AN EVALUATION OF PREEMERGENCE HERBICIDES FOR CONTROL OF PROSTRATE SPURGE (EUPHORBIA SUPINA RAF.) IN CONTAINER NURSERY PRODUCTION OF LOW WATER USE LANDSCAPE PLANTS IN THE DESERT SOUTHWEST

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1. Design used to evaluate five preemergence herbicides (H), each at three rates (x, 2x and 4x), on seven container-grown arid landscape ornamentals (Sp). Each herbicide at each rate was replicated (P) nine times on each species. Additionally, there were two untreated control containers, one-hand weeded (C_1) and one non-weeded (C_2) 26

ABSTRACT

Five preemergent herbicides were evaluated for control of prostrate spurge (<u>Euphorbia supina</u> Raf.) in seven container-grown arid landscape ornamentals at the following rates in kilograms active ingredient per hectare: oxyfluorfen, 0.6, 1.1 and 2.0; oryzalin, 3.0, 6.0 and 12.0; Dacthal, 22.4, 44.8 and 89.7; norea, 1.2, 2.2 and 4.5; and oxadiazon, 2.2, 4.5 and 9.0, respectively. Prostrate spurge reaches its peak in summer.

During the first test, February 5 - May 20, 1981, or 104 days, all herbicides provided satisfactory to complete control at all rates, except norea at 1.2 and 2.2 and oxadiazon at 2.2 were ineffective in one test species.

During the second test, May 21 - August 17, 1981 or 88 days, oryzalin gave the best overall control; oxyfluorfen provided effective control only at 2.2; oxadiazon produced erratic results; and norea and Dacthal became ineffective at all rates after 23 days. No phytotoxicity to the plants was observed.

CHAPTER 1

INTRODUCTION

Prostrate spurge (*Euphorbia supina* Raf.) is probably the most pervasive, aggressive and pernicious weed to infest container-grown ornamentals in southern Arizona.

Almost no research about the control of prostrate spurge in container-grown ornamentals has been reported in Arizona. Some information about the control of prostrate spurge in bermudagrass turf and other areas of the landscape is available.

Research reports about the control of prostrate spurge and other closely related *Euphorbia* species in container-grown ornamentals are available from studies conducted in other regions of the country. These results may require qualification when applied to the desert southwest because of different growing conditions of the region, *e.g.*, low humidity, high temperatures, and high light intensities. Moreover, the tolerance of most arid ornamental species to the herbicides remains untested.

Weeds compete for light, nutrients, and moisture within the limited space of containers in which ornamentals are produced. Fretz (1972) demonstrated that some weeds compete severely enough to reduce plant size almost 50%. Creager (1982a, 1982b) implied the competitiveness of weeds when he observed from studies that "plant size was proportional to the degree of weed control obtained." Neel (1977) cited research showing plant growth reduction by weeds that secrete inhibitory or alleolopathic substances. The author was unable to locate any research relevant to the secretion of such substances by prostrate spurge.

The effectiveness and safety of chemical herbicides for container-grown ornamentals are influenced by several variables. Root systems of ornamentals are confined to a limited media mass consisting of various combinations and proportions of sand, clay, organic matter, or other materials. Upchurch and Mason (1962) showed that the higher the organic matter content, the greater amount of chemical material required to achieve effective control of weeds.

A highly porous medium, often used in container mixes, increases leaching. Excessive leaching dilutes the herbicide in the zone of seed germination and can concentrate it in the root zone of the crop, decreasing ornamentals' tolerance of the herbicide (Monaco 1974; Monaco and Hodges 1974). The practice of applying large amounts of irrigation water to container-grown ornamentals, especially to plants produced in the dry and hot desert southwest, can further affect the movement of herbicides in the soil.

Other important variables which may make a herbicide inactive and thereby reduce its effectiveness include other chemical, physical, and microbial processes, e.g., adsorption by soil colloids; photochemical decomposition caused by ultraviolet light; chemical reactions with soil constituents; volatilization; and microbial decomposition (Klingman and Ashton 1975; Anderson 1983).

In the container nursery industry, mechanical cultivation as practiced under field conditions is not possible. Hand weeding is too costly, however. Based on studies and current labor costs, hand weeding probably costs as least $8,000 per hectare of container plants, which represents more than 20% of the total production costs of many nurseries (Padgett and Frazier 1962; Elmore 1975; Elmore and Mast 1977b; Dickey et al. 1978). Hand weeding can even be less productive than chemical control and cost twice as much as chemicals.

Hand weeding is impractical, especially for species with spines and thorns. Like all *Euphorbia* species, prostrate spurge exudes a milky sap that is a skin irritant. Workers are soon discouraged by these characteristics.

Prostrate spurge competes with container-grown ornamentals and other weeds in containers because it establishes and spreads rapidly. Its root system binds it to the soil well. Hand weeding may remove only part of the plant; the rest of the plant can regenerate new growth.

To remain competitive with other local and regional growers, most nurseries find it necessary to use chemicals in an attempt to control prostrate spurge. Growers in southern Arizona have tried various preemergence herbicides to control prostrate spurge, but report verbally that none of the chemicals has given satisfactory control. Regardless of the effectiveness of a preemergence herbicide, some growers prefer granules to spray material, and vice versa.

Some growers hesitate to use granules because they can easily be trapped in the basal rosette of leaves of Agavaceae, Cactaceae, and succulents that are produced in large quantities in Arizona's nurseries. Unless the granules are completely washed out of the whorl of leaves of the plant, leaf burn or other injury may occur.

This study used arid landscape ornamentals grown in containers under desert conditions. The objectives of the study, in order of priority, were:

1. To evaluate the efficacy and residual weed control of five preemergence herbicides which demonstrate varying degrees of promise for control of prostrate spurge in container culture.

2. To establish rates, duration of control, and intervals of application of the preemergence herbicides that will give control of prostrate spurge, at a competitive cost, in container-grown arid landscape ornamentals.

3. To evaluate the tolerance of heretofore untested species to the preemergence herbicides.

4. To generate data relevant to registration of preemergence herbicides not yet labelled for use in container-grown arid landscape ornamentals.

It is hoped that the results of this study will be useful in general to wholesale growers of container-grown arid landscape ornamentals in Arizona and elsewhere. Availability of healthy and attractive plants with low water requirements that are produced as efficiently and economically as possible should encourage more people to use these plants in residential, commercial and municipal landscapes of the southwest. Ultimately, growers and consumers will benefit, for everyone will be using limited water resources more judiciously.

CHAPTER 2

LITERATURE REVIEW

Prostrate spurge (Euphorbia supina Raf.) is a low-growing herbaceous summer annual. When competing for light it may display a more upright growth habit, and in mild winters at lower elevations in the desert southwest, it may persist into the following year (Heathman, Hamilton, and Doty 1981).

According to a survey by the U. S. Department of Agriculture (1972), prostrate spurge is considered one of the most common weeds to infest Arizona. It is an especially aggressive pest in bermudagrass turf (Parker 1972) and often becomes the dominant weed in container-grown nursery stock.

Prostrate spurge reproduces by seed. Each plant produces thousands of small seeds, a strategy which guarantees its survival and persistence. Seeds are disseminated by wind or dispersed by insects, animals, equipment, and occasionally by man. Wilson (1980) showed the potential for weed seed to be spread in irrigation water from canals. A container soil mix can thus be contaminated in several ways.

An understanding of a weed's life cycle is essential to finding a method of control. Studies at the University of California, Riverside (Shaner and Krueger 1979; Krueger and Shaner 1980, 1982), have shown that seed germination and seedling establishment of prostrate spurge were influenced particularly by temperature. Maximum germination occurred when daily temperatures alternated between a low of 15 to 25 C and a high of 30 to 35 C. An optimum temperature for germination was about 30 C.

Krueger and Shaner also found that prostrate spurge can germinate under light levels as low as 12.5% of full sunlight. The higher the light intensity was, however, the larger the seedling produced. Depending upon the amount of shade provided by the canopy of a container-grown ornamental, the competitive edge could be in favor of the ornamental over the prostrate spurge growing within the same container. The researchers noted that once seedlings emerged, they grew faster and more vigorously under day-lengths of 12 or more hours and that the optimal light intensity for continued growth occurred at 40% or more of full sunlight.

Other important characteristics were identified by Krueger and Shaner. Prostrate spurge seeds produced at different times of the year varied in amount of dormancy. In the research reported, about 50% of the seeds produced in August germinated in the same season, while only 5 to 10% of the seeds produced in November germinated, leaving some seeds in the soil to germinate the next spring. Dormant seeds that were not stratified during the winter could still germinate after irrigations during hot summer days.

The researchers also learned that the emergence and establishment of prostrate spurge seedlings were most likely to occur at depths ranging from just beneath the soil surface to 0.5 cm. Only a few seeds at depths below 1 cm emerged. Their tests showed further that with an increase of the pH above 6.0 germination decreased.

In the literature cited in this study, prostrate spurge is a common name given to three taxon, e.g., *Euphorbia supina* Raf., *E. maculata* L., and *E. prostrata* Ait. All three species are so similar taxonomically that the author has assumed that effects of an herbicide on one species would be identical to those on the other two species. In some of the citations, prostrate spurge is called spotted spurge or spotted prostrate spurge because some plants have red blotches on the leaves. The author considers this morphological difference to be insignificant with respect to the weed's response to various herbicides.

In the container production nursery industry, chemical control offers the most effective control of weeds at reasonable cost and with relative safety to the crop, man and the environment. In its life cycle the weed is most vulnerable to chemicals as the weed germinates and before seedling establishment. Preemergence herbicides interrupt germination or inhibit growth of seedling weeds. Different herbicides exhibit different modes of action to achieve this goal (Klingman and Ashton 1975; Elmore, Humphrey, and Hesketh 1979; Anderson, 1983).

The herbicides selected for use in this study were oxyfluorfen, oryzalin, DCPA, norea, and oxadiazon. Most of these herbicides have been evaluated extensively throughout the country and have demonstrated satisfactory control of a wide spectrum of broadleaved weeds in container-grown ornamentals.

Few evaluations have been devoted to their effectiveness for control of prostrate spurge in arid landscape ornamentals grown in containers under conditions of the desert southwest. In research and commercial nursery production, some of the herbicides have exhibited varying degrees of promise in controlling prostrate spurge. The effectiveness of each as a preemergent control of prostrate spurge in container-grown ornamentals under production in southern Arizona requires further study and elaboration.

Oxyfluorfen (Goal^R)

Oxyfluorfen, a diphenyl ether compound, is a selective preemergence and postemergence herbicide for the control of annual broadleaf weeds and grasses. It is registered for use in certain fruit and nut crops as well as woody ornamentals. The manufacturer, Rohm and Haas and Company, does not list Euphorbia species among weeds controlled by oxyfluorfen.

The company maintains in its research reports that oxyfluorfen is highly insoluble in water and does not break down under high moisture conditions. The company also states that the herbicide is unaffected by variations in soil pH and organic matter content and has shown little or no performance differences with varying soil types. Research of Fadayomi and Warren (1977) supports these claims.

The manufacturer reports further that, based on winter applications of oxyfluorfen, ultraviolet photodecomposition is not considered a significant problem and that high temperatures speed contact activity of the herbicide. Oxyfluorfen disrupts the energy-producing mechanisms, photophosphorylation, within the target weed.

A relatively new herbicide, oxyfluorfen is marketed under the trade name Goal[R]. It has been actively evaluated in container-grown ornamentals, mainly with the 2% granular formulation, since the late 1970s. Reports of its control of spurges are inconsistent. Humphrey and Elmore (1979) reported acceptable to excellent control of spotted spurge (*E. maculata* L.) with 2% material at 2.2 and 4.5 kg/ha and 2% emulsifiable concentrate at 4.5 kg/ha but unacceptable control with the 2EC formulation at 2.2 kg/ha. Some treatments deleteriously affected plant vigor and growth, e.g., growth of *Cupressus arizonica* (Arizona cypress) was suppressed by both the 2G and 2EC formulations and necrosis developed in the tips.

Currey and Weatherspoon (1979) found that oxyfluorfen applied every three weeks gave excellent control of spurges (species not enumerated) at the rate of 2.2 kg/ha as recommended by the manufacturer and higher rates of 4.5 and 9.0 kg/ha. In a later test, acceptable control was obtained only at 9.0 kg/ha. Based on studies of Singh and Tucker

(1983), a rate of 4.5 kg/ha applied at 90-day intervals was consistently more effective than a lower rate of 2.2 kg/ha in the control of E. maculata L., a major weed pollutant in the test containers.

The efficacy of oxyfluorfen as a control of other broadleaf weeds and some grasses in containers is well documented (Elmore et al. 1977; Humphrey and Elmore 1979; Reavis and Whitcomb 1980; Singh, Glaze, and Tucker 1980). In general, higher rates of 4.5 and 9.0 kg/ha were more effective for longer periods, e.g., four-month efficacy instead of two-month, than the recommended rate of 2.2 kg/ha or lower (Elmore and Mast 1977; Creager 1982a, 1982b; Singh and Tucker 1983). Fretz, Koncal, and Sheppard (1980) noted that at 2.2 kg/ha the 2EC formulation gave better control than the 2G material at comparable rates of active ingredient.

Tolerance of container-grown ornamentals to higher rates of oxyfluorfen has varied sufficiently to warrant continued tests for crop safety. The herbicide was used with relative safety in experiments of Fretz and Sheppard (1978) with several species, e.g., cotoneaster, spirea, and dogwood, and of Creager (1982a, 1982b) with such species as euonymus, holly, and rhododendron.

At 9.0 kg/ha oxyfluorfen was, however, phototoxic to several cultivars of azaleas (Singh, Glaze, and Phatak 1981) and severely retarded growth of Japanese holly (Singh, Phatak, and Glaze 1984). In a comparative study of Fretz, Koncal, and Sheppard (1980) the 2EC formulation caused significantly more injury than the 2G material.

Oryzalin (Surflan^R)

In a technical report, Elanco Products Company, a division of Eli Lilly and Company, describes oryzalin as a yellow-orange crystalline solid with a water solubility of 2.5 ppm. The manufacturer states that the herbicide is strongly adsorbed into the soil and is resistant to movement by water and that adsorption on soil organic matter does not restrict its availability. This dinitroanaline compound has low vapor pressure and is susceptible to decomposition by ultraviolet irradiation.

Oryzalin prevents weed growth by inhibition of root development. The herbicide is registered under the trade name Surflan^R as a selective preemergence surface-applied herbicide for control of a wide spectrum of broadleaf weeds and grasses. It is recommended for use in more than 100 established container-grown ornamental plants and other crops. The product label indicates that Surflan^R 75W will give long-term (six to eight months) control of prostrate spotted spurge (species not listed).

In tests conducted by Elmore, Humphrey, and Hesketh (1979) in California, where *E. maculata* L. is considered a major weed (U. S. Department of Agriculture 1972), orzalin controlled the weed quite well for about four months at a rate of 4.4 kg/ha.

Excellent control of broadleaf weeds, including spurges (species not enumerated) has been reported by Weatherspoon and Currey (1975) and Singh and Tucker (1983), using oryzalin at 4.5 and 9.0 kg/ha. Singh and Tucker found that the 4.5 kg/ha rate was effective in a common Florida citrus grove soil (Astatula fine sand) used in containers but ineffective in a synthetic mix.

The crop safety of oryzalin has come under close examination by researchers. Whitcomb and Butler (1975) questioned the suitability of the herbicide for use in containers because of excessive leaching and potential for crop damage. While some downward movement of a soil-applied herbicide is usually required to produce chemical contact with germinating weed seeds, excessive leaching can move the chemical to deep-rooted plants, injuring them, and also decreasing weed control efficacy (Koncal 1972).

Singh, Glaze, and Phatak (1981) noted restricted growth, retarded root development, and lowered marketability in azaleas when oryzalin was applied at rates of 9.0 kg/ha or higher. Evidence of Weatherspoon and Currey (1975, 1979) had suggested that an accumulation of the herbicide resulting from repeated applications was more significant than rate in suppressing growth in azaleas.

The conclusions of Creager (1982b) differed greatly. In research of the U. S. Department of Agriculture, he demonstrated that, in most treatments, the more efficacious the weed control the larger the ornamental plant produced. Injury, if any, was within the limits of commercial acceptability. In Creager's trials a 5G material available only for research was used at rates ranging from 1.1 to 9.0 kg/ha during a two-year period on several woody ornamentals, including cultivars of holly, euonymus, and rhododendron. In earlier work of Elmore

(1975) and Fretz (1977) the authors found insufficient evidence to demonstrate that oryzalin is unsuitable for use on a wide range of established container-grown ornamentals.

DCPA (Dacthal[R])

DCPA is a white, crystalline solid with a water solubility of 0.5 ppm. The herbicide is adsorbed on organic matter, which prevents its leaching (Klingman and Ashton 1975). Its mode of action inhibits germinating seeds and root growth.

DCPA, sold under the trade name Dacthal[R], is a selective pre-emergence herbicide for control of annual grasses and certain broad-leaved weeds in agronomic crops, turf, nursery stock, and established ornamentals. According to its manufacturer, Diamond Shamrock Corporation, Dacthal[R] 75W can be applied to a wide variety of nursery stock at a rate of 16 to 18 kg/ha. The label indicates that spotted spurge is moderately acceptable to the herbicide.

There is comparatively little research information about the effectiveness of DCPA in the control of spurges in nursery stock. In the 1970s, when DCPA was included in several comparative studies of herbicides, Currey and Whitcomb (1973) found that DCPA at the high rates of 22.4 and 44.8 kg/ha gave 80% or better control of _E. maculata_ L. for eight weeks. Elmore (1975) used lower rates of 11.2 and 16.8 kg/ha to achieve 50 - 70% and 70% or better control, respectively, of _E. maculata_ L.

The future of DCPA in any comprehensive nursery herbicide program is uncertain. While the herbicide gives good control of grasses, its effectiveness in the control of broadleaf weeds is variable (Neel 1972; Fretz 1973; Fretz and Smith 1973; Monaco and Hodges 1974; Elmore 1975; Nishimoto et al. 1980). Moreover, to be effective, relatively high rates must be used. As Wadsworth (1975) reports, the product is considerably more expensive than other herbicides. Despite the fact that DCPA is generally non-toxic to ornamentals, high rates could increase the potential for injury and reduced growth of container nursery stock.

Nevertheless, use of DCPA as a possible control of *Euphorbia* species in nursery stock deserves further research. It is one of the few herbicides available today which, with repeated applications, offers control of spurge in bermudagrass turf and other landscape areas of the desert southwest (Gibeault, Autio, and Elmore 1980; Heathman, Hamilton, and Doty 1981).

Norea (Herban^{R})

Norea is a white, crystalline solid with a water solubility of 150 ppm. Formulated as a wettable powder, it is used to control annual weeds in cotton and other agricultural crops (Klingman and Ashton 1975). It is not registered for use on ornamentals.

Norea is a member of the urea family of herbicides, which in general exhibit certain common chracteristics. Urea herbicides are adsorbed easily to soil colloids and resist leaching. They are most effective when applied as preemergents to broadleaved weeds. They inhibit photosynthesis. Photodecomposition may occur when these herbicides are exposed to extended periods of sunlight under hot, dry conditions, but volatilization is limited (Anderson 1983).

The author could locate only one experiment that reports the use of norea in container-grown nursery stock. Ryan (1976) found that the herbicide showed promise for use in container culture, confirming tests performed in western Washington prior to 1970. Norea gave excellent control of annual bluegrass (Poa annua L.) and bittercress (Cardamine oligosperma Nutt.) and good control of other weeds at rates of 3.6 and 7.2 kg/ha during an 87-day experiment. There were no adverse effects on any of the test plants, which included holly and azalea.

Norea is now available only for research. Its manufacturer, Boots Hercules Agrochemicals Co., made a quantity of the technical norea formulated as Herban® 80W available for this study.

Oxadiazon (Chipco® Ronstar®)

Technical oxadiazon was synthesized by Rhône-Poulenc of France and is formulated as a 2% granule on a clay base in the United States under the trade name, Chipco® Ronstar® G. The herbicide interferes with the development of the coleoptile of monocots and the cotyledon of dicots.

Oxadiazon, an oxadiazole compound, is a stable, white crystalline powder of negligible volatility. The manufacturer's trade manual states that the herbicide has a low solubility in water of 0.7 ppm. and does not break down by photodecomposition or leach deeper into the soil by gravitational moisture. The herbicide is unaffected by soil texture, organic matter content, or pH. Weatherspoon and Currey (1979) substantiate these characteristics of the herbicide.

According to the product label, Chipco^R Ronstar^R G is a selective preemergence herbicide for control of a broad spectrum of annual broadleaf weeds, including prostrate spurge, and grasses. Crop tolerance extends to more than 100 established container-grown ornamental species and varieties. The herbicide is probably the most frequently used preemergence chemical in the nursery industry today. It is also registered for use on turf and greenhouse roses and in forest nurseries.

The manufacturer recommends a rate of 3.4 to 4.5 kg/ha for the control of most broadleaf weeds and grasses but suggests the higher rate for control of prostrate spurge. The label cautions against applying granular material on species in which the granules will collect in leaf bases or crowns.

Since 1972 oxadiazon has been evaluated extensively throughout the country and has become identified as one of the most promising preemergents for control of weeds, including spurges (Fretz 1974, 1977b;

Weatherspoon and Currey 1975a, 1979; Ryan 1976; Manley, Wadsworth, and Carlyle 1976; Currey, Tucker, and Oswalt 1977; Fretz and Sheppard 1979).

Nishimoto et al. (1980) found that Chipco[R] Ronstar[R] 2G at 4.5 kg/ha gave complete control of prostrate spurge (*E. prostrata* Ait.), perhaps at greater safety than oryzalin, to 44 species of ornamentals grown in nurseries in Hawaii.

Bailey and Simmons (1979) conducted trials with granular formulations of oxadiazon using varying concentrations and rates throughout the country, including the southwest. Treatments at 4.5 kg/ha on several broadleaf weeds, including spotted spurge (*E. maculata* L.), averaged 90% during a two-year experiment. They observed retarded growth of *Yucca aloifolia* L., one of only three species of 63 ornamentals adversely affected by the herbicide. They reported that granules may have become trapped in the rosettes of leaves. The chemical would have been absorbed into the plants and suppressed their growth.

An even distribution of granules over the soil surface is essential to achieving effective weed control. At the Ohio Agricultural Research and Development Center, Fretz and Sheppard (1979) compared three different granular formulations of oxadiazon for control of large crabgrass (*Digitaria sanguinalis*), rough pigweed (*Amaranthus retraflexus*) and lambsquarter (*Chenopodium album*). The 2G material gave the most even distribution while the 5G and 10G formulations were more difficult to distribute evenly and gave less effective control. The 2G formulation at rates of 9.0 and 17.9 kg/ha caused the most phytotoxicity, however. The researchers inferred that uniform distribution of the granules gave greater root absorption of the material and thereby increased the potential for phytotoxicity. The workers added that, after three to four months, injury to the test plants, e.g., forsythia, red osier dogwood, and cranberry cotoneaster, was unnoticeable.

Numerous research reports of weed scientists of the University of California at Davis attest to the interest in oxadiazon to control *E. maculata* L. in a state that has one of the country's largest container nursery industries (Elmore et al. 1975, 1977; Elmore and Mast 1977a, 1977b; Humphrey et al. 1977; Elmore 1978; Elmore, Humphrey, and Hesketh 1979). Oxadiazon has shown acceptable to excellent control of *E. maculata* L. for as long as four months at a rate of 4.5 kg/ha (Elmore et al. 1975; Humphrey and Elmore 1979). At this rate, with both 2G and 75WP formulations, some reduction in plant size of coniferous ornamentals was reported (Humphrey and Elmore 1979).

Weed scientists of the University of Florida also have published ample information to confirm both the efficacy and safety of oxadiazon. Infestations of spurges, e.g., *E. hirta*, *E. hyssopifolia*, and *E. maculata* L., were not always as effectively suppressed as were those of most other broadleaf weeds (Weatherspoon and Currey 1975b, 1979; Currey, Tucker, and Oswalt 1977; Neel 1977). To improve the overall performance of oxadiazon, including its control of spurge, Weatherspoon and Currey (1975a, 1979) suggested repeated applications at two-month intervals at a rate of 4.5 kg/ha. While none of this work reported any serious phytotoxicity with oxadiazon, Weatherspoon and Currey (1975a) observed a necrotic band on palm leaves, possibly caused by granules trapped at the base of new leaves.

Creager (1982a) concluded that oxadiazon "can provide acceptable weed control in container-grown ornamentals with a wide safety margin in terms of plant injury and satisfactory plant size."

Data generated at the University of Georgia support the efficacy of oxadiazon as a weed control but indicated injurious effects to some cultivars of azalea and holly and at the same rates used by Creager. Singh, Glaze, and Phatak (1981) reported that azaleas were tolerant of the 4.5 kg/ha rate but some cultivars were severely injured at rates of 9.0 and 17.9 kg/ha. These higher rates also caused unacceptable injury to Japanese holly and adversely affected Chinese holly (Singh, Phatak, and Glaze 1984). The researchers suggested continued use of oxadiazon because of its excellent control but encouraged further research to ascertain specificity of phytotoxicity. They recommended further that rates and frequency of treatments should be adjusted to coincide with growing conditions, e.g., seasonal variations in temperature that affect germination and growth of weeds.

Herbicides in Combination

Oxyfluorfen, oryzalin, oxadiazon and DCPA have been evaluated in various combinations for control of grasses and broadleaf weeds in container nursery stock (Fretz 1977b; Humphrey, Elmore, and Mock 1977;

Ryan 1981; Alexander 1984). While this study deals with herbicides singly, use of combinations is germane to the general inquiry into the control of prostrate spurge.

There are advantages in using combinations. The synergistic effect of the combination may enhance efficacy. The application of smaller amounts of each component material may make possible a formula that results in reduction of both phytotoxicity and cost (Holmes 1981).

In tests of several combinations applied to arid landscape plants in a University of Arizona study, Alexander (1984) reported excellent control of prostrate spurge using combinations, e.g., oxyfluorfen-oryzalin, oxyflurofen-oxadiazon, and oxadiazon-oryzalin. Although reduced growth, particularly in *Yucca* species, was observed, all three combinations showed sufficient promise to warrant further evaluation with other container plants.

CHAPTER 3

MATERIALS AND METHODS

Seven container-grown ornamental species, growing under typical nursery conditions in southern Arizona, were treated with five different preemergence herbicides to evaluate their control of prostrate spurge (Euphorbia supina Raf.), one of the most pervasive and pernicious broadleaf weeds of the region. Tolerance of the ornamental plants to the herbicides was also observed.

The study was initiated February 5, 1981 and concluded on August 17, 1981. This experimental period coincided approximately with the growing season of prostrate spurge, a summer annual. In the Phoenix-Glendale area of the state, germination of prostrate spurge begins in February-March and continues through August-September or later.

The experiment was conducted in the container plant production area of the Mountain States Wholesale Nursery in Glendale at an elevation of about 1,100 feet. Relatively uniform one-gallon container-grown plants of less than one-year's growth were selected from the nursery stock.

The seven species chosen are widely used in residential, commercial, and municipal landscapes at lower elevations up to about 2,500 ft. in southern Arizona. The species are representative of plants with low water requirements:

1. *Cercidium floridum* Benth. (blue palo verde)
2. *Cassia artemisioides* Gaud. (feathery cassia)
3. *Justicia spicigera* Schechtend. (Mexican honeysuckle)
4. *Acacia redolens* (prostrate Ongerup acacia)
5. *Yucca recurvifolia* Salisb. (pendulous yucca)
6. *Dasylirion wheeleri* S. Wats. (desert spoon or sotol)
7. *Agave macroculmis* (maguey)

The herbicides were selected for several reasons:

1. Based on previous research, the herbicides have shown some promise in the control of prostrate spurge and other closely related *Euphorbia* species.

2. To compare previous, often inconsistent, research results in the control of prostrate spurge.

3. To test the herbicides at rates higher than those recommended by the manufacturer.

4. To test the herbicides under the climatic conditions of low elevations of the desert southwest.

5. To evaluate the tolerance of several arid species, heretofore untested, to the herbicides at various rates.

6. To generate data relevant to registration of preemergence herbicides not yet labelled for use in container-grown arid landscape ornamentals.

Herbicides included in the study were:

oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene];

oryzalin (3, 5-dinitro-N^4,N^4-dipropylsulfanilamide);

DCPA (dimethyl tetrachloroterephthalate);

norea [3-(hexathydro-4, 7-methanoindan-5-yl)-1,1-dimethylurea]; and

oxadiazon [2-tert-butyl-4-(2,4 dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one].

The herbicides were used in the following formulations:

oxyfluorfen (Goal^R 2E),

oryzalin (Surflan^R 75W),

DCPA (Dacthal^R 75W),

norea (Herban^R 80W),

oxadiazon (Chipco^R Ronstar^R 2G).

Treatment rates were applied at three different levels, 1X, 2X and 4X:

oxyfluorfen at 0.6, 1.1 and 2.2 kg/ha

oryzalin at 3.0, 6.0 and 12.0 kg/ha

DCPA at 22.4, 44.8 and 89.7 kg/ha

norea at 1.2, 2.2 and 4.5 kg/ha

oxadiazon at 2.2, 4.5 and 9.0 kg/ha.

Each treatment was replicated nine times and on each species. Additionally, there were two untreated control containers, one hand-weeded and one non-weeded, of each species with each treatment group. The containers were arranged in a design as shown in Figure 1. A total of 1,155 containers were used in the experiment.

The containers were placed in the general production area of the nursery for the duration of the experiment. All weeds were removed from the containers by hand before herbicides were applied.

The container soil mix consisted of 3 parts soil and 1 part pine bark by volume with a pH of 7.3 and organic matter content of 4.6%. The soil portion of the mix was a sandy loam.

The soil mix had not been fumigated or sterilized. Weed infestation of the containers was possible by (1) contaminant seeds of prostrate spurge residual in the container soil mix, (2) wind dissemination, and (3) other sources of weed contamination associated with typical nursery operations.

Spray formulations were applied to the soil surface at the base of the plants, using a three-gallon stainless steel compression sprayer with 8004 Tee Jet nozzles. This delivered a volume equivalent of 40 gallons of water per acre at 55 psi. The granular formulation was uniformly distributed by hand to the soil surface, using a glass shaker.

Immediately after application of herbicides, all containers were irrigated for one-half hour to incorporate the material. Routine irrigation and fertilization programs were continued thereafter under the direction of nursery managers until the completion of the experiment.

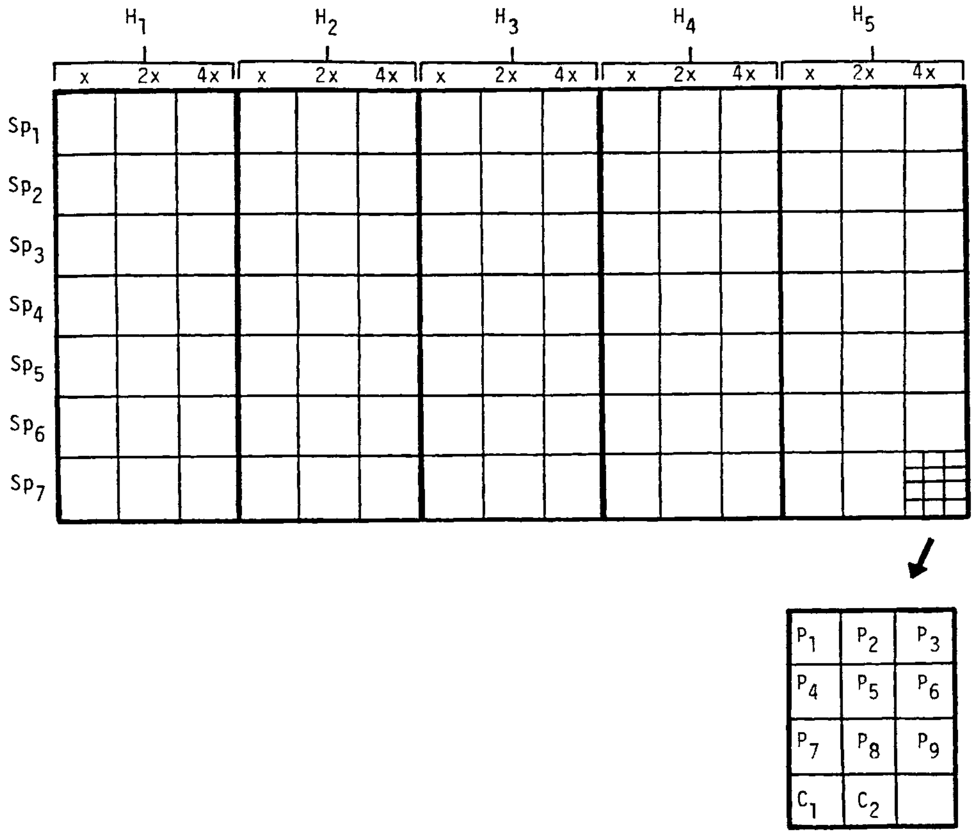

Figure 1. Design used to evaluate five preemergence herbicides (H), each at three rates (x, 2x and 4x), on seven container-grown arid landscape ornamentals (Sp). Each herbicide at each rate was replicated (P) nine times on each species. Additionally, there were two untreated control containers, one-hand weeded (C_1) and one non-weeded (C_2).

It is common practice to irrigate container ornamentals daily from June through September at this nursery.

The first application of herbicides was made on February 5, 1981. Weed control was evaluated by visual rating on March 5, 1981 and April 16, 1981 or 28 and 70 days, respectively, after application. Evaluations of the effectiveness of control of prostrate spurge were made using a weed control scale of 0 - 100%. Values of 70% or above were considered commercially acceptable. Observations of any phytotoxicity were also recorded.

All prostrate spurge plants were harvested on May 20, 1981 or 104 days after application. They were then dried for approximately 24 hours in a dry oven at a temperature of 90C. Afterward, the dried material was weighed in grams. All other weed species had been removed manually during the experiment.

The second application of herbicides was made on May 21, 1981. Weed control was evaluated by visual rating on June 13, 1981 and July 18, 1981 or 23 and 58 days, respectively, after application. The same evaluation procedures of the first application were followed for the second application.

All prostrate spurge plants were harvested on August 17, 1981 or 88 days after the second application. Again, plants were dried and weighed using the same methods of the first application.

CHAPTER 4

RESULTS AND DISCUSSION

During the first experimental period, February 5, 1981 through May 20, 1981, or 104 days, presence of prostrate spurge (*Euphorbia supina* Raf.) was limited. No prostrate spurge seedlings emerged in the non-treated controls of four of the seven test species. The total dry weights of prostrate spurge plants harvested from two other non-treated controls were no greater than the amounts harvested from treated containers and actually were less than one treatment (Table 1).

The low emergence of prostrate spurge during the first test period is probably because of three factors:

1. Fewer prostrate spurge seeds germinate under lower temperatures of late winter and early spring than under higher temperatures of late spring and summer (Krueger and Shaner 1982). The air temperature at the nursery averaged about 18 C during the first test period and 31 C during the second test period, May 21, 1981 through August 17, 1981, or 13 C higher than the average temperature of the first experimental period.

2. Fewer prostrate spurge seeds would have been in the medium of containers potted up since the preceding November compared with containers that had been in the nursery during the flowering season of prostrate spurge from late spring to early fall of the preceding year.

Table 1. Dry weights of prostrate spurge (*Euphorbia supina* Raf.) harvested from container-grown test species.[z]

Herbicide	Formu-lation	Rate[y]	*Cercidium floridum*	*Cassia artemisioides*	*Justicia spicigera*	*Acacia redolens*	*Yucca recurvifolia*	*Dasylirion wheeleri*	*Agave macroculmis*	Total
oxyfluorfen (Goal[R])	2E	0.6	7.52[x]	0.00	4.65	0.00	2.60	0.00	10.76	25.53
		1.1	3.58	0.00	1.95	4.25	0.51	0.68	9.50	20.47
		2.2	0.55	0.00	1.92	0.00	0.00	0.00	3.38	5.85
oryzalin (Surflan[R])	75W	3.0	4.72	0.00	0.00	0.00	0.00	0.00	5.06	9.78
		6.0	0.30	0.00	0.00	0.00	0.00	0.00	1.18	1.48
		12.0	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
DCPA (Dacthal[R])	75W	22.4	1.27	0.00	0.45	0.00	0.00	0.00	5.41	7.13
		44.8	0.00	0.00	0.36	0.00	0.00	0.00	2.51	2.87
		89.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
norea (Herban[R])	80W	1.2	4.03	3.23	7.65	0.00	0.71	0.00	18.32	33.94
		2.2	11.52	0.56	14.32	1.96	2.18	0.10	16.75	47.39
		4.5	6.73	2.18	6.22	0.00	0.26	0.12	11.34	26.85
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	9.64	0.00	6.17	0.00	0.00	0.00	16.58	32.39
		4.5	8.55	0.00	6.95	0.00	0.00	0.00	12.26	27.76
		9.0	5.46	0.00	4.53	0.00	0.00	0.00	6.32	16.31
control (non-treated)	---	---	7.71	0.35	8.58	0.00	0.04	0.79	11.31	28.78

z Prostrate spurge plants were harvested on May 20, 1981 or 104 days after first application of herbicides on February 5, 1981.

y Kilograms active ingredient per hectare.

x Dry weight in grams.

3. As prostrate spurge reaches maximum flower production sometime in summer, fewer seeds would have been produced by weed plants in the containers, the nursery, and surrounding areas during late winter and spring when the first test period was conducted.

Evaluations of the effectiveness of the treatments in the control of prostrate spurge were based on visual ratings, using a scale of 0 - 100% with values of 70% or above considered acceptable. Control from 90 - 100% was judged excellent to complete; 80%, good; 70%, satisfactory; 60%, poor; and below 60%, very poor.

All herbicidal treatments gave excellent to complete control of prostrate spurge for 70 days of the first test period in all test species except in _Agave macroculmis_ (Tables 2 & 3). For 104 days, the duration of the first experimental period, all treatments provided complete control of prostrate spurge in _Dasylirion wheeleri_; excellent to complete control in _Cassia artemisioides_, _Acacia redolens_ and _Yucca recurvifolia_; good to complete control in _Cercidium floridum_; and satisfactory to complete control in _Justicia spicigera_. In _Agave macroculmis_ control varied from satisfactory to complete at 70 days and from unacceptable to complete at 104 days.

Oxyfluorfen gave excellent to complete control of prostrate spurge for 104 days, except for three treatments. The herbicide provided good control at a rate of 0.6 kg/ha in _Cercicium floridum_ and at lower rates of 0.6 and 1.1 kg/ha in _Agave macroculmis_.

Table 2. Evaluation of control of prostrate spurge (*Euphorbia supina* Raf.) in four of the seven container-grown test species.

			Percent Weed Control [z]											
			Cercidium floridum			*Cassia artemisioides*			*Justicia spicigera*			*Acacia redolens*		
Herbicide	Formulation	Rate [y]	3/5	4/16	5/20	3/5	4/16	5/20	3/5	4/16	5/20	3/5	4/16	5/20
oxyfluorfen (Goal[R])	2E	0.6	100	90	80	100	100	100	100	100	90	100	100	100
		1.1	100	100	90	100	100	100	100	100	90	100	100	90
		2.2	100	100	100	100	100	100	100	100	90	100	100	100
oryzalin (Surflan[R])	75W	3.0	100	100	90	100	100	100	100	100	100	100	100	100
		6.0	100	100	100	100	100	100	100	100	100	100	100	100
		9.0	100	100	100	100	100	100	100	100	100	100	100	100
DCPA (Dacthal[R])	75W	22.4	100	100	90	100	90	100	100	100	100	100	100	100
		44.8	100	100	100	100	100	100	100	100	100	100	100	100
		89.7	100	100	100	100	100	100	100	100	100	100	100	100
norea (Herban[R])	80W	1.2	100	100	90	100	100	90	100	90	80	100	100	100
		2.2	100	100	80	100	100	100	100	100	70	100	100	90
		4.5	100	100	80	100	100	90	100	90	80	100	100	100
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	100	100	80	100	100	100	100	100	80	100	100	100
		4.5	100	100	80	100	100	100	100	100	80	100	100	100
		9.0	100	90	80	100	100	100	100	100	90	100	100	100
control (non-treated)	--	---	100	90	80	100	100	100	100	90	80	100	100	100

z Evaluations were based on visual ratings, using a scale of 0-100% with values of 70% or above considered acceptable. Application of herbicides was made on February 5, 1981. Evaluations were made on March 5, 1981; April 16, 1981 and May 20, 1981 or 28, 70 and 104 days, respectively, after application.

y Kilograms active ingredient per hectare.

Table 3. Evaluation of control of prostrate spurge (*Euphorbia supina* Raf.) in three of the seven container-grown test species.

			Percent Weed Control [z]								
			Yucca recurvifolia			*Dasylirion wheeleri*			*Agave macroculmis*		
Herbicide	Formulation	Rate [y]	3/5	4/16	5/20	3/5	4/16	5/20	3/5	4/16	5/20
oxyfluorfen (Goal[R])	2E	0.6	100	100	90	100	100	100	100	90	80
		1.1	100	100	100	100	100	100	100	90	80
		2.0	100	100	100	100	100	100	100	100	90
oryzalin (Surflan[R])	75W	3.0	100	100	100	100	100	100	100	100	100
		6.0	100	100	100	100	100	100	100	100	100
		12.0	100	100	100	100	100	100	100	100	100
DCPA (Dacthal[R])	75W	22.4	100	100	100	100	100	100	80	100	80
		44.8	100	100	100	100	100	100	70	100	90
		89.7	100	100	100	100	100	100	90	100	100
norea (Herban[R])	80W	1.2	100	100	100	100	100	100	100	90	50
		2.2	100	100	90	100	100	100	100	80	50
		4.5	100	100	100	100	100	100	100	90	70
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	100	100	100	100	100	100	90	90	60
		4.5	100	100	100	100	100	100	100	90	70
		9.0	100	100	100	100	100	100	100	90	80
control (non-treated)	---	---	100	100	100	100	100	100	100	60	80

z Evaluations were based on visual ratings, using a scale of 0-100% with values of 70% or above considered acceptable. Application of herbicides was made on February 5, 1981. Evaluations were made on March 5, 1981; April 16, 1981, and May 20, 1981 or 28, 70 and 104 days, respectively, after application.

y Kilograms active ingredient per hectare.

Oryzalin provided almost complete control of prostrate spurge with all treatments in all species for the duration of the first test period.

DCPA gave almost complete control for 104 days except for treatments in *Agave macroculmis*. Some seedlings emerged in the latter test species during the first 28 days, but all seedlings were suppressed by the next observation, 70 days after application. By the end of the test period, control became satisfactory, good or complete at rates of 22.4, 44.8 and 89.7 kg/ha, respectively.

Norea provided good to complete control of prostrate spurge for 104 days, except for four treatments. Control was satisfactory at a rate of 2.2 kg/ha in *Justicia spicigera* and 4.5 kg/ha in *Agave macroculmis*. The herbicide gave unacceptable control at rates of 1.2 and 2.2 kg/ha in *Agave macroculmis* compared to the total dry weights of untreated controls.

Oxadiazon gave excellent to complete control of prostrate spurge with all treatments in all test species for 70 days and good to complete control for 104 days, except for two treatments. Control was satisfactory at a rate of 4.5 kg/ha and unacceptable at 2.2 kg/ha by the end of the test period.

Prostrate spurge reached a higher level of infestation in the test containers during the second experimental period, May 21, 1981 through August 17, 1981, and was typical of the infestation of the weed in all areas of the nursery. The higher production of prostrate spurge confirms the research of Krueger and Shaner (1982) that emergence of the weed is influenced principally by temperature and day-length. The significantly higher average air temperature at the nursery of 31 C during the second test period approximates these researchers' reported optimal temperature for germination of prostrate spurge.

Dry weights of prostrate spurge recorded at the end of the second test period on August 17, 1981, 88 days after application of herbicides, exceeded those of amounts harvested at the end of the first test period on May 20, 1981, 104 days after application of herbicides (Tables 1, 4, 5 & 6).

Oxyfluorfen provided excellent control of prostrate spurge in five of seven test species at the manufacturer's recommended rate of 2.2 kg/ha for the duration of the second test period or 88 days (Tables 7 & 8). In the other two test species, Cassia artemisioides and Justicia spicigera, control was satisfactory to excellent for 58 days, but dropped sharply thereafter.

At the lower rates of 0.6 and 1.1 kg/ha the herbicide gave good to excellent control in all test species for 23 days. Satisfactory control continued for 58 days in only three of seven test species at a rate of 0.6 kg/ha and one species at a rate of 1.1 kg/ha.

Relatively low rates of oxyfluorfen were selected for use in this study as previous research showed that rates above 2.2 kg/ha could

Table 4 . Dry weights of prostrate spurge (*Euphorbia supina* Raf.) harvested from container-grown test species.[z]

Herbicide	Formulation	Rate[y]	*Cercidium floridum*	*Cassia artemisioides*	*Justicia spicigera*	*Acacia redolens*	*Yucca recurvifolia*	*Dasylirion wheeleri*	*Agave macroculmis*	Total
oxyfluorfen (Goal[R])	2E	0.6	39.59[x]	31.01	71.38	15.95	27.18	21.34	40.44	246.89
		1.1	19.47	57.66	64.44	39.40	34.30	20.17	39.40	274.84
		2.2	1.69	21.11	39.87	4.08	1.09	4.55	3.36	75.75
oryzalin (Surflan[R])	75W	3.0	19.58	21.27	47.94	4.90	7.41	11.87	38.01	150.98
		6.0	14.93	8.35	50.07	4.72	2.06	2.05	27.68	109.86
		12.0	3.72	1.57	34.54	1.37	0.81	0.00	1.19	43.20
DCPA (Dacthal[R])	75W	22.4	56.32	66.11	76.93	25.13	43.86	14.73	35.45	318.53
		44.8	40.82	98.12	61.10	8.02	17.77	15.66	30.19	271.68
		89.7	28.23	68.03	66.45	22.78	33.95	19.99	35.04	274.47
norea (Herban[R])	80W	1.2	37.03	89.51	81.44	15.83	43.37	24.05	39.78	331.01
		2.2	64.74	85.24	94.46	12.53	36.22	20.73	51.23	365.15
		4.5	64.72	103.78	66.89	61.08	62.11	17.38	46.62	422.58
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	52.09	35.24	63.40	11.19	24.46	19.26	49.83	255.47
		4.5	30.07	34.89	57.00	1.35	7.59	14.10	42.29	187.29
		9.0	25.46	22.48	21.49	5.74	1.08	4.05	17.30	97.60
control (non-treated)	---	---	71.51	100.94	81.13	42.20	49.59	17.87	35.65	398.89

z Prostrate spurge plants were harvested on August 17, 1981 or 88 days after second application of herbicides on May 21, 1981.

y Kilograms active ingredient per hectare.

x Dry weight in grams.

Table 5. Mean dry weight of prostrate spurge (*Euphorbia supina* Raf.) harvested from four of the seven container-grown test species.

Herbicide	Formu-lation	Rate[z]	*Cercidium floridum* 5/20/81[y]	*Cercidium floridum* 8/17/81[x]	*Cassia artemisioides* 5/20/81	*Cassia artemisioides* 8/17/81	*Justicia spicigera* 5/20/81	*Justicia spicigera* 8/17/81	*Acacia redolens* 5/20/81	*Acacia redolens* 8/17/81
oxyfluorfen (Goal[R])	2E	0.6	0.84[w]	4.40	0.00	3.45	0.52	7.93	0.00	1.77
		1.1	0.40	2.16	0.00	6.41	0.22	7.16	0.47	4.38
		2.2	0.06	0.19	0.00	2.35	0.21	4.43	0.00	0.45
oryzalin (Surflan[R])	75W	3.0	0.52	2.18	0.00	2.36	0.00	5.33	0.00	0.54
		6.0	0.03	1.66	0.00	0.93	0.00	5.56	0.00	0.52
		12.0	0.00	0.41	0.00	0.17	0.00	3.84	0.00	0.15
DCPA (Dacthal[R])	75W	22.4	0.14	6.26	0.00	7.35	0.05	8.55	0.00	2.79
		44.8	0.00	4.54	0.00	10.90	0.04	6.79	0.00	0.89
		89.7	0.00	3.14	0.00	7.56	0.00	7.38	0.00	2.53
norea (Herban[R])	80W	1.2	0.45	4.11	0.36	9.95	0.85	9.05	0.00	1.76
		2.2	1.28	7.19	0.06	9.47	1.59	10.50	0.22	1.39
		4.5	0.75	7.19	0.24	11.53	0.69	7.43	0.00	6.79
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	1.07	5.79	0.00	3.92	0.69	7.04	0.00	1.24
		4.5	0.95	3.34	0.00	3.88	0.77	6.33	0.00	0.15
		9.0	0.61	2.83	0.00	2.50	0.50	2.39	0.00	0.64
control (non-treated)	---	---	0.86	7.95	0.04	11.22	0.95	9.01	0.00	4.69

z Kilograms active ingredient per hectare.

y Prostrate spurge plants harvested 104 days after first application of herbicides on February 5, 1981.

x Prostrate spurge plants harvested 88 days after second application of herbicides on May 21, 1981.

w Mean dry weight in grams.

Table 6. Mean dry weight of prostrate spurge (*Euphorbia supina* Raf.) harvested from three of the seven container-grown test species.

Herbicide	Formulation	Rate [z]	*Yucca recurvifolia* 5/20/81[y]	*Yucca recurvifolia* 8/17/81[x]	*Dasylirion wheeleri* 5/20/81	*Dasylirion wheeleri* 8/17/81	*Agave macroculmis* 5/20/81	*Agave macroculmis* 8/17/81
oxyfluorfen (Goal[R])	2E	0.6	0.29[w]	3.02	0.00	2.37	1.20	4.49
		1.1	0.06	3.81	0.08	2.24	1.06	4.38
		2.2	0.00	0.12	0.00	0.51	0.38	0.37
oryzalin (Surflan[R])	75W	3.0	0.00	0.82	0.00	1.32	0.56	4.22
		6.0	0.00	0.23	0.00	0.23	0.13	3.08
		12.0	0.00	0.09	0.00	0.00	0.11	0.13
DCPA (Dacthal[R])	75W	22.4	0.00	4.87	0.00	1.64	0.60	3.94
		44.8	0.00	1.97	0.00	1.74	0.28	3.35
		89.7	0.00	3.77	0.00	2.22	0.00	3.89
norea (Herban[R])	80W	1.2	0.08	6.76	0.00	2.67	2.04	4.42
		2.2	0.24	4.02	0.01	2.30	1.86	5.69
		4.5	0.03	6.90	0.01	1.93	1.26	5.18
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	0.00	2.72	0.00	2.14	1.84	5.54
		4.5	0.00	0.84	0.00	1.57	1.36	4.70
		9.0	0.00	0.12	0.00	0.45	0.70	1.92
control (non-treated)	---	---	0.00	5.51	0.09	1.99	1.26	3.96

z Kilograms active ingredient per hectare.

y Prostrate spurge plants harvested 104 days after first application of herbicides on February 5, 1981.

x Prostrate spurge plants harvested 88 days after second application of herbicides on May 21, 1981.

w Mean dry weight in grams.

Table 7. Evaluation of control of prostrate spurge (Euphorbia supina Raf.) in four of the seven container-grown test species.

Herbicide	Formulation	Rate [y]	Percent Weed Control [z]: *Cercidium floridum* 6/13	7/18	8/17	*Cassia artemisioides* 6/13	7/18	8/17	*Justicia spicigera* 6/13	7/18	8/17	*Acacia redolens* 6/13	7/18	8/17
oxyfluorfen (Goal[R])	2E	0.6	90	50	20	90	70	20	90	30	0	80	70	60
		1.1	90	80	50	100	50	0	90	30	0	90	40	10
		2.0	100	100	90	100	80	40	100	70	0	100	90	90
oryzalin (Surflan[R])	75W	3.0	90	70	50	100	80	40	100	60	0	100	90	90
		6.0	100	90	70	100	90	80	100	70	0	100	90	90
		12.0	100	90	90	100	90	90	100	80	10	100	100	100
DCPA (Dacthal[R])	75W	22.4	60	0	0	90	50	0	60	0	0	70	60	30
		44.8	80	40	10	80	20	0	80	20	0	100	80	80
		89.7	90	50	20	90	30	0	80	10	0	90	60	30
norea (Herban[R])	80W	1.2	70	40	10	60	10	0	40	10	0	100	90	60
		2.2	40	20	0	70	40	0	40	10	0	80	70	70
		4.5	50	10	0	70	30	0	50	20	0	80	50	0
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	80	40	0	100	50	10	80	50	0	100	100	80
		4.5	100	70	20	90	70	10	90	50	0	100	100	90
		9.0	100	70	30	100	80	30	100	80	40	100	90	80
control (non-treated)	---	---	60	10	0	80	20	0	60	10	0	80	20	0

z Evaluations were based on visual ratings, using a scale of 0 - 100% with values of 70% or above considered acceptable. Application of herbicides was made on May 21, 1981. Evaluations were made on June 13, 1981; July 18, 1981, and August 17, 1981 or 23, 58 and 88 days, respectively, after application.

y Kilograms active ingredient per hectare.

Table 8. Evaluation of control of prostrate spurge (*Euphorbia supina* Raf.) in three of the seven container-grown test species.

			Percent Weed Control [z]								
			Yucca recurvifolia			*Dasylirion wheeleri*			*Agave macroculmis*		
Herbicide	Formu-lation	Rate [y]	6/13	7/18	8/17	6/13	7/18	8/17	6/13	7/18	8/17
oxyfluorfen (Goal[R])	2E	0.6	90	70	20	90	40	40	80	10	0
		1.1	90	50	20	90	60	50	80	10	0
		2.2	100	100	100	100	100	90	90	100	90
oryzalin (Surflan[R])	75W	3.0	100	90	80	100	90	80	80	20	0
		6.0	100	90	90	100	100	90	100	80	10
		12.0	100	90	100	100	100	100	100	90	90
DCPA (Dacthal[R])	75W	22.4	90	50	10	80	30	40	50	0	10
		44.8	100	70	60	100	40	40	70	20	20
		89.7	100	60	10	80	40	30	90	30	10
norea (Herban[R])	80W	1.1	80	30	0	70	40	30	40	10	0
		2.2	90	30	10	80	60	40	50	0	0
		4.5	80	10	0	90	70	50	60	20	0
oxadiazon (Chipco[R] Ronstar[R])	2G	2.2	100	70	30	90	80	50	60	20	0
		4.5	100	90	80	100	80	70	80	30	0
		9.0	100	100	100	100	100	90	100	80	60
control (non-treated)	---	---	90	50	0	70	30	40	40	10	10

z Evaluations were based on visual ratings, using a scale of 0 - 100% with values of 70% or more considered acceptable. Application was made on May 21, 1981. Evaluations were made on June 13, 1981; July 18, 1981, and August 17, 1981 or 23, 58 and 88 days, respectively, after application.

y Kilograms active ingredient per hectare.

be phytotoxic to container-grown ornamentals (Humphrey and Elmore 1978). The author observed no injury or stunting of the test species at any rates used in this study.

Control of prostrate spurge beyond the three months of this study might require rates as high as 4.5 and 9.0 kg/ha, based on recent research of Creager (1982a, 1982b) and Singh, Phatak, and Glaze (1984). Tolerance of container-grown arid landscape ornamentals to these higher rates of oxyfluorfen would have to be tested, however.

While Alexander (1984) reported effective control of prostrate spurge with oxyfluorfen in combination with oryzalin, stunting of *Yucca* species was observed in treatments using oxyfluorfen at a rate of 4.5 kg/ha. Alexander concluded that the efficacy of the combination in the control of prostrate spurge warranted further evaluation of oxyfluorfen with desert plant species, however.

Oryzalin gave the best overall control of prostrate spurge during the second test period. Higher rates were consistently more effective than lower rates. At 12.0 kg/ha, good to complete control was obtained in all but one species for 88 days. In *Justicia spicigera* the herbicide provided good control for 58 days but dropped to very poor control at 88 days.

The 6.0 kg/ha rate gave satisfactory to complete control throughout the duration of the second test period, except no control to very poor control in *Justicia spicigera* and *Agave macroculmis*, respectively, at the conclusion of the test period.

Singh, Phatak, and Glaze (1984) reported that oryzalin was phytotoxic to both Chinese and Japanese hollies at rates of 9.0 kg/ha and higher. Although neither retarded growth nor injury was observed in this study at a rate of 12.0 kg/ha, tolerance of untested arid landscape species to the herbicide at this rate should be evaluated.

DPCA gave satisfactory to complete control of prostrate spurge in all test species at the higher rates of 44.8 and 89.7 kg/ha for only 23 days. Despite the high rates of material used in the study, the effectiveness of DCPA was reduced sharply after one month, and the herbicide became ineffective by the conclusion of the second test period.

Although DCPA is reported to control spurges in bermudagrass turf in the desert southwest, based on the results of this study and the high cost of the material, DCPA shows insufficient potential for control of prostrate spurge in container-grown arid landscape ornamentals to justify further research in container culture.

In general, norea was also ineffective in controlling prostrate spurge throughout the second test period. Norea at the higher rates of 2.2 and 4.5 kg/ha seemed to stimulate growth of prostrate spurge; several treatments produced greater amounts of harvested weed plants in dry weight than the non-treated controls produced.

In the second test period, oxadiazon did not give as good or consistent control of prostrate spurge as was reported by previous research

(See Literature Review). The herbicide is one of the most frequently used preemergence herbicides in the country's nursery industry. Currey and Weatherspoon (1979) reported erratic control of spurges using oxadiazon, however.

The manufacturer recommends a rate of 4.5 kg/ha for control of prostrate spurge. This rate gave satisfactory to complete control of prostrate spurge in five of the seven test species for 58 days or longer. At the conclusion of the second test period, or after 88 days, the herbicide provided satisfactory control or better in three of the seven test species. Control was very poor in the other four species: *Cercidium floridum*, *Cassia artemisioides*, *Justicia spicigera* and *Agave macroculmis*.

At the highest rate of 9.0 kg/ha oxadiazon gave satisfactory to complete control for 58 days in all test species, but this level of control was maintained for 88 days in only three test species: *Acacia redolens*, *Yucca recurvifolia* and *Dasylirion wheeleri*.

The lowest rate of 2.2 kg/ha provided good to complete control of prostrate spurge for only 23 days in all test species. Efficacy at this rate diminished significantly in all of the seven test species, except *Acacia redolens*, before termination of the second test period.

The erratic results obtained with oxadiazon in this study may have resulted from uneven distribution of the granules over the soil surface, a common problem reported in research and by nursery managers, although every effort was made to ensure even distribution at the time of application of the material.

This study evaluated the herbicides for their control of prostrate spurge. Observations of the test plants' tolerance to the herbicides were noted throughout the experiment. Data relevant to phytotoxicity were not collected for analysis because the growth of the test plants was not adequately uniform for research purposes. Irrigation and fertilization practices and disease and insect control, some of the variables which affect plant growth, were, moreover, supervised by nursery managers.

The growth of the test plants was compared regularly with similar species under production in the general area of the nursery. Few differences in growth between the test plants and others in the nursery were observed. The herbicide program of the nursery differed from the treatments used in this study.

In general all test species tolerated all treatments. Injury to Agave macroculmis was suspected from some treatments, but the manager of the nursery showed similarly stunted growth to non-test plants which was caused by worms eating the roots and basal leaves of the plants. Retarded growth in a few test species was believed to be caused by water deprivation resulting from strong winds that disrupted the spray pattern of irrigation water.

The study was designed to be useful to growers in Arizona in establishing a program of chemical control of prostrate spurge. Timing of application of preemergence herbicides is as critical as rate in the effectiveness of the chemical (Anderson 1983).

Based on the results of this study, the first application of a preemergence herbicide should be made in early February to coincide with the early germination period of prostrate spurge in southern Arizona. Adequate control should continue until late April.

A second application should be made in late April or early May. The timing of this application can be determined by observing the level of infestation of the weed.

The intervals between the second and subsequent applications probably will become shorter because of the higher temperatures and longer day-lengths of summer. Application may be necessary at 60-day intervals from May through September, depending upon both the level of infestation of the weed and the length of residual activity of the herbicide.

A final application in September should give adequate control through November. As germination of prostrate spurge is minimal from November through January, no further application should be necessary until the following February.

Since germination of prostrate spurge is considerably lower in winter and spring, the rate of the first application could be commensurately lower than rates of the second and subsequent applications of late spring and summer.

Based on the results of this study, two preemergence herbicides, oryzalin and oxyfluorfen, gave the most effective control of prostrate spurge throughout the lengthy infestation period of this warm season or summer annual in container-grown ornamentals produced in a typical wholesale nursery of southern Arizona.

Results of the first test period suggest that oryzalin be applied at a rate of 3.0 kg/ha for the first application of the calendar year, recommended for early February. The rates of subsequent applications during the summer peak of germination of prostrate spurge should be increased to at least 6.0 kg/ha or higher, depending on the observed level of infestation. A rate of 6.0 kg/ha applied at 60-day intervals during late spring or early fall should provide better than satisfactory control of prostrate spurge.

Results of this study also suggest that oxyfluorfen gives effective control of prostrate spurge at a rate of 2.2 kg/ha for the first application of late winter. Until further research determines if a rate of 4.5 kg/ha is safe for container-grown arid landscape ornamentals, subsequent applications should be made at the same rate of 2.2 kg/ha, but at shorter intervals of 60 days through September.

Research to find the most effective chemical control of prostrate spurge in container-grown ornamentals produced in the southwest needs to continue. Additional information about rates of application and intervals between applications is required. Simultaneously, the tolerance of a wide range of untested container-grown arid landscape plants to various herbicides needs to be evaluated. Special attention should be given to further testing of combinations of herbicides for the control of prostrate spurge. The use of slow-release herbicide tablets to control this pernicious weed of the southwest might also be investigated.

While it was beyond the focus of this study, research into the effects of important variables which make an herbicide inactive and thereby reduce its effectiveness would be useful in finding an effective preemergence herbicide for control of prostrate spurge in container culture. Variables of particular relevance to weed control in the southwest are photochemical decomposition caused by ultraviolet light and volatilization influenced by high soil-surface temperatures.

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