1323190

ALEXANDER, JUDITH ANN

HERBICIDE COMBINATIONS FOR PREEMERGENCE WEED CONTROL IN CONTAINER-GROWN ARID LANDSCAPE PLANTS

THE UNIVERSITY OF ARIZONA M.S. 1984

University Microfilms International 300 N. Zeeb Road, Ann Arbor, MI 48106

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark _√_.

1. Glossy photographs or pages _____
2. Colored illustrations, paper or print _____
3. Photographs with dark background _____
4. Illustrations are poor copy _____
5. Pages with black marks, not original copy _____
6. Print shows through as there is text on both sides of page _____
7. Indistinct, broken or small print on several pages _√_
8. Print exceeds margin requirements _____
9. Tightly bound copy with print lost in spine _____
10. Computer printout pages with indistinct print _____
11. Page(s) ________ lacking when material received, and not available from school or author.
12. Page(s) ________ seem to be missing in numbering only as text follows.
13. Two pages numbered ________. Text follows.
14. Curling and wrinkled pages _____
15. Other ____________________

HERBICIDE COMBINATIONS FOR PREEMERGENCE WEED CONTROL IN CONTAINER-GROWN ARID LANDSCAPE PLANTS

by

Judith Ann Alexander

A Thesis Submitted to the Faculty of the

DEPARTMENT OF PLANT SCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN HORTICULTURE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 8 4

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Judith Ann Alexander

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Charles M. Sacamano — April 30 1984

CHARLES M. SACAMANO
Professor of Plant Sciences

Date

ACKNOWLEDGMENTS

The author wishes to give special thanks to her major professor, Dr. Charles Sacamano, for his guidance, support and friendship during the course of this study.

Also, appreciation is extended to Dr. Paul Bessey and Dr. Chi Won Lee for their comments and suggestions in preparation of this manuscript.

Many thanks to Mr. Ron Gass, owner of Mountain States Wholesale Nursery, who so kindly provided the landscape plants and the use of his nursery for this study.

Thanks are also extended to Mr. L. T. Clark, Mr. Ali Mohamed Ibrahim and Mr. Gary Zech for their help with many of the organizational and physical tasks of this experiment.

Finally, the author is most grateful to the Interregional Research Project No. 4 Program for its financial support of the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

Four preemergence herbicide combinations were evaluated for control of Euphorbia supina in container-grown Yucca elata, Yucca valida, Calliandra eriophylla, Prosopis sp. and Simmondsia chinensis.

Oxyfluorfen + oryzalin provided 100% weed control at 2.2 + 2.2, 4.5 + 4.5 and 1.1 + 6.7 kg/ha. However, unacceptable growth stunting of Yucca sp. and C. eriophylla was observed at 2.2 + 2.2 and 4.5 + 4.5 kg/ha.

Oxyfluorfen + oxadiazon provided a mean of 97.8% weed control at 0.6 + 6.7, 1.1 + 4.5, and 2.2 + 4.5 kg/ha. A wide range (10-42%) of reduced growth rates of Yucca sp. and S. chinensis were observed at 2.2 + 4.5 and 0.6 +6.7 kg/ha.

Oxadiazon + oryzalin provided a mean of 96.8% weed control at 2.2 + 2.2, 4.5 + 4.5, and 1.1 + 6.7 kg/ha respectively. Growth of S. chinensis was reduced 25-32% at 4.5 + 4.5 and 1.1 + 6.7 kg/ha respectively.

Oxyfluorfen + pendimethalin provided limited weed control. The 1.1 + 0.6 kg/ha rate gave only 50% control throughout the study. Rates of 2.2 + 1.1 and 3.4 + 1.7 kg/ha provided a mean of 95% control during August through January, however, efficacy dropped to 40% during May through July. Y. elata exhibited 20% to 40% reduction in growth depending on treatment rate.

INTRODUCTION

In some parts of the country, the container plant industry is undergoing major changes. A substantial increase in the cost of water, coupled with government restriction of water for landscape use, has initiated a shift from production of high water-use landscape plants to low water-use landscape plants. Research relating to weed control in the container production of low-water use plants has been scarce. As a result, nurserymen require specific information about safe, effective, weed control in container-grown arid landscape plants.

Variations in climate demand that weed control materials be adaptable. In desert nurseries, environmental factors such as temperature and sunlight play an important role in herbicide activity. High temperatures and intensive ultraviolet light can alter herbicide effectiveness by increasing volatilization and photodecomposition. Thus, it is reasonable to evaluate some of the weed control materials that are currently being tested for the typical container nursery and attempt to apply them to the needs of the arid plant industry.

Since manual weeding of containers is time-consuming and expensive, preemergence herbicides have come to play an important role in reducing weed populations in container-grown ornamentals. However, to achieve and maintain acceptable weed control, these herbicides must be used repeatedly during the growing season (Humphrey, Elmore, and Mock 1977). Such usage can result in toxic injury to nursery stock and inflated production expenses for nurserymen. In search of a solution to these problems, recent research has been directed toward evaluating combinations of preemergence herbicides.

Major benefits have been realized through selection of particular herbicide combinations. In some cases, the synergistic effect of combined materials lowers the application rates of individual herbicides while maintaining or increasing weed control effectiveness (Holmes 1981). Thus, combinations can reduce the hazard of phytotoxicity to sensitive nursery stock. Additionally, the expense of high application rates and repeated treatments can be avoided by utilizing herbicide combinations. Finally, the application of two or more chemicals produces control of a broad spectrum of weed species.

Previous research has evaluated the effectiveness of oryzalin (Surflan[R]), oxadiazon (Ronstar[R]), oxyfluorfen (Goal[R]) and pendimethalin (Prowl[R]) in the container plant industry. In various combinations, these herbicides provide acceptable weed control in containers of high water-use plant species. Although commercial experience suggests that these herbicides are effective in the desert nursery, research has been limited. Therefore, the focus of this study is to evaluate the effects of preemergence herbicide combinations when used under desert conditions on container-grown arid landscape plants.

LITERATURE REVIEW

The germinating seed or seedling is the easiest stage of the plant life cycle to interrupt. Thus, preemergence herbicides comprise the largest number of weed control chemicals. Moreover, preemergence herbicides are generally the safest to landscape plants (Elmore, Humphrey, and Hesketh 1979).

Oryzalin, manufactured by Elanco Products, is a dinitroanaline compound used as a preemergence herbicide in fruit and nut crops, soybeans and woody ornamentals. A yellow-orange, crystalline solid, it has a water solubility of 2.5 mg/l. The compound has a low vapor pressure and is relatively stable in sunlight. It is not recommended for use in soils with more than 3% organic matter as it adsorbs strongly to these particles restricting herbicide availability (Thompson 1982, Klingman 1975). Previous research found oryzalin to be a promising herbicide for some container landscape plants. Creager (1982) observed 75% weed control at the 2.2 kg/ha rate for 2 months with no injury to seven species of woody ornamentals. Elmore and Mast (1977) experienced good results with rates of 4.48 kg/ha in containers of *Cotoneaster glaucophylla* Franch.

However, other studies report that oryzalin has caused unacceptable damage to some landscape plants. Whitcomb and Butler (1975) state that oryzalin is "unsuitable to use in containers due to excessive leaching and potential for crop damage." They found stunted top and root growth of *Ilex cornuta* (Lindl) 'Burford' at rates of 4.5, 8.9 and 13.5 kg/ha.

In 1975, Wadsworth tested oryzalin on 32 plant species of container nursery stock. He reported that at 8.97 kg/ha oryzalin severely damaged 17 of the 32 plant species tested. Even at the 4.48 kg/ha rate, unacceptable damage occurred. Ryan (1981) found that oryzalin toxicity was eliminated when application intervals were extended to 3 months.

Oxadiazon is an oxadiazole compound manufactured by Rhone-Poulenc Inc. and is used as a preemergence herbicide in turf, fruit crops and ornamentals. It is an odorless, white, crystalline powder available in several formulations: emulsifiable concentrate, wettable powder, granular and flowable. It does not leach readily in the soil, has a very low water solubility and is non-volatile (Thomson 1982, Hilton 1974). Oxadiazon has been investigated by several researchers and is considered to be one of the chemicals most favored for weed control in containers.

Neel (1977) evaluated the weed control effects of oxadiazon on 16 species of container-grown nursery stock. Using rates of 2.24, 4.48 and 8.97 kg/ha, weed growth was reduced 72% at the lowest rate to 96% at the highest rate with no adverse effects on any of the ornamentals. Interestingly, the growth of 3 ornamental species was actually improved by the herbicide treatment. He suggests this could be due to decreased weed competition, or possibly growth stimulatory effects of the herbicide. Elmore et al. (1977) controlled common groundsel in containers of *Buxus microphylla* with oxadiazon at 2.24, 4.48 and 8.97 kg/ha. *Buxus microphylla* remained free of phytotoxic symptoms at all rates.

Few reports of phytotoxic effects of oxadiazon are available. However, relevant to this study, are the results that Wadsworth (1975) observed when he applied oxadiazon granules to container-grown plants of *Yucca aloifolia*. At rates of 4.48 and 8.97 kg/ha, oxadiazon was slightly toxic to this arid plant. He contributes this damage to the granules being trapped in the axis of leaf blades. Although the Yucca survived, growth was stunted.

Oxyfluorfen, manufactured by Rohm & Haas Co., is a diphenyl ether compound used as a preemergence herbicide in fruit and nut crops and woody ornamentals. The manufacturer states that it is highly insoluble in water, does not leach readily in soil, and is unaffected by high temperatures and ultraviolet light. Although oxyfluorfen has exhibited good weed control in containers of landscape plants (Creager 1982, Elmore et al. 1977, Elmore and Mast 1977, Whitcomb and Reavis 1979), it appears that at many of the test rates it also caused unacceptable injury to the landscape plant. Oxyfluorfen at 17.9 kg/ha significantly reduced the dry weight of harvested foliage of *Buxus microphylla* (Elmore et al. 1977). Another study that compares oxyfluorfen with oryzalin and oxadiazon reports that oxyfluorfen was more phytotoxic to nursery stock than the other herbicides (Reavis and Whitcomb 1979). Elmore and Mast (1977) observed leaf spotting on *Pyracantha fortunei* after an application of oxyfluorfen at 8.97 kg/ha.

Pendimethalin, like oryzalin, is a dinitroanaline compound. It is strongly adsorbed on soil organic matter and resists leaching.

Water solubility is 0.5 mg/l. Although pendimethalin has been proven an effective herbicide in agricultural crops (Walker and Brown 1982, Thomson 1982), there is little evidence of its use in container plant production except in combination with oxyfluorfen. A combination of 2% oxyfluorfen and 1% pendimethalin is manufactured as Ornamental Herbicide II (OH II) by O.M. Scott & Sons. The product label states it will control 21 grass and broadleaf weeds in 27 genera of field-grown and container-grown ornamentals. Oregon State University (William 1983) reports that OH II effectively controls annual weeds in field-grown woody perennials, woody ornamentals and nursery stock in containers. Apparently the product is most efficacious against chickweed and groundsel. Although the manufacturer has requested that registration of the product be expanded to the Southwest, their request was denied due to lack of regional research.

Research of herbicide combinations is ongoing. Results are continually reinforcing the belief that combinations are more efficient than individual herbicides. In 1973, Bennett concluded that the combination of simazine (Princep^R) at 1.12 kg/ha and diphenamid (Dymid^R and Enide^R) at 4.48 kg/ha provided increased weed control with a reduction in plant injury. Similarly, Carpenter and Weller (1983) report that a fellow researcher (Lanphear, F.) at Purdue University evaluated several herbicide combinations and determined that lesser amounts of chemicals could be used with better results. By combining simazine and diphenamid, he was able to reduce the recommended rate of simazine by 1/3 and the recommended rate of diphenamid by 1/2 yet achieve weed control as good as or better than when these herbicides were used alone at recommended rates.

Fretz (1973) states that when trifluralin (Treflan^R^) at 4.48 kg/ha + linuron (Lorox^R^) at 1.12 kg/ha was applied to grass and broadleaf weeds in containers of Ilex crenata and Rhododendron obtusum, weed control was significantly better than when either of the herbicides were used alone.

Various combinations of oxadiazon, oryzalin and oxyfluorfen have proven to be particularly successful in controlling weeds in landscape plant production. Humphrey, Elmore, and Mock (1977) observed long-term weed control with combinations of oryzalin + oxadiazon, oryzalin + oxyfluorfen and oxadiazon + oxyfluorfen. These combinations at various rates provided 100% control of bittercress and groundsel in containers of Buxus microphylla for 10 months with only one application.

Ryan (1981) revealed important information about combinations of oryzalin and oxadiazon. Oryzalin alone at 4.5 kg/ha did not control common groundsel in nursery containers, however, a combination of oxadiazon + oryzalin (4.5 + 4.5 kg/ha) controlled the weed for 8 weeks. Similarly, control of barnyardgrass was 67 to 74% with oryzalin alone (4.5 kg/ha), but increased to 92 to 96% with a combination of oryzalin + oxadiazon (4.5 + 4.5 kg/ha). Finally, oxadiazon at 3.4 kg/ha combined with oryzalin at 4.5 kg/ha controlled chickweed 99.5 to 100%. Oxadiazon alone gave less than 70% control of this weed.

Every production nursery requires its own individual weed control program because specific weed pests vary from site to site. In the arid plant nursery, prostrate spurge Euphorbia supina Raf. poses a serious weed problem. In Shearmans (1982) description of the life cycle of prostrate spurge, he states that these plants have been observed to produce as many as 3,500 seeds per plant. Germination begins when soil temperatures (2.54 cm deep) reach 12 - 16°C and continues through temperatures of 32°C. The wide temperature range for germination and extensive seed production makes prostrate spurge difficult to control. Moreover, this multi-branched, radiating stemmed weed forms a low, dense mat on the soil surface (Wilkinson and Jaques 1972). During the hot summer months it takes only a few weeks for one weed plant to cover the soil surface of a one-gallon nursery container. Competition with the landscape plant for nutrients and water can be consequential. Lastly, prostrate spurge exudes a milky sap when its stems are broken. In some cases, this sap can cause severe irritation and blistering to the skin making handweeding hazardous (Muenscher 1980, Heathman, Hamilton and Doty 1981).

MATERIALS AND METHODS

Plant species selected for the experiment represent some of the most economically important landscape plants in the arid container-plant industry:

Prosopis sp. L. (Mesquite) is a graceful, spreading shade tree prevalent in desert landscapes.

Simmondsia chinensis (Link) C. K. Schneid. (Jojoba) is a landscape shrub widely used for its interesting foliage pattern.

Calliandra eriophylla Benth. (Fairy Duster) owes its popularity as a landscape shrub to its showy, pink flowers; a key plant in roadway median landscaping.

Yucca elata Engelm. (Soap Tree Yucca) and *Yucca valida* T.S. Brandegee. are rosette-type accent plants prized for the striking silhouettes they lend to desert landscapes.

Well-established plants in one-gallon metal can containers were used in the study. The soil mix consisted of 3 parts soil and 1 part fir bark with a pH of 7.3 and 4.7% organic matter content.

Four preemergence herbicides in various combinations were evaluated. Oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-trifluoromethyl)benzene], oxadiazon [2-tert-butyl-4-(2-,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazolin-5-one], and oryzalin(3,5-dinitro-N^4,N^4-dipropylsulfanilamide) were chosen in an effort to compare previous research results on high water-use plants with results on low water-use plants. All three herbicides have label clearance for use on ornamentals. The pendimethalin [N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine] + oxyfluorfen combination is sold commercially as Ornamental Herbicide II, but is not available in the Southwest. Test rates used in the study along with manufacturers suggested rates are listed in Table 1.

A latin square within a split-split plot design was used for the experiment. Four replications were made. A total of 240 plants received herbicide treatments; 80 plants were used as controls (Figure 1).

The experiment was conducted in a Glendale, Arizona, wholesale nursery that specializes in container-grown arid landscape plants. The study spanned a period of 11 months to ensure that results reflect the influence of all four seasons.

The experiment was established June 1, 1982. For the initial application of herbicides, plants were placed in groups of 20; four plants of each species. Each group was treated with the appropriate combination of herbicides, then positioned in the experimental plot. Granular herbicide formulations were applied evenly over the soil surface of each container by hand shaker. Liquid formulations were uniformly applied by a pressure sprayer at 30 psi with a hand-held wand and single nozzle. Calibration trials with the sprayer resulted in depositing 7 ± 0.5 ml of liquid into each container. This volume along with surface area measurement of a one-gallon nursery container ($0.6\ m^2$) were the criteria used to calculate actual amount of herbicides applied.

Table 1. Herbicide combinations and application rates used on container-grown arid landscape plants.

Herbicide	Formulation	Test Rate[y]			Recommended Rate[z]
oxyfluorfen +	G	1.1	2.2	3.4	2.2
pendimethalin	G	0.6	1.1	1.7	1.1
oxyfluorfen +	2E	0.6	1.1	2.2	1.1 - 4.5
oxadiazon	2% G	6.7	4.5	4.5	2.2 - 4.5
oxyfluorfen +	2E	2.2	4.5	1.1	1.1 - 4.5
oryzalin	75 WP	2.2	4.5	6.7	0.6 - 1.4
oxadiazon +	2% G	2.2	4.5	1.1	2.2 - 4.5
oryzalin	75 WP	2.2	4.5	6.7	0.6 - 1.4

[y] kg/ha

[z] manufacturer label rate - kg/ha

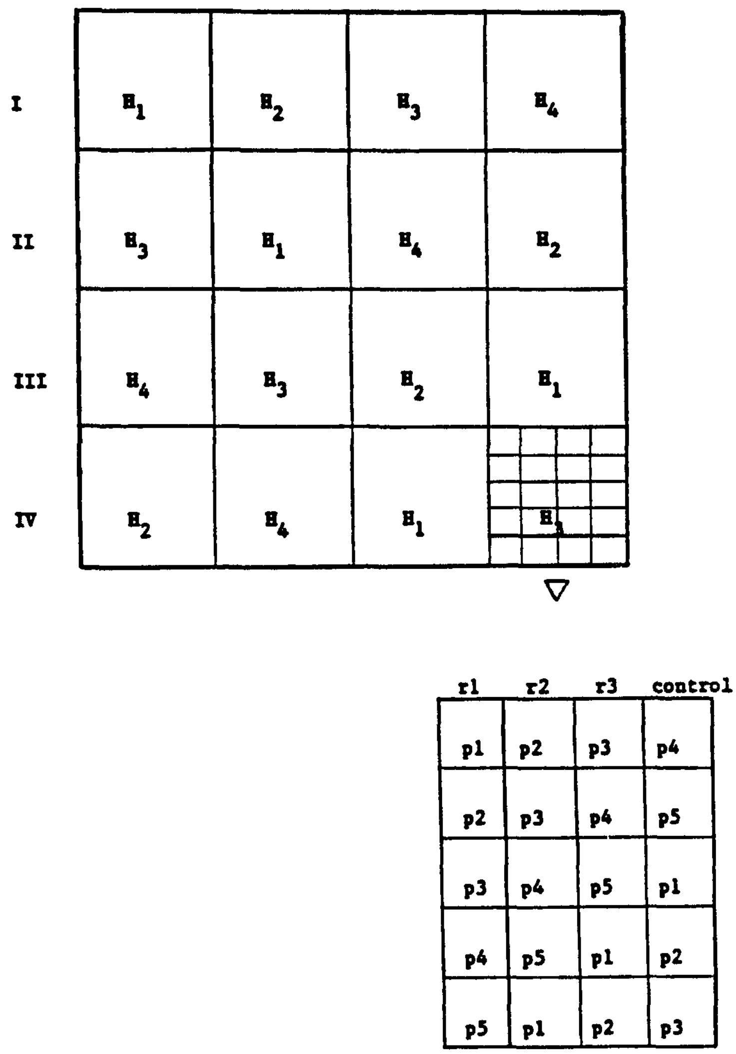

Figure 1. Experimental plot design used to test effects of four preemergence herbicide combinations (H) at three rates (r) on five landscape plants (p) with controls.

Only two herbicides were applied simultaneously. The pendimethalin + oxyfluorfen combination is incorporated into a granular formulation by the manufacturer. Consequently, both chemicals were applied at the same time. All other chemicals were applied individually, in sequence. After all herbicides were applied, containers were watered lightly to move the herbicide into the soil.

By August 1, 1982, there was no significant weed growth in any of the 320 containers. It was assumed that by this time, events such as wind and irrigation would have deposited weed seed in the test containers. Since this did not occur, it was decided to over-seed each container with weed seed. On August 11, 1982, twenty seeds of Euphorbia supina were introduced into each container.

This plant is one of the most serious weed problems in the arid plant production industry. One weed plant produces several hundred seed that fall from the plant, with any slight disturbance, to reseed. Thus, it was not necessary to repeat the overseeding procedure for the duration of the experiment.

Herbicides were again applied on August 11, 1982, and at approximate 90-day intervals thereafter. Before each application, weeds were harvested from all containers, dried at 65.5°C for 24 hours, then weighed. Throughout the experiment, herbicide drift was avoided by inserting a large sheet of plywood between the rows of containers during spray applications.

An overhead sprinkler system supplied water to the experimental plot. In desert nurseries, daily irrigation is the rule, and from June through September, it is not unusual to irrigate twice daily.

On March 10, 1983, and again at the end of the experiment July 21, 1983, growth measurements were obtained to evaluate phytotoxicity effects on the salable plant. Internode lengths were measured on shrub and tree specimens. Leaf counts were performed on rosette-type plants.

Analysis of variance was performed on growth measurements of all five plant species. Herbicide treatment effects were defined by linear contrast. Additionally, analysis of variance was performed on dry weights of weeds. Differences between herbicide treatments were examined via mean separation (Fisher's LSD procedure, 5% level). Rates within herbicide treatments were also compared via the LSD procedure, 5% level.

RESULTS AND DISCUSSION

The four herbicide combinations were first evaluated for their effectiveness in controlling weeds in the nursery containers. Subsequently, the response of each of the plant species to the herbicide treatments was determined. Finally, each herbicide combination was assessed according to its effectiveness on the weed plant vs. its risk to the ornamental plant.

Herbicide Treatment Effectiveness

Throughout the experiment, the oxyfluorfen + oryzalin combination proved to be the most effective herbicide treatment (Figure 2). One hundred percent weed control was observed at all rates of this combination. These results are favorably compared with those of Creager (1982). He reported that oxyfluorfen and oryzalin used separately at a rate of 2.2 kg/ha provided 75% control of bittercress, crabgrass and oxalis. Although different weed species were involved, it is noteworthy that the combination of these two chemicals at the same rate provided better than 75% control of *E. supina*. Moreover, since total success was achieved at the lowest test rate of 2.2 + 2.2 kg/ha, this combination may provide acceptable weed control at even lower rates. Also, it may be possible to extend intervals between applications of the herbicides and still maintain good weed control.

The combination of oxyfluorfen + oxadiazon also provided excellent control of *E. supina*. Although not significantly different

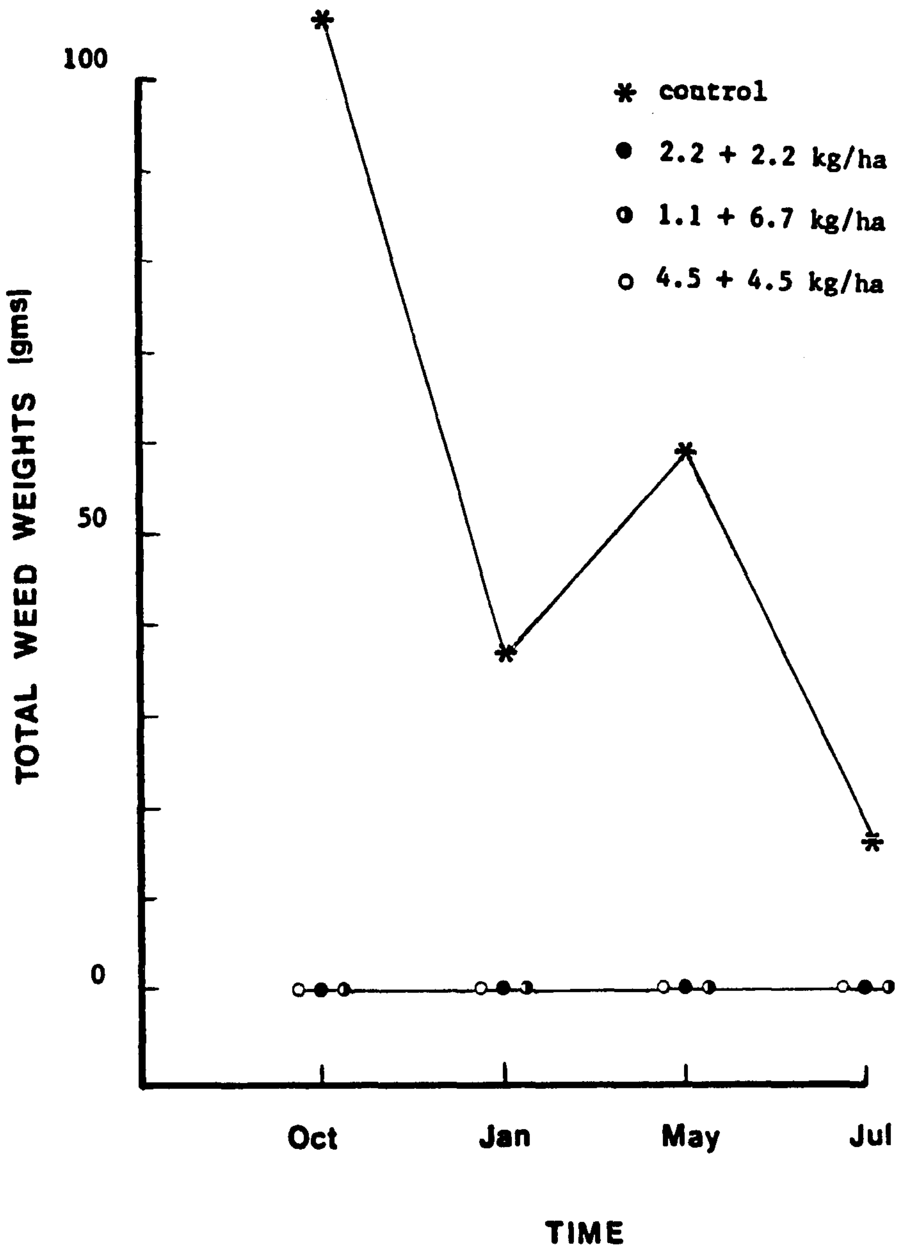

Figure 2. Total dry weights of weeds for three rates of oxyfluorfen + oryzalin and a control over time.

from results achieved with the oxyfluorfen + oryzalin combination, some weed growth was observed at rates of 1.1 + 4.5 kg/ha and 0.6 + 6.7 kg/ha. Figure 3 shows that all spurge growth took place during the peak summer growing season of the weed. This combination averaged 97.6% weed control over the course of the investigation.

Similarly, combinations of oxadiazon + oryzalin provided a mean of 96.8% weed control over all rates. More frequent weed growth was observed with this combination as compared to the oxyfluorfen + oxadiazon treatment. Most weed growth, however, occurred at the lowest rate, 2.2 + 2.2 kg/ha (Figure 4). All other rates provided 99±1% control throughout the experiment.

Overall, the least effective herbicide treatment was the oxyfluorfen and pendimethalin combination (Figure 5). The 1.1 + 0.6 kg/ha rate provided an average of only 50% weed control over the entire test period. The other test rates provided an average of 95% control during the period of August through January. However, efficacy dropped to an average of 40% from May through July. Since this significant decrease occurred during the summer months, the trend may suggest that the oxyfluorfen + pendimethalin combination undergoes chemical degradation in the presence of high temperatures and intensive sunlight, thus reducing its weed control effects. Alternatively, it is possible that test rates were too low to control spurge during its most vigorous growth period.

It should be noted that although this experiment focused on control of _E. supina_, there was no attempt to protect the nursery

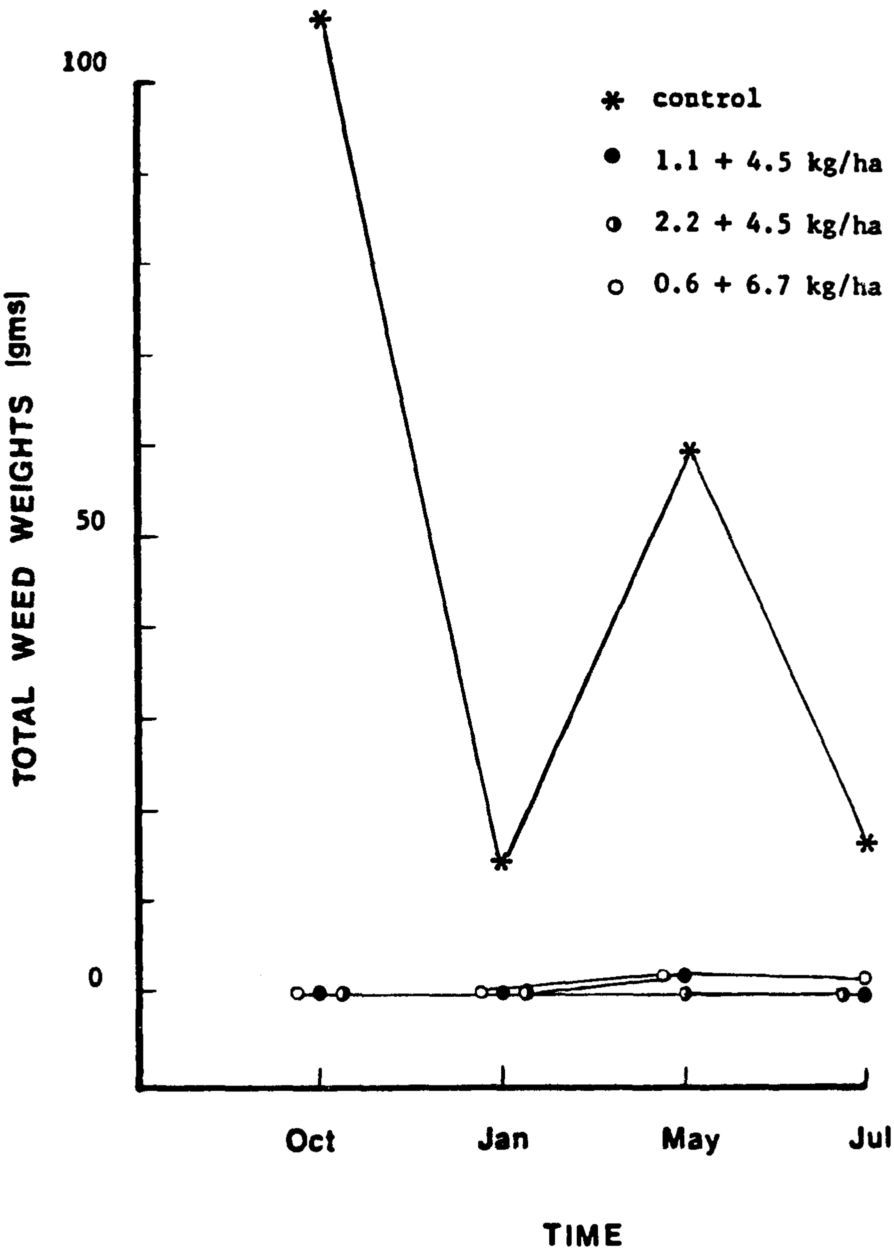

Figure 3. Total dry weights of weeds for three rates of oxyfluorfen + oxadiazon and a control over time.

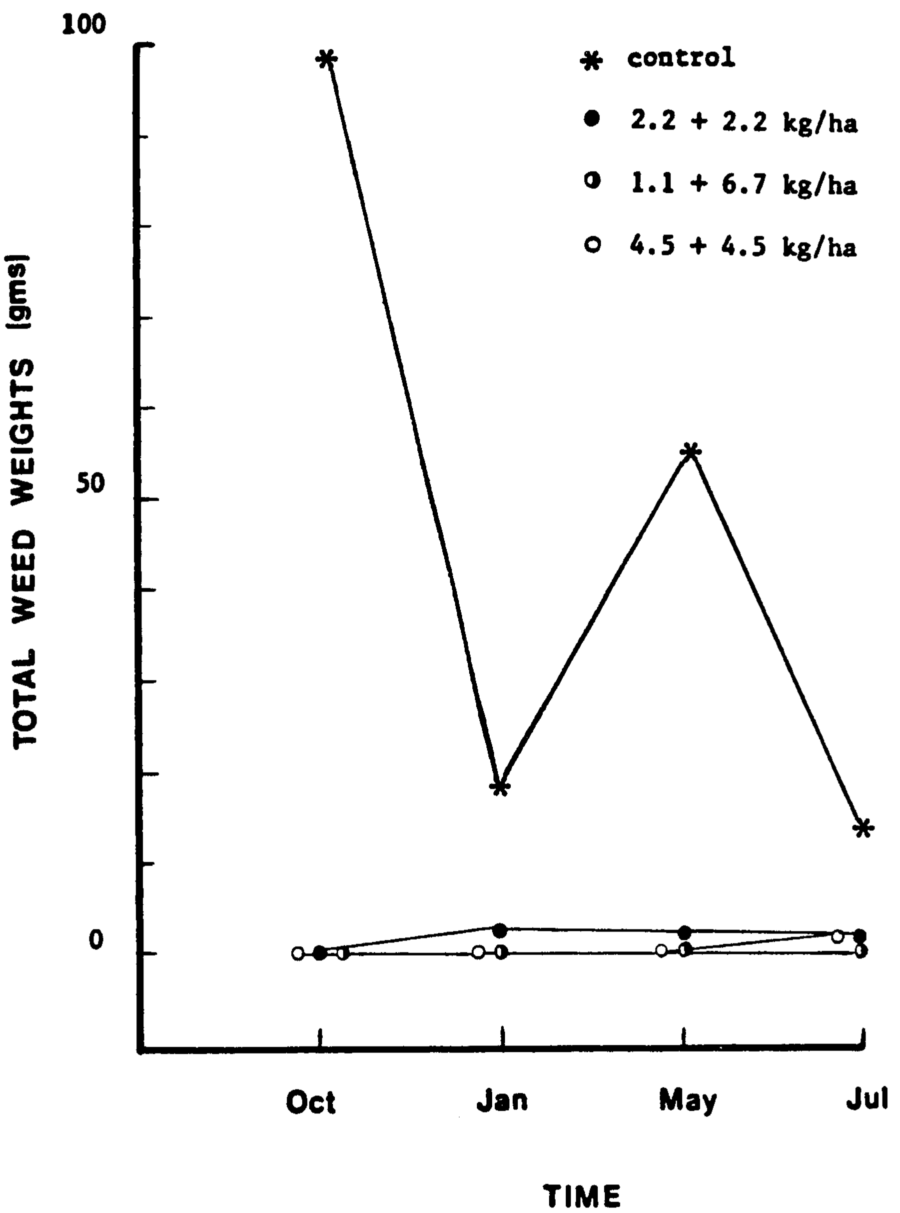

Figure 4. Total dry weights of weeds for three rates of oxadiazon + oryzalin and a control over time.

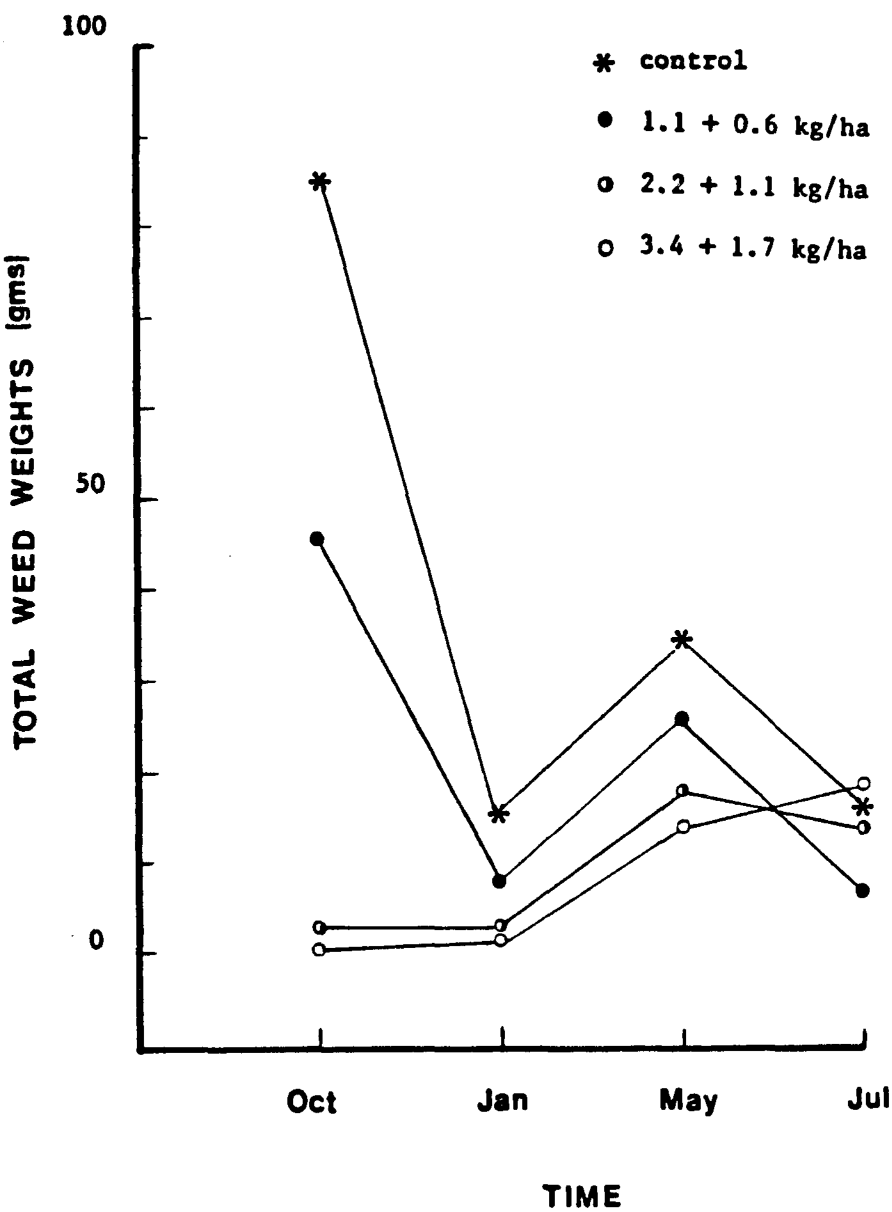

Figure 5. Total dry weights of weeds for three rates of oxyfluorfen + pendimethalin and a control over time.

containers from contamination by other weed species. No infestations of any other weed were observed in the treated containers. However, annual sow thistle occasionally occurred in the control containers. Perhaps the herbicide combinations were controlling other weeds as well as *E. supina*. There is no scientific proof of this.

Species Response to Herbicide Treatments

Of the five plant species used in the study, *Yucca elata* proved to be the most sensitive to herbicide treatment (Table 2). It was least tolerant of the oxyfluorfen + oryzalin combination. Leaf counts of *Y. elata* that were treated with this combination indicate that at rates of 2.2 + 2.2 kg/ha and 1.1 + 6.7 kg/ha the number of leaves was 30-35% lower than leaf counts of control plants. Any reduction of growth over 25% was considered unacceptable. Since no weed growth occurred in any of the nursery containers treated with this herbicide combination, reduced leaf counts cannot be attributed to competition. Thus, this combination caused unacceptable growth stunting of *Y. elata*.

Combinations of oxyfluorfen + pendimethalin also caused stunting of *Y. elata*. In terms of leaf counts, the 2.2 + 1.1 kg/ha rate reduced growth by approximately 40%. Rates of 0.6 + 1.1 kg/ha and 3.4 + 1.7 kg/ha reduced plant growth by 20% and 25% respectively.

A classic trend of reduced growth was exhibited by *Y. elata* in response to the oxyfluorfen + oxadiazon combination. As herbicide rates increased, leaf numbers decreased. However, only the rate of 0.6 + 6.7 kg/ha caused an unacceptable 35% reduction in leaf counts.

Table 2. Effects of four herbicide combinations on growth of *Yucca elata* over time.

Herbicide	Rates kg/ha	Number of Leaves[y] 3/10/83	7/21/83
	Control	88.50a[z]	99.50a
oxyfluorfen +	1.1 + 0.6	54.25b	80.75a
pendimethalin	2.2 + 1.1	51.75b	60.25b
	3.4 + 1.7	41.50b	74.75ab
	Control	76.75a	104.75a
oxyfluorfen +	1.1 + 4.5	68.75a	93.50ab
oxadiazon	2.2 + 4.5	51.25ab	77.25bc
	0.6 + 6.7	37.00b	64.25c
	Control	68.00a	84.00a
oxyfluorfen +	2.2 + 2.2	47.75ab	58.50b
oryzalin	1.1 + 6.7	62.25a	76.75ab
	4.5 + 4.5	30.75b	59.00b
	Control	72.00a	97.25ab
oxadiazon +	2.2 + 2.2	73.00a	110.00a
oryzalin	1.1 + 6.7	55.00a	92.50b
	4.5 + 4.5	63.75a	93.75b

[y] Mean number of leaves per plant based on 4 replications.

[z] Mean separation in columns within each treatment by linear contrast. F distribution, 5 % level.

Y. elata appeared to be most tolerant of the oxadiazon + oryzalin combination. Leaf counts show that 92-100% of growth was maintained at all rates.

Yucca valida exhibited 40% reduced growth with oxyfluorfen + oxadiazon at 0.6 + 6.7 kg/ha. Also, applications of oxyfluorfen + oryzalin at 2.2 + 2.2 kg/ha and 4.5 + 4.5 kg/ha resulted in a decrease in leaf numbers of 50% and 60% respectively (Table 3). Since this combination was also damaging to *Y. elata*, it may be concluded that the oxyfluorfen + oryzalin combination should not be recommended for use on *Yucca* sp.

Prosopis sp. tolerated all herbicide treatments well (Table 4). No growth stunting was observed. The only significant differences are between rates within particular herbicide combinations. For example, the oxyfluorfen + pendimethalin combination revealed a significant increase in internode lengths from the control rate to the 2.2 + 1.1 kg/ha rate. This is probably due to the weed control effects and a reduction in competition for water and nutrients, or perhaps due to stimulatory growth effects as suggested by Neel (1977). A similar trend is apparent with the oxyfluorfen 1.1 + oxadiazon 4.5 kg/ha combination.

The growth of *Simmondsia chinensis* appeared to be significantly reduced with the combination of oxadiazon + oryzalin at rates of 4.5 + 4.5 kg/ha and 1.1 + 6.7 kg/ha (Table 5). However, this difference is a result of a plant death within each rate. The cause of death was undetermined, but not likely to be a result of herbicide damage since the other 3 plants in each group remained vigorous. In an analysis of

Table 3. Effects of four herbicide combinations on growth of *Yucca valida* over time.

Herbicide	Rates kg/ha	Number of Leaves[y] 3/10/83	7/21/83
	Control	18.50a[z]	32.50a
oxyfluorfen +	1.1 + 0.6	16.50a	30.00a
pendimethalin	2.2 + 1.1	14.00a	23.75a
	3.4 + 1.7	16.00a	28.50a
	Control	13.00a	25.75a
oxyfluorfen +	1.1 + 4.5	11.50a	23.75ab
oxadiazon	2.2 + 4.5	14.50a	31.50a
	0.6 + 6.7	11.00a	15.00b
	Control	10.00ab	23.75a
oxyfluorfen +	2.2 + 2.2	6.50ab	12.50b
oryzalin	1.1 + 6.7	14.00a	23.00a
	4.5 + 4.5	5.50b	10.00b
	Control	15.75a	25.75a
oxadiazon +	2.2 + 2.2	11.75a	21.75a
oryzalin	1.1 + 6.7	13.50a	22.50a
	4.5 + 4.5	11.00a	22.25a

[y] Mean number of leaves per plant based on 4 replications.

[z] Mean separation in columns within each treatment by linear contrast. F distribution, 5 % level.

Table 4. Effects of four herbicide combinations on growth of *Prosopis* sp. over time.

Herbicide	Rates kg/ha	Internode Lengths (mm)[y] 3/10/83	7/21/83
	Control	25.00a[z]	22.50a
oxyfluorfen +	1.1 + 0.6	26.25a	22.50a
pendimethalin	2.2 + 1.1	22.50b	30.00b
	3.4 + 1.7	17.50c	22.50a
	Control	21.25a	21.25a
oxyfluorfen +	1.1 + 4.5	26.25b	26.25b
oxadiazon	2.2 + 4.5	23.75ab	23.75ab
	0.6 + 6.7	25.00ab	25.00ab
	Control	22.50a	22.50a
oxyfluorfen +	2.2 + 2.2	23.75a	23.75a
oryzalin	1.1 + 6.7	23.75a	23.75a
	4.5 + 4.5	22.50b	22.50a
	Control	23.75a	23.75a
oxadiazon +	2.2 + 2.2	22.50a	22.50a
oryzalin	1.1 + 6.7	22.50a	22.50a
	4.5 + 4.5	21.25a	21.25a

[y] Mean length of three internodes per plant based on 4 replications.

[z] Mean separation in columns within each treatment by linear contrast. F distribution, 5 % level.

the 3 live plants, the reduction of growth in the treated plants does not exceed 20.4% at either rate. An analysis problem also occurred with the oxyfluorfen + oryzalin combination. Although it appeared that all treated plants grew significantly larger than the non-treated plants, the mean internode length of the control group was unusually small due to the death of one of the plants. This plant fatality was contributed to poor drainage of the nursery container. When compared to the three remaining control plants, growth rates of treated plants ranged from 76% to 87% at rates of 1.1 + 6.7 kg/ha and 2.2 + 2.2 kg/ha respectively. S. chinensis displayed reduced growth with oxyfluorfen 0.6 + oxadiazon 6.7 kg/ha and oxyfluorfen 3.4 + pendimethalin 1.7 kg/ha. However, since growth decreased no more than 21% in either case, this reduction was considered acceptable.

Calliandra eriophylla tolerated all herbicide treatments well (Table 6). Its most significant response was exhibited with the oxadiazon + oryzalin combination. At rates of 1.1 + 6.7 kg/ha, analysis revealed much greater growth in the treated plants than in the control plants. This is probably a result of decreased competition with weeds due to herbicide effects. Reduced growth was observed with oxyfluorfen + oryzalin at 2.2 + 2.2 and 4.5 + 4.5 kg/ha, but did not exceed an acceptable reduction of 20%.

Unfortunately, observation of the experimental plot during the first few days after the application of herbicides was impossible due to traveling distance. Therefore, immediate foliar effects that the herbicide treatments may have had on the ornamentals are unknown. It

Table 5. Effects of four herbicide combinations on growth of *Simmondsia chinensis* over time.

Herbicide	Rates kg/ha	Internode Lengths (mm)[y] 3/10/83	7/21/83
	Control	21.25a[z]	22.50a
oxyfluorfen +	1.1 + 0.6	22.50a	20.00ab
pendimethalin	2.2 + 1.1	20.00ab	20.00ab
	3.4 + 1.7	17.50b	18.75b
	Control	25.00a	23.75a
oxyfluorfen +	1.1 + 4.5	17.50b	20.00b
oxadiazon	2.2 + 4.5	18.75b	22.50ab
	0.6 + 6.7	20.00b	18.75b
	Control	12.50a	12.50a
oxyfluorfen +	2.2 + 2.2	18.75b	20.00b
oryzalin	1.1 + 6.7	13.75a	17.50b
	4.5 + 4.5	17.50b	18.75b
	Control	21.25a	20.00a
oxadiazon +	2.2 + 2.2	17.50b	22.50a
oryzalin	1.1 + 6.7	15.00b	13.75b
	4.5 + 4.5	12.50b	15.00b

[y] Mean length of three internodes per plant based on 4 replications.

[z] Mean separation in columns within each treatment by linear contrast. F distribution, 5 % level.

Table 6. Effects of four herbicide combinations on growth of *Calliandra eriophylla* over time.

Herbicide	Rates kg/ha	Internode Lengths (mm)[y] 3/10/83	7/21/83
	Control	15.00a[z]	15.00a
oxyfluorfen +	1.1 + 0.6	8.75b	12.50a
pendimethalin	2.2 + 1.1	12.50a	15.00a
	3.4 + 1.7	13.75a	13.75a
	Control	15.00a	12.50a
oxyfluorfen +	1.1 + 4.5	12.50a	13.75a
oxadiazon	2.2 + 4.5	12.50a	13.75a
	0.6 + 6.7	12.50a	15.00a
	Control	12.50a	17.50a
oxyfluorfen +	2.2 + 2.2	12.50a	13.75b
oryzalin	1.1 + 6.7	11.25a	17.50a
	4.5 + 4.5	11.25a	15.00b
	Control	11.25a	12.50a
oxadiazon +	2.2 + 2.2	11.25a	12.50a
oryzalin	1.1 + 6.7	16.25b	17.50b
	4.5 + 4.5	12.50a	13.75a

[y] Mean length of three internodes per plant based on 4 replications.

[z] Mean separation in columns within each treatment by linear contrast. F distribution, 5 % level.

is important to note, however, that monthly visual inspections revealed no foliar damage indicative of herbicide toxicity.

Herbicide Effectiveness vs. Species Response

The oxyfluorfen + pendimethalin combination did not control *E. supina* during its vigorous summer growth period. Reduced effectiveness could be due to accelerated chemical degradation resulting from high temperatures and intense sunlight or due to herbicide rates too low for effective control of *E. supina*. Since only *Yucca* sp. exhibited sensitivity to this particular combination, further testing should be done on other arid plant species. Rates higher than 3.4 + 1.6 kg/ha should be used in an attempt to increase the weed control effectiveness of the combination. If, in fact, this combination suffers degradation under desert nursery conditions, further testing under these conditions will substantiate this hypothesis.

Due to significant growth stunting, the combination of oxyfluorfen + oryzalin cannot be recommended for use on *Yucca* sp. However, it performed so well on the other four plant species that it should be considered as a candidate for use on certain arid landscape plants.

The oxyfluorfen + oxadiazon combination also requires further evaluation. Even though stunting of *Yucca* sp. and *Simmondsia chinensis* occurred in this study, many other desert plant species may benefit from this combination since it displayed such good weed control.

Considering both efficacy and phytotoxicity data, the combination of oxadiazon + oryzalin gave an impressive performance in this study. It should be considered an effective weed control material for use in the production of desert landscape plants.

These combinations should be evaluated further; testing their effects on other arid container plants. It is important that the list of effective herbicides and herbicide-tolerant plant species be expanded as rapidly as possible for greater efficiency in container production of arid landscape plants.

LITERATURE CITED

Bennett, W. J. 1973. Herbicides and combinations in field liners. Proc. Intl. Plant Prop. Society. 23: 326-327.

Carpenter, P. and S. Weller. 1983. Why use combinations or tank mixes of herbicides? Coop. Ext. Purdue Univ. p. 9-10.

Creager, R. A. 1982. A comparison of oxyfluorfen and oryzalin in container-grown woody ornamentals. HortScience 17: 207-209.

Elmore, C. L., W. A. Humphrey and K. A. Hesketh. 1979. Container nursery weed control. Coop. Ext. Univ. Calif. Leaflet #21059.

Fretz, T. A. 1973. Herbicide combinations for weed control in container nursery stock. Proc. Intl. Plant Prop. Society. 23: 315-319.

Heathman, S. E., K. C. Hamilton and C. H. Doty. 1981. How to control prostrate spurge in Arizona. Coop. Ext. Univ. of Ariz. #8103.

Hilton, J. L. 1974. Herbicide Handbook of the Weed Science Society of America. 3rd edition. p. 286-290.

Holmes, F. A. 1981. Herbicide combinations: benefits and problems. Proc. Calif. Weed Conf. 33: 92-96.

Humphrey, W. A., C. L. Elmore and T. W. Mock. 1977. Long-term weed control in container-grown plants. Flower and Nursery Rpt. Coop. Ext. Univ. Calif. May/June.

Klingman, G. C. and F. M. Ashton. 1975. Weed Science. John Wiley & Sons. New York. p. 85-87, 196-197.

Little, T. M. and F. J. Hills. 1978. Agricultural Experimentation Design & Analysis. John Wiley and Sons, Inc. p. 42-44, 78-85, 101-113.

Muenscher, W. C. 1980. Weeds. Comstock Pub. Cornell Univ. Press. Ithaca, New York. p. 298.

Neel, P. L. 1977. Effects of oxadiazon preemergence herbicide on weed control and growth of sixteen species of containerized ornamental plants. Proc. Fla. State Hort. Society. 90: 353-355.

Reavis, R. and C. E. Whitcomb. 1979. Effects of herbicide combinations for weed control in a field nursery. Oklahoma State Univ. Research Rpt. #P-791. Oct. p. 52-53.

Ryan, G. F. 1981. Combinations with oxadiazon for weed control in nursery containers. Proc. Western Society of Weed Science. 34: 129-139.

Shearman, R. 1982. Troublesome turfgrass weeds. Research update. Golf Course Management. Aug. p. 78.

Thomson, W. T. 1982. Agricultural Chemicals - Book II - Herbicides. Thomson Publications. Fresno, Calif. p. 44-51, 210-211.

Wadsworth, G. L. 1975. Evaluation of eight herbicides in container nursery stock. Comb. Proc. Intl. Plant Prop. Society. 25: 471-476.

Whitcomb, C. E. and J. F. Butler. 1975. Performance of trifluralin, nitralin, and oryzalin in nursery containers. Jour. of the Amer. Soc. for Hort Sci. 100: 225-229.

Whitcomb, C. E. and R. Reavis. 1979. A comparison of Ronstar and Goal for weed control in containers. Oklahoma State Univ. Research Rpt. #P-791. Oct. p. 49.

Wilkinson, R. E. and H. E. Jaques. 1972. How to Know the Weeds. William C. Brown Co. Pub. p. 47.

William, R. D. 1983. Oregon Weed Control Handbook. Oregon State Univ. Ext. Service. p. 114-117.