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Seeding dates and field establishment of ten southwestern desert wildflower species

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The University of Arizona, 1988
SEEDING DATES AND FIELD ESTABLISHMENT
OF TEN SOUTHWESTERN DESERT WILDFLOWER SPECIES

by

June Eileen Marie Sullivan

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

1988
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SIGNED: June Eileen Marie Sullivan

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

C. M. Sacamano
Professor of Plant Science
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The effects of planting date were evaluated on field establishment and flowering of ten southwestern wildflower species combined in a mix.

Species tested include *Baileya multiradiata*, *Castilleja lanata*, *Eschscholtzia californica*, *Eschscholtzia mexicana*, *Gaillardia pulchellum*, *Lesquerella gordonii*, *Lupinus sparsiflorus*, *Orthocarpus purpurascens*, *Penstemon eatonii*, and *Phacelia campanularia*. Seeds of all species were combined in a mix and directly seeded into field plots. All species are native to the southwestern deserts of the United States.

Treatments consisted of five planting dates, starting September 30, 1987 and continuing through November 30, 1987, with treatments planted at two week intervals during the ten week period.

There were significant differences in both plant stand and flowering between planting dates. The October 15 planting had the optimum plant stand with regard to the largest spectrum of species represented by desirable numbers. Flowering was most pronounced in the September 30 and October 15 plantings.
Wildflowers have traditionally been defined as any flowering plant which grows without intentional cultivation by man (Martin, 1986). This horticultural definition has become outdated with the increased popularity of wildflower gardening. Manipulation by man through selective breeding might be criterion for distinguishing between wildflowers and traditional cultivated flowers. For the purposes of this study desirable herbaceous angiosperm species native to or naturalized within a region are wildflowers. Wildflowers are an important part of native plant communities, involved in complex interactions between soil, climate, survival strategies and pollinators.

Interest in using wildflowers in native plant landscapes has increased in recent years (Salac, Traeger, and Jensen, 1982). Present demands on water conservation, especially in the southwest, constantly challenge the landscape industry to supply attractive yet drought tolerant plant material. The concept of using native wildflowers as part of the landscape is appealing but relatively untested. Little research based data have been collected concerning the cultural requirements of wildflowers, particularly indigenous southwestern desert species.
Incentives for testing wildflower cultivation techniques include economics, legislation, and conservation. Legislation by the Federal Highway Department mandates that 1/4 of 1% of federal highway landscaping funds be spent on native plantings. Beautiful landscapes and highways may attract tourism; important to regions where this is a major industry. Mandating the use of native plants in highway landscaping has sparked new interest in learning more specific information about cultivation of indigenous species (Anderson, 1988).

Increasing urban development has raised conservation awareness to protect our endemic plant species and their habitats. An understanding of cultivation requirements of native plants increases their successful use in the landscape and potentially decreases the destruction of habitat caused by harvesting plants from the wild.

Wildflower research is in progress on a nationwide basis at the National Wildflower Research Center in Austin, Texas. The center directs its native plant research at greenhouse, laboratory, and field testing of regional wildflowers and serves as a clearinghouse for information from similar projects around the country.

Previous research has evaluated various aspects of wildflower cultivation in other regions of the country. Studies have indicated a correlation between air
temperature, soil temperature, and soil moisture in relation to the presence of particular plant species in the desert (Went, 1949). The southwest deserts are unique ecological areas in terms of climate and plant material. Understanding the ecology of the region and physiology of its plant material is important in the development of horticultural practices.

The literature indicates autumn is the proper time to seed desert winter ephemerals, but many species have a narrow tolerance of germination conditions. A more defined planting date based upon observed responses of wildflower species to air temperature, soil temperature, and precipitation data would be desirable. The objective of this study is to evaluate the effects of planting date on the field establishment and flowering of a mix containing wildflowers native to the southwestern deserts of the United States.
LITERATURE REVIEW

Various aspects of wildflower cultivation have been investigated. Research has been conducted on germination, cultivated field studies, and ecological studies.

Essential to both the preservation of native vegetation and to wildflower cultivation is to determine propagation techniques (Taylor and Hamblin, 1963). Information available on germination of wildflower seeds is limited to a few species and has been developed primarily under greenhouse and laboratory conditions (Salac, et al., 1982).

A study of desert annuals by Went (1949) indicated winter annuals germinated best during an 18°C day and 8-13°C night regime. Optimum temperatures for summer desert annuals were a 27°C day and a 26°C night.

Seed of Coreopsis tinctoria, Ipomopsis rubra, Linum perenne, and Asclepias tuberosa were tested on a thermogradient plate to determine optimum germination temperatures. It was determined that 25°C resulted in superior germination for L. perenne, while C. tinctoria and A. tuberosa germinated best at 30°C. I. rubra exhibited poor germination at all temperatures tested (Kasper and McWilliams, 1982).
Young and Young (1986) state that seeds of *Phacelia campanularia* require light for germination, and should be incubated above 60°F. Fresh seed of perennial species of *Lupinus* do not require pretreatment, but stored seeds require hot water or acid scarification.

The germination of many seeds is influenced by the presence of nitrate ions. Potassium nitrate is widely used as a source of nitrate ion enrichment. Potassium nitrate is often used to augment germination after scarification, stratification or light treatment. Customary germination of many agronomic species require addition of 0.2% potassium nitrate to the substrate during germination. Germination of *Phacelia campanularia* and *Eschscholtzia californica* may be improved by addition of potassium nitrate (Young and Young, 1986).

The mode of action of gibberellic acid in seed germination is not known, but germination of some species has been enhanced by very low concentrations of this growth substance. Concentrations from 1-150ppm are commonly used in germination enhancement. Seeds of *Penstemon palmeri* demonstrate more effective germination with gibberellic acid treatment. Combinations of gibberellic acid and potassium nitrate are often more effective than either material alone (Young and Young, 1986).

The genus *Castilleja* may be partially root-parasitic.
Considering the widespread occurrence of *Castilleja* sp., there is very little known about its germination. (Young and Young, 1986).

The effect of date of seeding on field establishment of 12 species of native Nebraska wildflowers indicated plant emergence response was similar to plant stand response. Seeding in November yielded highest emergence for *Echinacea angustifolia* and *Penstemon grandiflorus*. April seeding promoted maximum emergence of *Asclepias tuberosa*, *Lespedeza capitata*, *Petalostemon purpureum*, *Salvia pitcheri*, and *Yucca glauca*. November and April were equally effective for planting *Ratibida pinnata*, *Liatris punctata*, *Liatris aspera*, *Liatris pycnostachya*, and *Helianthus maximiliani* (Salec, et al., 1982).

Mycorrhizal fungi (*Glomus etunicatum*) were inoculated on seedlings of *Baptisia austalis* and *Liatris aspera* grown in prairie soil to determine the effect on growth. Under conditions of drought stress and low fertility inoculated seedlings of both species grew significantly larger than noninoculated seedlings. Enhancement of growth may be more pronounced in plants with a taproot because feeder roots are found below the zone of decomposition in the zone of reduced available nutrients (Zajicek, et al., 1987).

Wildflower sods using commercial peat-lite mixes and cheesecloth netting as a root binder were tested by Airhart,
et al. (1983). Sods used to establish turf provide a quick and effective groundcover used for slope stabilization or erosion control along highways. The study was designed to test potentially useful wildflowers for sod production in Massachusetts. Thirteen species of wildflowers were tested with *Rudbeckia hirta*, *Chrysanthemum leucanthemum*, *Oenothera lamarckiana*, and *Achillea millefolium* producing favorable results.

Grassland management techniques and dates of seeding for field establishment of five wildflower species in Nebraska have been investigated. Management techniques included burning, mowing, glyphosate application followed by mowing, and an untreated control. The management techniques had no significant effect on seedling establishment. Results from the experiment indicate seeding date may have a significant influence on successful establishment of wildflowers (Zajicek, et al., 1986).

Wildflowers are commonly direct seeded alone or in mixtures with grasses. Poor wildflower establishment frequently occurs because of failure to compete with more aggressive plant species, improper time of seeding, use of nonviable seed and/or failure to overcome dormancy (Salac, et al., 1982).

Dormancy conditions in native plants present a problem in propagation. These conditions are related to survival
for the plant in its natural environment, usually consisting of biochemical mechanisms within the seed to prevent germination until favorable conditions for growth exist (Phillips, 1985). Salac and Hesse (1975) determined four Nebraska wildflower species germinated best when subjected to temperature and photoperiod regimes simulating the natural growing environment.

An understanding of the ecology and physiology of native desert plants is useful in determining cultivation techniques. Many studies have examined various aspects of desert plant ecology and physiology in the southwestern United States. North American desert annuals can be divided between summer and winter groups which coincide with seasons of maximum precipitation. Winter annuals respond to precipitation in late fall, winter, and early spring (MacMahon, 1985), germinating when ambient temperatures are below 20°C (Gutierrez and Whitford, 1987). Winter precipitation occurs as storms of frontal origin move in from the Pacific coast and cover broad areas of the southwestern U.S. Relative humidity is high, air temperatures are low, and soil moisture is favorable for plant growth. Winter annuals usually belong to a group of plants known as drought evaders. These plants grow during months when soil moisture favors growth and reproduce before summer drought conditions set in (Monson and Smith, 1982).
Summer desert annuals respond to precipitation in summer and early fall when ambient temperatures are above 20°C (Gutierrez and Whitford, 1987). Summer annuals are often taller, more weedy, and include many grasses (MacMahon, 1985). Summer precipitation in the southwestern desert occurs as localized thunderstorms originating over the Gulf of Mexico. Low relative humidity, high air and soil temperatures, and high insolation characterize summer conditions (Monson and Smith, 1982).

The plant composition in southwestern deserts is determined by seasonal precipitation. The herbaceous component of the Mohave desert contains mostly winter annuals. Summer species are the majority of ephemerals in the Chihuahuan desert. The Sonoran desert with its biseasonal rainfall peaks contains both winter and summer annuals.

The difference in photosynthetic pathways between winter and summer desert annuals is of particular significance. Most summer annuals are C4 plants while winter annuals are almost exclusively C3 plants. C4 plants carry on photosynthesis more effectively at high temperatures and high light intensities, use water more efficiently and produce more material than C3 plants under these same extreme conditions (MacMahon, 1985). C3 plants germinate during cool periods with optimum temperatures for
effective photosynthesis within the range of 15 to 25 C.

The anatomy of a C4 plant contains a distinctive sheath of cells containing large chloroplasts surrounding the vascular bundles. This feature is known as Kranz anatomy. An examination of 64 winter desert annuals and 66 summer species demonstrated a lack of the Kranz anatomy in all winter species. There is a complete lack of the C3 photosynthetic pathway in Mohave desert summer annuals. A large number of Sonoran desert summer annuals have the C3 photosynthetic pathway which is typically characteristic of weedy or moist habitats. Approximately 2/3 of Sonoran summer annuals are C4 plants (Mulroy and Rundel, 1977).

Morphologic differences occur between the desert C3 and C4 plants. C4 leaves are often subdivided into leaflets, or have serrated margins to dissipate heat. C3 leaves may be simple single bladed entire leaves (MacMahon, 1985) or conspicuously highly dissected margins (Mulroy and Rundel, 1977). C3 plants germinate during cool periods, often forming prostrate rosettes of leaves. Such rosettes may heat up, even during cold periods because they are at ground surface (MacMahon, 1985). When ambient temperatures warm later in the spring, these species frequently change form and growth becomes elevated to keep plants away from the hot surface microclimate (Werk, et al., 1983).

Mulroy and Rundel (1977) suggest the leaf dissection
decreases boundary layer effects allowing greater exchange of air at the leaf surface where carbon dioxide can be absorbed through the stomata. Water loss is minimized and maximum leaf temperatures are achieved with entire broad leaves, but these are offset by resistance to gas exchange. As availability of carbon dioxide influences the photosynthetic rate and biomass production this adaptation could be favored in desert winter annuals. The degree of dissection is greatest among desert annuals in basal rosettes. Boundary layer effects would be maximized due to minimal air movement at ground level, overlapping rosette leaves, and prostrate habit if leaves were not dissected.

Field water relations have been examined in winter and summer annuals of the Sonoran desert. Winter annuals have large interspecific variation in water relation parameters, but leaves generally have high conductances of water vapor and high water potentials during early growth periods. These high values were short lived and reduced by peak flowering periods. In comparison with other plant life forms, leaf conductances and leaf water potentials are high in desert annuals, which is consistent with the idea that annuals are ephemeral and drought evading. Some winter and summer annuals are capable of tolerating low leaf water potentials and are not drought evading in the traditional sense. Available data suggests that high leaf conductances
and photosynthetic capacities are not characteristic of all desert annuals, but are characteristic of a large fraction of them (Forseth, et al., 1984).

High photosynthetic capacities are associated with high leaf conductances to water vapor. Although desert winter annuals possess the C3 photosynthetic pathway, many have very high rates of photosynthesis. It has been suggested that the high photosynthetic capacities in several Sonoran desert winter annuals may be related to resource availability. Successful exploitation of short unpredictable growth periods is possible if the plant has a high potential for photosynthesis.

Data from a study of seasonal water potential components of Sonoran desert plants by Monson and Smith (1982) indicates a lack of adaptation to aridity in water relations of plants possessing the desert annual growth habit. A notable exception is Gerea canescens, a Mohave desert winter annual, which has a very high capacity for osmoregulation. Under conditions of low water stress, high osmotic potentials probably allow plant metabolic processes to function more efficiently. This advantage is offset during water stress, favoring species with low osmotic potentials.

Winter and summer desert annuals are characterized by low subterranean biomass allocation. Low root:shoot ratios
suggest that a small fraction of carbon gained in photosynthesis is used for water acquisition. Carbon is instead used for vegetative and reproductive growth (Forseth, et al., 1984). Recent studies indicate that plants with a relatively short lifespan allocate a large proportion of biomass to reproduction (Bell, et al., 1979).

Relief of nitrogen stress in desert annuals appears to lead to increased vegetative development which produces a greater biomass of vegetative and reproductive structures. After water, nitrogen is the most limiting factor in North American deserts. Gutierrez and Whitford (1987) demonstrated a positive response of ephemeral plant cover to nitrogen amendments. In the Mohave and Sonoran deserts, growth of winter annuals appears to be so dependent upon nutrient availability that nitrogen rich fertile areas beneath shrubs support much larger plants with higher production efficiencies than nitrogen poor soil in open areas. Soil nitrogen in deserts depends on litter produced by perennial shrubs. Gutierrez and Whitford found that species diversification was highest in test plots with highest nitrogen concentrations (2.4 g N/m²). Short-lived species appear to invest nitrogen in building biomass rapidly to insure seed production.

C4 plants have a higher efficiency in nitrogen utilization compared to C3 plants, particularly under low
nitrogen supply. The efficiency apparently results from a lower investment in photosynthetic carboxylating enzymes compared to C3 plants. It has been noted that desert winter annuals may have very high rates of photosynthesis, although possessing the C3 photosynthetic pathway. High leaf nitrogen contents (protein levels) characteristic of many winter annuals may represent a large investment in photosynthetic enzymes (Werk, et al., 1983).

Gutierrez and Whitford (1987) studied the effects of water supplementation of Chihuahuan desert annuals and determined that most species in irrigated plots emerged earlier and had an extended growing season compared to those in non-irrigated plots.

Phenological events in the Mohave desert are triggered by heavy rains exceeding 25 mm. The most predictable precipitation occurs between late September and early December. This rainfall is the precurser of successful vegetative and reproductive growth during the winter and following spring. If the heaviest rain is between 15 mm and 25 mm, only scattered plants are physiologically active. Heavy late September rain is effective only if autumn temperature regimes have replaced summer air and soil temperature regimes. Early December rain is effective only if autumn temperatures prevail (Beatley, 1974).

Early December rains are favorable for germination of
species of the Brassicaceae and Boraginaceae, while late September soil temperatures approach upper limits of the range favorable to members of the Polemoniaceae, Hydrophyllaceae, Polygonaceae, Fabaceae, and Onagraceae (Beatley, 1974).

An interesting feature of a large percentage of winter and summer desert annuals is heliotropism, the ability to move the leaves diurnally so that they remain perpendicular to the direct rays of the sun. As a result, individual leaves are exposed to high irradiances throughout the day, allowing for high photosynthetic capacity. Selection for high photosynthetic capacities may be related to the shortness of growing season or to high irradiances which characterize warm desert habitats (Werk, et al., 1983).
MATERIALS AND METHODS

Ten species of wildflowers native to the southwestern United States were combined in a mix, and evaluated to determine the effects of seeding date on field establishment and flowering. Species included in the mix were chosen based upon commercial availability and aesthetic appeal. Most species are winter ephemerals. Seed was supplied by Wild Seed, Inc., an Arizona-based seed company. Species are listed below. Background information for species was derived from Kearney and Peebles (1951), Munz (1962), and Art (1986).

**Baileya multiradiata** Harv. & Gray, (Asteraceae) "Desert Marigold", is a biennial or perennial gray woolly herb, 15 to 45 cm, with numerous solitary yellow heads and alternate basal leaves. The plant flowers March to November and is distributed from west Texas to southern Utah and Nevada south to Chihuahua, Mexico up to 1500 m.

**Castilleja lanata** Gray, (Scrophulariaceae) "Desert Paintbrush", is a perennial herb, 10 to 40 cm, with flowers in conspicuously red bracted terminal spikes, and a leafy stem with leaves deeply pinnately cleft. The plant is reported to be partially root parasitic. Flowering period
is throughout the year in its distribution of west Texas to southern Arizona and northern Mexico at an elevation of 750 to 2100 m.

*Eschscholtzia californica* Cham., (Papaveraceae) "California Poppy", is an annual or perennial herb, 20 to 60 cm, with terminal open funnel shaped flowers having four petals of deep orange to yellow, and alternate highly dissected blue green leaves. The hypanthium upon which the flower is borne has a conspicuous rim. Flowering period is February to September in its wide distribution of up to 2000 m on open grasslands in California.

*Eschscholtzia mexicana* Greene, (Papaveraceae) "Mexican Gold Poppy", is an annual herb, up to 40 cm in height, with orange yellow cup shaped flowers borne singly on stalks, and alternate highly dissected blue green leaves. The conspicuous rim found on the hypanthium of *Eschscholtzia californica* is usually absent. The plant blooms March to May and is found below 2000 m in southeastern California to the western tip of Texas and south to northern Mexico.

*Gaillardia pulchellum* Foug., (Asteraceae) "Blanket-Flower", "Fire-Wheel", is an annual, 30 to 60 cm, with solitary heads, the ray flowers being red tipped with a yellow apex and disk flowers deep red, oblong leaves with toothed or plain margins and covered with short hairs. Flowering period is May to July in its range of 1000 to 1700
m in Nebraska and Missouri to Louisiana west to Colorado and south to Arizona.

Lesquerella gordonii Gray, (Brassicaceae) "Bladderpod", is an annual silvery green pubescent herb, up to 20 cm, with bright yellow or white tinged with purple 4-petaled flowers in loose racemes, and largely basal leaves. The plant flowers February to May and is distributed from Oklahoma to Utah, Arizona, California, and south to northern Mexico at an elevation of 1500 m or lower.

Lupinus sparsiflorus Benth., (Fabaceae) "Coulter's Lupine", is an annual herb, 20-40 cm, with terminal racemes of lilac blue flowers, slender erect branched stems, and alternate palmately compound leaves. The plant blooms January to May in Nevada and Arizona to California, as well as Sonora, Mexico to Baja California, Mexico below 1375 m.

Orthocarpus purpurascens Benth., (Scrophulariaceae) "Owl's Clover", "Escobita", is an annual herb, up to 15 cm, with a spicate inflorescence containing masses of rose and yellow flowers among dense leafy green or purple-pink bracts, and a leafy stem of alternate, entire, green, threadlike leaves. Flowering period is March to May in its range of southern and western Arizona to California and Baja California, Mexico from 450 m to 1375 m.

Penstemon eatonii Gray., (Scrophulariaceae) "Firecracker Penstemon", is a perennial herb, up to 75 cm,
with showy, scarlet red tubular flowers on a terminal raceme, and glabrous, opposite, simple, mostly basal leaves, with upper leaves sessile. The plant flowers February to June in southwest Colorado to central Arizona and California from 600 m to 2100 m.

*Phacelia campanularia* A.Gray, (Hydrophyllaceae) "Canterbury Bell", "California Bluebell", is an annual herb, up to 60 cm, with elongate scorpioid racemes having flowers with a deep blue corolla with stamens extending beyond the corolla, and pubescent leaves cordate, round, or slightly elongate with irregular edges and rust colored veins and stems. Flowering period is February to May in the Mohave Desert in California below 1200 m.

The determination of actual quantity of seed used in the experiment was based upon pure live seed and the desired proportion of the species in the mix (Table 1). Most species had been tested for purity and germination by the Utah State Seed Lab in Salt Lake City, Utah.

Seed of each species in the mix was weighed individually, then combined in the mix to be planted. The proportion of each species in the mix was determined by communication with seed producers, recommendations from the literature, and personal experience. Species were evaluated for the mix based upon color, texture, form, and period of bloom.
Table 1. Adjusted seeding rate based on pure live seed.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lbs./Acre *</th>
<th>PLS y</th>
<th>g seed/plot z</th>
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<tbody>
<tr>
<td><strong>Baileya multiradiata</strong></td>
<td>6</td>
<td>0.71</td>
<td>1.92</td>
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<td><strong>Castilleja lanata</strong></td>
<td>1</td>
<td>0.60</td>
<td>0.38</td>
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<td><strong>Eschscholtzia californica</strong></td>
<td>5</td>
<td>0.88</td>
<td>1.30</td>
</tr>
<tr>
<td><strong>Eschscholtzia mexicana</strong></td>
<td>2</td>
<td>0.74</td>
<td>0.61</td>
</tr>
<tr>
<td><strong>Gaillardia pulchellum</strong></td>
<td>3</td>
<td>0.72</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Lesquerella gordonii</strong></td>
<td>3</td>
<td>0.71</td>
<td>0.96</td>
</tr>
<tr>
<td><strong>Lupinus sparsiflorus</strong></td>
<td>3</td>
<td>0.90</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>Orthocarpus purpurascens</strong></td>
<td>3</td>
<td>0.38</td>
<td>1.79</td>
</tr>
<tr>
<td><strong>Penstemon eatonii</strong></td>
<td>3</td>
<td>0.68</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Phacelia campanularia</strong></td>
<td>3</td>
<td>0.74</td>
<td>0.92</td>
</tr>
</tbody>
</table>

*Recommended seeding rates are given in lbs./acre.

yPLS is % purity multiplied by % germination.

zActual seeding rate for the experiment.
The field plot experiment was conducted at the University of Arizona Campbell Avenue Research Farm in Tucson, Arizona. The experiment commenced on September 30, 1987.

Field plots were outlined as one meter by two meters in dimension, and randomized in a completely randomized design with five replications per treatment.

Treatments consist of varying planting dates, starting on September 30, 1987 and continuing through November 30, with treatments planted every two weeks during the ten week period. Five planting dates comprise the experiment.

Soil preparation for the experiment included manual levelling of the field plots and tilling the soil to 20 cm using a rototiller.

Field plots were planted with the wildflower seed mix by evenly scattering the seed mixed with two parts #20 silica sand to insure a more uniform distribution. Seeds were protected from local fauna by a 45 cm chicken wire fence, and bird netting stretched over the plots.

Plots were irrigated with sprinklers twice weekly during establishment of the treatments. Approximately 25 mm was applied at each irrigation. Irrigation was reduced to once weekly after establishment of all the field plots. Weeds were controlled by hand-weeding on a weekly basis.

An inventory of flowers for each species tested was
recorded once weekly, listing the number of species in bloom. An inventory of plants in the mature stand was also taken.

Climatological data including daily soil temperature, maximum and minimum air temperature and precipitation was recorded. The air temperature sensor is located at the Campbell Avenue Research Farm nursery in a box raised approximately 1.4 m above the ground. The soil temperature sensor is buried 6 cm below the soil surface.

Vandalization of the plots occurred the first week of the experiment. The irrigation system was left on overnight. Possible effects of the flooding are discussed in the Results section of this thesis.

Analysis of variance was performed on the plant stand and the number of flowers during the season. Differences between treatments were examined by mean separation using the Student-Newman-Keuls Test at the 5% level.
RESULTS AND DISCUSSION

The five planting dates were first evaluated for their effect on field establishment of each of the species in the plant stand. Subsequently the response of flowering to the planting date treatments was determined.

Statistical analysis exhibited a significant difference between planting date and the effect on field establishment of *Phacelia campanularia*, *Lesquerella gordonii*, *Orthocarpus purpurascens*, *Gaillardia pulchellum*, and *Baileya multiradiata* (Table 2 and Table 3). The October 15 planting was best for germination and establishment of *Lesquerella gordonii*, *Orthocarpus purpurascens*, *Gaillardia pulchellum*, and *Baileya multiradiata*. A later planting date appears to be better for *Phacelia campanularia*, but it should be noted that large plants from the earlier planting date treatments were killed by cold December temperatures, thus changing the final plant stand count. The October 15 planting date is not significantly different from the later planting dates for *Phacelia campanularia*, when comparing mean separations.

No significant difference was revealed for the effects of planting date treatments on *Eschscholtzia californica*, *Eschscholtzia mexicana*, and *Lupinus sparsiflorus*. 
Table 2. Effect of seeding date on plant stand establishment of 4 southwestern desert wildflower species.\textsuperscript{w}

<table>
<thead>
<tr>
<th>Seeding date</th>
<th>Baileya multiradiata</th>
<th>Eschscholtzia sp.\textsuperscript{y}</th>
<th>Gaillardia pulchellum</th>
<th>Lesquerella gordonii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 30, 1987</td>
<td>17.3b\textsuperscript{z}</td>
<td>29.3a</td>
<td>15.2b</td>
<td>2.5ab</td>
</tr>
<tr>
<td>Oct. 15, 1987</td>
<td>37.8a</td>
<td>22.4a</td>
<td>32.4a</td>
<td>5.8a</td>
</tr>
<tr>
<td>Oct. 30, 1987</td>
<td>5.9b</td>
<td>36.5a</td>
<td>14.6b</td>
<td>2.8ab</td>
</tr>
<tr>
<td>Nov. 15, 1987</td>
<td>0.7b</td>
<td>28.5a</td>
<td>12.7b</td>
<td>1.4b</td>
</tr>
<tr>
<td>Nov. 30, 1987</td>
<td>0.8b</td>
<td>43.7a</td>
<td>12.7b</td>
<td>1.8b</td>
</tr>
</tbody>
</table>

\textsuperscript{w}Castilleja lanata and Penstemon eatonii did not germinate and are excluded from the tables.

\textsuperscript{x}Plant stand was recorded on March 17, 1988.

\textsuperscript{y}Eschscholtzia californica and Eschscholtzia mexicana combined as they are indistinguishable in the vegetative state.

\textsuperscript{z}Mean separations within columns for each measurement conducted with Student-Newman-Kuels, 5\% level.
Table 3. Effect of seeding date on plant stand establishment of 3 southwestern desert wildflower species.

<table>
<thead>
<tr>
<th>Seeding date</th>
<th>Plant stand (no. of stems/m²)</th>
<th>Lupinus sparsiflorus</th>
<th>Phacelia campanularia</th>
<th>Orthocarpus purpurascens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 30, 1987</td>
<td>0.0</td>
<td>3.0b^2</td>
<td>8.9b</td>
<td></td>
</tr>
<tr>
<td>Oct. 15, 1987</td>
<td>0.0</td>
<td>9.5ab</td>
<td>46.5a</td>
<td></td>
</tr>
<tr>
<td>Oct. 30, 1987</td>
<td>0.6</td>
<td>6.5b</td>
<td>17.4b</td>
<td></td>
</tr>
<tr>
<td>Nov. 15, 1987</td>
<td>0.4</td>
<td>15.4a</td>
<td>15.0b</td>
<td></td>
</tr>
<tr>
<td>Nov. 30, 1987</td>
<td>0.2</td>
<td>21.1a</td>
<td>23.9b</td>
<td></td>
</tr>
</tbody>
</table>

^Plant stand was recorded on March 17, 1988.

^YStatistical analysis was not performed because of the zero values for several dates of seeding.

^ZMean separations within columns for each measurement conducted with Student-Newman-Kuels, 5% level.
Germination for both species of *Eschscholtzia* was good in all treatments. It was observed that growth in treatments planted early in the season was much more vigorous than treatments planted later in the season. As the two *Eschscholtzia* species are indistinguishable in the vegetative stage when plant stand counts were taken, both were combined in the statistical analysis. *Lupinus sparsiflorus* exhibited poor germination in all treatments.

Seeds of *Castilleja lanata* and *Penstemon eatoni* did not emerge. An unfavorable environment or seed dormancy conditions may have been the reason *Castilleja* and *Penstemon* were absent in the plant population.

Overall, it appears that the October 15 planting date had the widest spectrum of species in the plant stand at an acceptable density. October 15 air and soil mean maximum and minimum temperatures have dropped approximately 5°C from the previous month (Figure 1 and Figure 2). In the two weeks after planting a total of 24 mm of precipitation occurred on three occasions (Figure 3). As plots were irrigated and there was no individual rainfall of 25 mm or more, precipitation probably was not influential in germination. Beatley (1974) states that 25 mm or more precipitation in a single rainfall is necessary to be effective on germination of winter annuals, and the precipitation needs to be concurrent with autumn temperature
Figure 1. Mean weekly maximum and minimum air temperatures during 1987-88 growing season.
During 1987-88 growing season.

Figure 2: Mean weekly maximum and minimum soil temperatures.

Date

Soil Temperature (°C)

Minimum Temperature

Maximum Temperature

Sept 16
Sept 23
Sept 30
Oct 7
Oct 14
Oct 21
Oct 28
Nov 4
Nov 11
Nov 18
Nov 25
Dec 2
Dec 9
Dec 16
Dec 23
Dec 30
Jan 6
Jan 13
Jan 20
Jan 27
Feb 3
Feb 10
Feb 17
Feb 24
Mar 2
Mar 9
Mar 16
Mar 23
Mar 30
Apr 6
Apr 13
Apr 20
Apr 27
Figure 3. Weekly precipitation during 1987-88 growing season.
regimes. Germination of most species in the wildflower mix may have been encouraged by the drop in temperatures in mid-October coupled with irrigation.

Precipitation in mid-December was enough to initiate germination, but temperatures had reached winter regimes and may not have been warm enough to stimulate seedling emergence of most species used in the wildflower mix. *Phacelia campanularia* responded to a later planting date, however, with the largest plant stand produced in treatments planted November 30. This is interesting as the literature states that members of the Hydrophyllaceae studied in the Mohave desert favor late September soil temperatures for germination. The late September planting treatment had the lowest number of plants in the mature plant stand, although some plants from this treatment had been killed by frost in December, as mentioned earlier. Perhaps early season growth is too tender to survive winter temperatures and a later planting date provides more cold resistant plants. Seedlings of all species planted on both November planting dates overwintered as smaller plants than those planted in September.

The effect of planting date on total number of flowers throughout the season was evaluated by statistical analysis. It was determined that planting date had a significant effect upon total number of flowers produced during the
season (Table 4).
The largest total number of flowers were produced in the plots planted on September 30. Most of these flowers were *Eschscholtzia californica*. *Eschscholtzia californica* may have crowded out potential flowers of other species by its unusually vigorous growth. The irrigation system was vandalized shortly after planting, flooding the field, possibly producing quick germination and vigorous plants of *Eschscholtzia californica*. It is difficult to determine the effect of the vandalized irrigation system, so repetition of this treatment the following growing season is desirable.

The October 15 planting date appears to be most desirable for the mix of species tested. The treatment resulted in a large number of blooming plants with a wide variety of species in bloom. Visual observation determined an aesthetically pleasing combination of flower color and progression of flowering period in this treatment.

The October 30 planting date was not significantly different from the two earlier planting dates in the statistical analysis, but the total number of flowers were fewer and a visual evaluation deemed the plants less vigorous.

Planting dates in November produced smaller plants and reduced flowering when compared with observations in the earlier planting dates.
Table 4. Effect of seeding date on the number of flowers per m² using the southwestern desert wildflower mix.

<table>
<thead>
<tr>
<th>Seeding date</th>
<th>Flowers/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 30, 1987</td>
<td>170.0a²</td>
</tr>
<tr>
<td>Oct. 15, 1987</td>
<td>161.7a</td>
</tr>
<tr>
<td>Oct. 30, 1987</td>
<td>114.0ab</td>
</tr>
<tr>
<td>Nov. 15, 1987</td>
<td>65.3b</td>
</tr>
<tr>
<td>Nov. 30, 1987</td>
<td>78.0b</td>
</tr>
</tbody>
</table>

²Mean separations within columns for each measurement conducted with Student-Newman-Kuels, 5% level.
It was determined from this experiment that planting date has a significant effect on field establishment and flowering of some species of southwestern desert wildflower species. While the effect was not significant for all species, most species in the mix responded in a manner that made it desirable to take planting date into consideration when using a mixture of several species of wildflowers.

The southwestern wildflower mix used in this experiment may be tested further to determine whether seeding density, seed treatment, or management practices may be improved. A study involving varying irrigation regimes would be desirable for the southwestern desert landscape. It would be beneficial to investigate additional wildflower species with potential for the landscape industry.

Research efforts in ecology and physiology are important to pursue and gain a better understanding of southwestern desert ephemerals so this knowledge may be applied in horticultural practices.
LITERATURE CITED


