the top weight of wateri pyracantha and cottonwood.

Although all herbicides when used alone substantially reduced the quantity of weeds, oxadiazon and oxyfluorfen suppressed the top weight of weeds better than either trifluralin or napropamide. However, trifluralin and napropamide, at certain rates, did significantly reduce the top weight of weeds.

Although combinations of oxadiazon, oxyfluorfen, trifluralin and napropamide did not increase the spectrum of weed control greater than when each herbicide was used alone, oxyfluorfen at 1 and 2 lbs./A (1.12 and 2.24 kg/ha) combined with napropamide at 2 and 3 lbs./A (2.24 and 3.36 kg/ha) did reduce weed weights better than either herbicide used alone.

Further investigations are needed in combining herbicides to enhance the spectrum of weed control and possibly to improve the growth of field nursery stock. Possibly the greatest potential lies in combining oxadiazon and oxyfluorfen, since this study has shown combinations of oxyfluorfen and oxadiazon with trifluralin or napropamide not as effective as initially perceived.

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