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16. Abstract

Germination and propagation of transplants for wildflowers was studied. Germination parameters were investigated for a number of species. Bluebonnets responded well to acid scarification. Germination of beach morning glory, red phlox and standing cypress is inhibited by light, but seeds of Texas bluebells require light for germination. Optimum temperatures for germination are established for a number of species.

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PROPAGATION OF WILDFLOWERS FOR ROADSIDE USE

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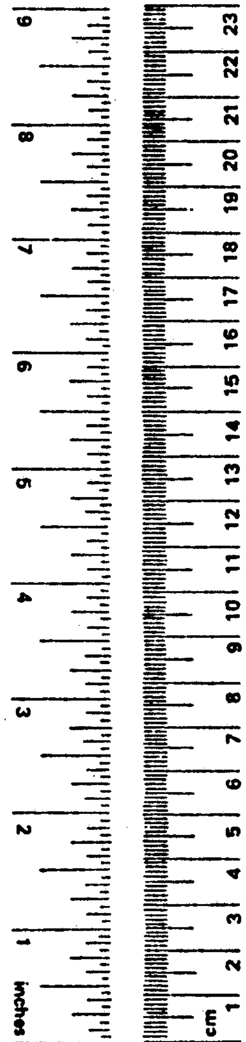
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

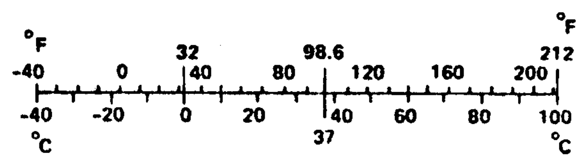
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Technical advice for selection of plant materials for study was furnished by staff of D18L, SDHPT. Wildseed, Inc. of Houston, Texas, furnished seed materials and germination reports for certain phases of studies in this report.

Key words: Wildflower propagation, seed germination, water stress, germination parameters, roadside vegetation management.

SUMMARY

A planned wildflower show along roadsides requires quality seed and a knowledge of their propagation requirements. Germination parameters and propagation techniques are offered for species of wildflowers.

Seed of many wildflowers are dormant because of either seed coat or embryo characteristics, or a combination of these. Bluebonnets germinate readily under laboratory conditions following acid scarification, and there is some suggestion of embryo dormancy.

Beach morning glory germinates readily in the dark if the hard seed coat is mechanically scarified. Seeds of red phlox and standing cypress germinate poorly in light. On the other hand, Texas bluebells need light to germinate.

Individual species of wildflowers vary in their temperature requirements for germination. Texas bluebell germinates within a very narrow range of temperatures while plains coreopsis and gaillardia respond to a very wide range of temperatures.

Many wildflowers can be grown and transplanted as tubelings. Although many plants will flower in the tubeling container, they should be transplanted much earlier.

Much of the wildflower seed sold commercially originates as bulk collections from volunteer stands. As wildflower technology develops and sales demand grows, production of quality seed under more controlled conditions will increase. In the meantime, seeds should be purchased on the basis of laboratory tests.

IMPLEMENTATION STATEMENT

The findings reported here are offered for the guidance of Landscape Architects and Vegetation Managers for propagation of some common wildflowers. These laboratory findings have been used successfully for greenhouse culture of many seed materials, but propagation of some plants such as Indian paintbrush is difficult, even with a favorable germination report. Field plantings should stress the use of quality seed, site preparation and proper seeding methods, often with mulching.

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INTRODUCTION

The Texas State Department of Highways and Public Transportation (SDHPT) has encouraged and planted wildflowers, principally bluebonnets, on their roadsides since 1929. Further awareness of the importance of wildflowers to the enjoyment of highway travellers was expressed in a policy established in 1934 suspending mowing until the spring wildflowers had bloomed. Recent revisions in the mowing policy further limiting mowing encourage blooming of summer and fall wildflowers.

At least four important benchmarks emphasize the importance of wildflowers in SDHPT policies and operations.

* Initiation in 1929 of a policy encouraging the culture and preservation of wildflowers on roadsides through the bloom period, amended in 1934 to delay mowing until wildflowers had bloomed.

* Conception and implementation of beautification awards to SDHPT personnel by Mrs. Lady Bird Johnson.

* A vegetation management system concept installed in 1983 emphasizing an unannounced landscape which blends with that of adjacent properties.

* Implementation of a current policy specifying that 60 percent of the vegetation installed must be native plants.

Much has been accomplished through the efforts of many individuals in SDHPT to culture wildflowers on roadsides using flower hay and topsoil, but the wildflower show often has been erratic and undependable. An increase in the availability of commercial seed for a number of wildflowers in recent years prompted SDHPT and the Texas Transportation Institute (TTI) to initiate studies to determine cultural methods to better propagate wildflowers. Dependable methods of propagation together with an adequate supply of seed will yield a planned and more dependable wildflower show along Texas roadsides.

THE PROBLEM

Establishment of wildflowers by seeding is more direct and less expensive than by other methods of propagation. In landscaping situations where uniform plant development is preferred, transplants may be grown and selected for uniformity if facilities are available.

Landscape Architects and Vegetation Managers are hampered by the difficulty in growing wildflowers when and where desired. Most literature on wildflowers and other native plants concerns plant and seed identification and plant distribution. Very few systematic germination procedures exist, but efforts in this direction have intensified over recent years.

A seed, to germinate, must be placed in an environment where water, temperature, oxygen and light are adequate, and such items as salt or pH are not unfavorable (Colbry, et al., 1961; Toole and Toole, 1961). Water imbibed (absorbed) by the seed sets the germination process in motion by rehydrating the embryo and participating in biochemical reactions, but it should not restrict aeration. Temperature regulates the rate of biochemical reactions and is expressed in speed of germination. Seed of individual plants have an optimum temperature and range of temperatures over which germination proceeds. A supply of oxygen to the germinating seed is needed to satisfy increased respiration requirements of the active embryo plant. Some species germinate better in light, some germinate only in dark, but many germinate equally well in either light or dark. Excessive salts may contain ions toxic to seeds, but salts more commonly make water less available for absorption by the germinating seed. Most seeds grow when the pH is greater than 4.5-5.0, so acidity usually is not a factor in germination.

A seed which is alive but does not germinate is said to be dormant. Dormancy may rest in the seedcoat, in chemicals contained either in the seedcoat or the embryo or in physiological restrictions within the embryo itself. Chemicals which restrict germination are diluted by one or more cycles of wetting and drying. The mechanical restriction of a seedcoat to the entry of water or oxygen or the emergence of the germinating seedling can be neutralized by mechanical abrasion or by prescription treatment with caustic materials such as acid. Embryo dormancy is treated in a number of ways including moist chilling, application of chemicals known to regulate plant growth, warm temperatures and a specified humidity or with other specific treatments.

Germination requirements are fragmentary for Texas wildflowers (Taylor and Hamblin, 1973), but scattered reports are available. These range from general (Abbott, 1979), to plants grown for weed experimentation (Andersen, 1968) to specific reports (Secor and Farhadnejad, 1978; Went,1957).

PROPAGATION STUDIES

Seeds for germination studies were obtained from commercial sources or collected from selected native stands. Initial germination testing was done at room temperature (approximately 20°C). Seeds not germinating were tested for viability with tetrazolium (TZ) (Hartman and Kester, 1975). Seeds which were viable or which germinated were then subjected to replicated tests in an incubator or on thermogradient plates (Larsen, 1971) used by others (Sabo, et al., 1979). Temperature effects on germination were investigated first; later other perameters including scarification, reaction to light, response to moisture stress and response to salt were measured.

Later, seeds obtained from commercial sources with supporting data from testing laboratories were grown under greenhouse conditions. Seeds were mass planted, and seedlings were moved to individual cells in a styrofoam block purchased from Silvaseed Co. in Roy, Washington for tubeling production. Significant plant growth stages were noted and recorded.

RESULTS AND DISCUSSION

Tests of seed germination were conducted for a number of herbaceous plant species regularly found on Texas roadsides or for those which seem desirable to propagate.

1. Texas bluebonnet. Bluebonnet is a member of the lupine group which has been popular as wildflowers since the early 1900's. Although bluebonnets grow in great numbers in South Central Texas, laboratory propagation has yielded sporadic performance. Kaspar (1986) performed an in-depth literature examination supplemented by laboratory studies to reach the following conclusions:

   a. Like most legumes, bluebonnets produce large numbers of hard seed, seed which do not imbibe water. The proportion of hard seed depends on maturity at harvest, storage conditions, region in which the plant is grown (plant ecotype) and other factors.

   b. Germination is improved considerably by scarifying the seedcoat. Mechanical scarification may damage significant numbers of seed if it is not done carefully, but acid scarification is quite effective. Soaking seed in concentrated sulphuric acid for 2-2 1/2 hours followed by rinsing with water was most effective in promoting germination, but soaking in acid for as long as 5 hours did not significantly damage seed.

   c. Scarification should be done immediately before planting. Germination declined as much as 40% in seed scarified and stored for only a week.

   d. Germination of acid-scarified seed exceeded 90% in 72 hours over a temperature range of 17-33°C, but unscarified seed germinated 7-32% over the same temperature range. Germination declined rapidly in both scarified and unscarified seed at temperatures greater than 33°C , and no seed germinated at 40°C. At 12°C scarified seed germinated 80% and unscarified 20%.

   e. Seeds germinated equally well in either light or dark.

These observations help explain variation in stands from planting scarified seed, although plantings using flower hay on roadsides have proven generally satisfactory. The relatively good germination with scarification contrasts with directions from Abbott (1979) to soak seeds for several days in warm water, changing the water daily, or pouring boiling water over them. While this procedure may be considered a pre-germination treatment, it implies chemical interference with germination, certainly not expressed in Kaspar's study. Abbott's instructions are not referenced nor quantified. Kaspar also suggests that there may be embryo dormancy in addition to the impermeable seedcoat.

2. Beach Morning Glory. Beach morning glory grows on beaches and sand dunes along the Gulf Coast and in other warm regions around the world. It roots readily at the nodes, and produces large white flowers from April to November (Correll and Johnston, 1970). Seed are tan to dark brown, rounded with an angular face and from 1/4 to 3/8 inches in cross-section with a hard coat.

   Seed of this plant germinate readily at 30°C if scarified and kept dark. Cutting through the thick horny seedcoat using a file stimulated germination as soon as 2 days, but acid scarification was not effective.

These seeds are extremely sensitive to light, and will not germinate following very short exposure to light following imbibition. In nature these seeds likely are scarified by sand with wave action, or by degradation of the seedcoat over time. Seedlings are robust and vigorous, so they should emerge from seed covered with several inches of sand.

3. Other Plants. Seeds of other plants were tested for germination response under various parameters using the procedures outlined earlier. Seeds not responding well to preliminary tests were checked for life (viability) using TZ. Upon application of TZ healthy living tissues develop a strong red color while dead tissues remain white. Low viability may be sufficient reason to exclude a seedlot from further testing.

Results from seeds germinated in light and dark over a range of temperatures are presented in Tables 2-5. Examination of the germination performance of seeds of native and other plants used as wildflowers emphasizes several characteristics of these seeds:

a. Germination varies widely among plant species tested under standard conditions. Some of this variation can be narrowed by better seed processing, but seed dormancy in many native plants is a factor to be recognized and considered in propagation.

b. Seed from the same plant species grown in widely separated areas may or may not perform uniformly. In these tests, seed of plains coreopsis from Source A germinated better at slightly cooler temperatures than those from Source B. At the same time germination measured for gaillardia differed in amount but peaked at the same temperature.

c. The optimum temperature for germination is species specific. In these tests a warmer temperature was favored by butterfly milkweed while phlox performed better under cooler conditions. Phlox is a cool-season plant and one of the earliest plants to bloom. Butterfly milkweed is a warm-season plant that blooms from late spring throughout the summer.

d. An individual plant species may be very specific in its temperature requirements. Texas bluebell (Table 1) is very specific for a 30°C temperature, but plains coreopsis and gaillardia (Tables 1 and 3) germinate well over a temperature range of 15-35°C.

e. Some seeds are sensitive to light, and germinate only in the presence or absence of light. From the array of plants tested (Tables 1-4), only Texas bluebells showed a need for light in order to germinate. Seeds from red phlox and standing cypress germinate poorly if at all in light. Seeds of other plants tested were rather indifferent to the presence or absence of light during germination. Response to light occurs during the time water is being imbibed. Seeds requiring light to germinate should be covered very lightly; seeds requiring dark should be covered enough that light will not affect their performance. Germination of seeds which are indifferent to light is controlled more by available moisture in the seedbed than by radiation.

f. TZ is a reliable estimate of germination. Germination of standing cypress for seed from Source B under dark conditions matched the TZ estimate. Results from TZ tests indicating poor quality seed of Indian paintbrush and Texas bluebell were confirmed by a lack of significant germination.

Some of the wildflower seed sold commercially is collected in bulk from volunteer stands. As wildflower technology develops and sales demand grows, production of seed under more controlled conditions will increase. Results from TZ tests emphasize the importance of purchasing live seed. The buyer should insist on a recent laboratory germination report.

4. Response to Water Stress. Variations in energy requirements to absorb water from soil are estimated by germinating seeds on media moistened with various dilutions of Carbowax (Sabo, et al., 1979). A complex molecular polymer, Carbowax 4000 is not toxic to plants, and precise energy values can be attained under laboratory conditions.

Seeds from several plants varied in their ability to germinate when moisture is limited (Table 6). Butterfly milkweed, lemon mint and plains coreopsis germinated well through -12 bar suction. Gaillardia and red phlox were least capable of dealing with water stress, showing significant reductions in germination between -4 and -8 bars. Germination of blue flax and standing cypress essentially ceased at -12 bars.

Water is progressively less available as suction values increase, and -12 bars suction approximates the upper limit of moisture available for plant absorption from that held in the soil capillary reservoir. Results from these tests show that some seeds are able to extract moisture from soil throughout the capillary range for germination. As moisture becomes less readily available, the rate of germination and seedling growth slows. This inherent ability to extract moisture against a suction gradient adds an additional dimension to the propagation of these plant materials.

5. Production of Tubelings for Transplantings

Seeds of 18 wildflowers were planted in flats in a greenhouse and the seedlings transplanted individually into cells of styrofoam blocks to grow as tubelings. Tubeling culture requires less space than pots and promotes deeper rooting.

Plant development for various plants is shown in Table 7. Indian paintbrush and blue flax were slow and erratic in germination, and very few plants grew. Depending on the plant species, seedlings can be planted individually when they are 1-2 inches tall, generally by the time the second true leaves appear.

Where a range of days is shown, the shorter period is from a later planting. Depending on the target date for outplantings, a number of the species may require supplemental lighting to force quicker development.

Several of the species have been outplanted as tubelings, and all plants are living. Outplantings to date include blackeyed susan, crimson clover, dwarf red coreopsis, gaillardia, lemon mint, mexican hat, moss verbena, scarlet sage and tickseed.

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Table 1. Percentage germination of wildflower seeds from Source A subjected to several constant temperatures and light for 14 days.

Species	Temperature (C) 15°	20°	25°	30°	35°
	(Percent germination)				
Blue flax	0.5	8.0	7.5	0.5	0
Clasping coneflower	0	4.0	18.5	21.5	0.5
Evening primrose	0.5	7.5	19.0	17.0	4.5
Gaillardia	0	5.0	19.5	18.0	12.0
Indian paintbrush	0	1.5	0.5	0	0.5
Lemon mint	5.0	0	4.0	9.0	4.5
Plains coreopsis	20.0	40.0	46.0	24.0	28.5
Red phlox	5.5	7.0	6.0	0	0
Standing cypress	0	0.5	0.5	1.0	0.5
Texas bluebell	0	0	0.5	10.5	3.0

Table 2. Percentage germination of wildflower seeds from source A at a constant temperature of 26-27°C in dark.

Species	Percent Germination
Blue flax	0
Clasping coneflower	50
Evening primrose	32
Gaillardia	88
Indian paintbrush	0
Lemon mint	0
Plains coreopsis	78
Red phlox	100
Standing cypress	16
Texas bluebell	0

Table 3. Percentage germination of wildflower seeds from Source B subjected to several constant temperatures and light for 14 days.

Species	Temperature (C)				
	15°	20°	25°	30°	35°
	(Percent germination)				
Blue flax	45.5	44.5	40.0	29.5	13.0
Butterfly milkweed	0.5	7.0	42.0	39.5	14.5
Gaillardia	25.0	29.5	38.5	35.0	2.0
Lemon mint	29.0	31.5	37.5	47.0	40.0
Plains coreopsis	18.0	45.5	46.0	47.5	34.5
Red phlox	11.5	7.5	4.5	0.5	0
Standing cypress	2.5	1.5	1.5	0	0
Tickseed	1.5	12.5	20.5	8.5	0

Table 4. Percentage germination of wildflower seeds from source B at a constant temperature of 26-27°C in dark.

Species	Percent Germination
Blue flax	38.0
Butterfly milkweed	41.5
Gaillardia	38.5
Lemon mint	41.0
Plains coreopsis	37.5
Red phlox	18.5
Standing cypress	20.5
Tickseed	26.5

Table 5. Percentage viability as measured by tetrazolium chloride (TZ).

Species	Viability (%)
Beach morning glory	10
Blue flax	42
Indian paintbrush	0
Lemon mint	0
Plains verbena	5
Standing cypress	40
Texas bluebell	5

Table 6. Relative germination under water stress after 14 days at 25°C in the dark.

Species	Water Potential (bars) 0	-4	-8	-12
	Relative germination - %			
Blue flax	100 (88)[a]	66	34	7
Butterfly milkweed	100 (54)	100	74	78
Gaillardia	100 (84)	74	14	12
Lemon mint	100 (100)	100	90	86
Plains coreopsis	100 (100)	92	92	80
Red phlox	100 (36)	100	25	25
Standing cypress	100 (12)	100	50	0
Tickseed	100 (48)	79	50	33

[a] ( ) indicates absolute germination (%)

Table 7. Propagation of wildflowers for tubeling production.

Plant species	Days to Start Germination	Days to Peak Germination	Days to Primary Leaf	Days to Sec Leaf	Days to Flower
African daisy	5	8	8	10-43	38-57
Blackeyed susan	2	7			58
Bluebonnet	6	7	9		67
Blue flax		30			120
Cornflower	4	6	9		130
Corn poppy		6-10		9	120
Crimson clover	2	5	9	11	75
Dwarf red coreopsis	7	11			65
Indian paintbrush	14	39		65	
Gaillardia		6	10	14	120
Lemon mint	15			54	
Mexican hat	7	15		47	
Moss verbena		5	9	11	40
Plains coreopsis		12	15	18	
Purple coneflower		9			
Purple tansy	5	8			
Scarlet sage		6-11	8	11	35-92
Tickseed		5-7	12		125

Appendix I. Plant species mentioned in this report

Common Name	Scientific name
African daisy	*Dimorphotheca aurantiaca*
Beach morning glory	*Ipomoea stolonifera* (Cyr.) Gme
Blackeyed susan	*Rudbeckia divergens* T.V. Moore
Bluebonnet	*Lupinus texensis* Hook
Blue flax	*Linum lewisii* Pursh.
Butterfly milkweed	*Asclepias tuberosa* L.
Clasping coneflower	*Rudbeckia amplexicaulis* Vahl
Cornflower	*Centaurea cyanus* L.
Corn poppy	*Papaver rhoeas* L.
Crimson clover	*Trifolium incarnatum* L.
Drummond phlox - see Red phlox	
Dwarf red coreopsis	*Coreopsis tinctoria* Nutt.
Evening primrose	*Oenothera* sp. L.
Fiddleleaf morning glory - see Beach morning glory	
Gaillardia	*Gaillardia pulchella* Foug.
Indian blanket - see Gaillardia	
Indian paintbrush	*Castilleja indivisa* Engelm.
Lance coreopsis - see tickseed	
Lemon mint	*Monarda citriodora* Cerv.
Lewisflax - see Blue flax	
Mexican hat	*Ratibida columnaris* (Sims) D. Don
Moss verbena	*Verbena tenuisecta* Briq.
Plains coreopsis	*Coreopsis tinctoria* Nutt.
Purple coneflower	*Echinacea* sp. Moench
Purple tansy	*Phacelia tanacetifolia*
Red phlox	*Phlox drummondii* Hook.
Scarlet sage	*Salvia coccinea* Juss. ex Murr.
Showy prairie gentian - see Texas bluebell	
Standing cypress	*Ipomopsis rubra* (L.) Wherry
Tickseed	*Coreopsis lanceolata* L.
Texas bluebell	*Eustoma grandiflorum* (Raf.) Shinners
Texas bluebonnet - see Bluebonnet	
Texas paintbrush - see Indian paintbrush	
Tropical sage - see Scarlet sage	
Upright prairie coneflower - see Mexican hat	