is possible that root tissue represents the first water compartment and shoot tissues represents the second compartment. Similar analyses have been conducted on the root and shoot tissues of *Betula pubescens* and *Fraxinus angustifolia* (4). In both species, the moisture content in log scale was plotted separately against time of drying for root tissue and shoot tissue. They observed a straight line for shoot and one for root with different slopes, indicating that water released into dry air follows a first order reaction when analyzed separately for root and shoot tissues. Since we used whole trees for measuring drying response, it is possible the double first order reaction may be representing one reaction for root tissue and one for shoot tissue. It is also possible that the water in different cell types (for example, bark vs. wood tissues) may be the reason for the compartmentalization. Experiments are underway to clarify this point.

Results show that 'Red Delicious' scion with a MM.111 rootstock is more desiccation tolerant than other rootstocks tested. Its higher degree of desiccation tolerance seemed to be a result of its ability to tolerate more water loss from tissue. This conclusion is based on the observation that both the rate of water loss from the tissue and the critical water contents of 'Red Delicious'/MM.111 could not explain its superior desiccation tolerance.

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Improvement of Seedling Emergence of *Lupinus texensis* Hook. Following Seed Scarification Treatments[1]

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Abstract

Seeds from four commercial seedlots of *Lupinus texensis* Hook. (Texas bluebonnet) were placed in concentrated sulfuric acid for 0 to 120 minutes and then sown. Emergence was promoted by acid scarification in three of the four seedlots. For the lots that responded to acid scarification, the optimal scarification time was 30–60 minutes which resulted in 85–95% emergence one month after planting. In addition to increasing the total number of seedlings that emerged, acid scarification hastened emergence. The same aliquot of sulfuric acid was used for five 60-minute scarification periods before its efficacy was reduced. Acid scarification did not reduce seed coat thickness or strength but created several small pores in the seed coat which likely facilitated imbibition. Cutting, filing, or piercing the seed coat promoted emergence to a similar extent. Placement of seeds in 85°C (185°F) water and then cooling for 24 hrs promoted emergence relative to the non-treated controls, but was not as effective as other scarification techniques. Freezing and thawing of seeds had no effect on emergence. Results indicate that acid scarification functions by removing a mechanical rather than a chemical barrier to germination of *L. texensis*.

Index words: germination, native plants, seed propagation, sexual propagation, sulfuric acid, Texas bluebonnet

Significance to the Nursery Industry

Lupinus texensis is a potentially useful low maintenance annual but, as with other newly-domesticated species, propagation may be an obstacle to further development. Our findings indicate that considerable seedlot variability exists with regard to the need for sulfuric acid scarification. Growers should test the response of small seedlot samples to acid scarification before deciding on the length of the acid scarification period. If this is not possible, then a 45-minute acid treatment should promote emergence in most seedlots of *L. texensis* without causing significant damage to the sensitive lots. A given quantity of sulfuric acid can be used for at least five scarification treatments before its efficacy

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is reduced. Acid scarification works by removing a physical barrier to germination. Thus any treatment that produces a small pore in the seed coat will likely improve emergence.

Introduction

Lupinus texensis Hook. (Texas bluebonnet) is an attractive spring flowering annual native to Texas that has considerable potential for use as a low maintenance bedding plant or for use in roadside plantings. The species is adapted to a variety of environmental conditions and has been grown successfully in many areas of the world (1). Being a nitrogen-fixing legume, *L. texensis* requires little or no nitrogen input on a variety of Texas soils. Furthermore, the plant requires little irrigation on most sites and few, if any, pesticide applications. Because of these characteristics, there is considerable interest in commercial production of this species. In fact, over 270,000 transplants were sold by North Central Texas retail outlets during fall 1989 (2). In addition, a large amount of packaged seed was purchased for highway seeding projects and home landscape use.

An obstacle to the further development and commercial production of *L. texensis* is variability in seed germination and emergence. As with many other native species, growers have experienced problems in obtaining uniform emergence during greenhouse production. Because of the hard seed coat, scarification is required to obtain a high percentage of seedling emergence in a reasonable period of time. There is, however, currently no information on the optimal length of time for sulfuric acid scarification of seed of *L. texensis*. Optimum sulfuric acid scarification times vary from a few minutes in some species (3) to several hours in others (4). It is also possible that considerable seedlot-to-seedlot variability within a species may exist in response to seed scarification treatments.

The objectives of the current investigation were to determine: 1) the response of four commercial seedlots of *L. texensis* to a range of sulfuric acid scarification times; 2) how many times a given aliquot of sulfuric acid can be used before its scarification efficacy is reduced; 3) if acid scarification works primarily by removing the physical restraint to germination (i.e. the hard seed coat); and 4) the efficacy of a variety of mechanical scarification techniques in promoting seedling emergence of *L. texensis*. The development of mechanical scarification techniques would be desirable because the corrosive nature of sulfuric acid creates a potentially hazardous situation in the workplace.

Materials and Methods

Four commercial seedlots (designated A, B, C, and D) were obtained for use in the study. Some physical characteristics of the seedlots are given in Table 1. Four separate experiments were conducted: 1) *acid scarification time experiment*—seeds from each lot were placed in concentrated (36 N) sulfuric acid (about 60 seeds per 50 ml) for 0, 15, 30, 45, 60, 75, 90, or 120 min. The seed was then rinsed with distilled water several times before sowing; 2) *repeated use of acid experiment*—seeds from lot A were placed for 60 minutes in the same aliquot of sulfuric acid (about 60 seeds per 50 ml) that had been previously used zero to six times for 60 minute acid scarification treatments; 3) *mechanical scarification experiment*—seed from each lot was left non-treated (control), placed in concentrated sulfuric acid for 60 minutes, cut through the seed coat with a razor blade, or rubbed against a metal file until visible seed coat disturbance occurred; and 4) *other scarification treatment experiment*—seeds from lot A were a) left untreated (control), b) lightly tapped using a hammer and nail to create a small hole in the seedcoat, c) placed in tap water, frozen and thawed one time before planting, d) placed in tap water, frozen and thawed three times before planting, e) soaked in room temperature [22°C, (72°F)] tap water for 24 hr, and f) placed in 85°C (185°F) tap water which was allowed to cool for 24 hr.

Table 1. Fresh weight, volume, and density of the four commercial seedlots of *L. texensis* used in the scarification experiment.

Characteristic	Seedlot A	B	C	D
Wt./100 seeds (g)	3.62 a[z]	3.60 a	3.73 a	2.34 b
Vol./100 seeds (cm^3)	2.70 a	2.70 a	2.70 a	1.70 b
seed density (g/cm^3)	1.34 a	1.33 a	1.38 a	1.38 a

[z]Means within a row with common lower case letters are not significantly different at the 5% level of probability (n = 3).

After the seed treatments were administered, the seed was planted ⅛ in. deep in 27 × 53 cm (11 × 21 in) plastic flats containing a medium of peat:perlite (1:1 by vol). The flats were placed in an unshaded greenhouse (day/night temperature regime of about 27/20°C or 81/68°F) and emergence was evaluated after one week and again after one month.

For the acid scarification experiment, seeds from the different seed lots that had been placed in acid for 0 or 90 minutes were cut in half and seed coat thickness was measured using a dissecting microscope. Seed coat strength was measured by placing the seed in a Carver Laboratory Press and determining the force required to crack the seed coat. Also, seeds from lot A that had been left in acid for 180 minutes were photographed under a dissecting microscope to document the seed coat lesions caused by acid scarification.

All experiments were conducted at least twice utilizing a randomized complete block experimental design. The number of seeds per treatment is given in the respective tables or figures. Statistical inferences were made based upon 95% confidence limits after calculation of *z* values (8).

Results and Discussion

There was considerable seedlot-to-seedlot variability with regard to the need for acid scarification. Only 16 and 23% of the non-scarified seeds emerged after one month for the A and C lots, respectively (Table 2). In contrast, 50 and 71% of the non-scarified seeds emerged after one month for the B and D lots, respectively. For the D lot, acid scarification for any length of time did not significantly increase seedling emergence compared to non-scarified seed. In contrast, acid scarification promoted emergence in the remaining seedlots. For lots B and C, a 30 minute scarification period was sufficient for obtaining optimum emergence after one month; with lot A, 45 min. was needed. The highest percent emergence obtained in the acid scarification experiment ranged from 80% in lot D to 95% in lot A. Placement of seed in the acid for 120 minutes reduced

Table 2. Percent seedling emergence of *L. texensis* after one week and after one month following sowing of seeds placed in concentrated sulfuric acid for varying lengths of time.

Seedlot	Acid scarification time (min.)							
	0	15	30	45	60	75	90	120
				One month				
A	16 j[z]	24 ij	75 def	95 a	93 ab	93 ab	84 c	84 c
B	50 g	68 f	86 c	87 bc	83 cd	87 bc	83 cd	71 ef
C	23 ij	44 gh	94 ab	94 ab	84 c	86 c	75 def	72 ef
D	71 ef	74 ef	79 cde	80 cde	69 f	54 g	43 h	28 i
				One week				
A	0 o	7 n	41 i	58 cdef	72 a	73 a	65 abcd	61 bcdef
B	13 mn	29 j	66 abc	70 ab	61 bcdef	64 abcd	63 abcde	55 def
C	8 n	16 lm	65 abcd	59 cdef	71 ab	68 abc	68 abc	51 fgi
D	24 jkl	41 i	53 efg	67 abc	55 def	44 gi	42 i	27 jk

[z]Percentages with common lower case letters are not significantly different at the 5% level of probability (n = 120).

emergence compared to the 45 min. treatment in all seedlots. The most dramatic decline occured with lot D which only had 28% emergence after the 120 min. scarification treatment compared to 80% emergence for the 45 min. treatment. Lot D had the smallest seed size (Table 1) and apparently is quite susceptible to damage from sulfuric acid. These results demonstrate the need for testing small samples of seed from individual seedlots of *L. texensis* seedlots before deciding on the length of time needed for acid scarification. If this is not possible, our data suggest that a 45 minute treatment will be effective in promoting emergence in most seedlots of *L. texensis*, yet safe for lots that are highly sensitive to sulfuric acid (e.g. lot D).

Although acid scarification of lot D did not improve percent emergence after one month, it did speed emergence. One week after planting only 24% of the non-scarified lot D seed had emerged whereas emergence was significantly higher in the 15, 30, 45, 60, 75, and 90 minutes treatments (Table 3). The highest emergence percentage after one week (67%) occurred in the 45 minutes acid treatment. Similarly, all other seedlots showed improved emergence at one week in response to acid scarification. Thus, in addition to increasing the total number of seedlings that emerged, acid scarification also hastened emergence.

Table 3. Percent seedling emergence one week and one month after planting of *L. texensis* seed subjected to different scarification treatments.

Seedlot	Treatment			
	Control	Acid	Cut	Filed
		One month		
A	8 e[z]	85 b	80 b	98 a
B	40 cd	85 b	65 bc	100 a
C	20 de	85 b	80 b	85 b
D	80 b	80 b	65 bc	50 c
		One week		
A	5 f	65 bcd	80 bc	98 a
B	10 f	85 b	65 bcd	100 a
C	5 f	45 de	80 bc	80 bc
D	35 e	65 bcd	60 cd	45 de

[z]Percentages with a common lower case letter are not significantly different at the 5% level of probability (n ≥ 20).

The same aliquot of sulfuric acid was used for five 60-minutes scarification treatments before any significant change in efficacy was detected (Fig. 1). This was despite the fact that considerable change in the appearance of the acid occurred after repeated use. After being used for three 60-minutes scarification treatments the acid was very dark in color, presumably due to the extraction of unknown compounds from the seed coat. The consistency of the acid also changed after repeated use. Acid used several times became more viscous than unused acid. Despite these rather dra-

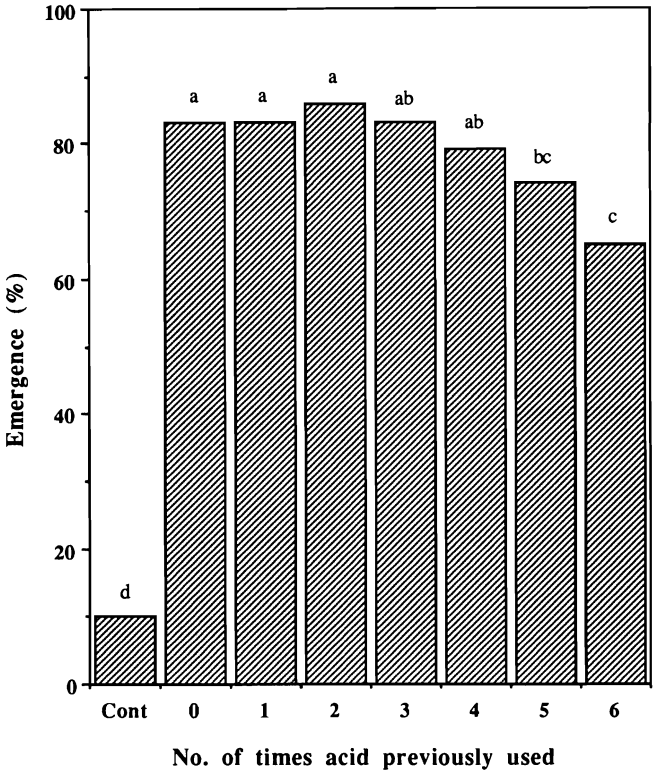

Fig. 1. Percent seedling emergence of *L. texensis* one month after planting seeds of lot A placed in sulfuric acid that had been previously used for zero to six 60 minute scarification treatments. Control seed was not treated with acid. Percentages with common lower case letters are not significantly different at the 5% level of probability (n = 80).

matic changes in physical properties, emergence was still 65% when the acid was used six times previously compared to 83% when not used previously. Thus, the common practice of discarding acid after one or two scarifications may not be important for *L. texensis*. Apparently, contact with seed coats of *L. texensis* does not substantially reduce sulfuric acid strength until after at least five or six scarification treatments.

Seed coat thickness and strength did not differ among seedlots and were unaffected by the 90-minute acid scarification treatment (data not presented). This was an unexpected result because acid scarification is generally thought to decrease seed coat thickness and strength (5). Sulfuric acid created several small, randomly-distributed pores in the seed coat of *L. texensis* (Fig. 2). These areas of the seed coat apparently are more susceptible to acid hydrolysis than the remaining portion of the seed coat. Although the small pores did not measurably affect seed coat strength, they probably served as channels for water uptake during imbibition. Thus, acid scarification seems to promote germination and emergence of *L. texensis* by facilitating water uptake through small localized areas rather than by causing a uniform thinning of the seed coat.

Cutting the seedcoat with a razor blade or rubbing the seed against a file improved emergence compared to the non-treated seeds in lots A–C (Table 4). With lot D, cutting the seed coat had no effect whereas filing the seed reduced emergence to 50%. The reason for this response is not clear, but may be related to the small size of the seed in lot D. The pressure exerted on the seed during filing may damage the embryo. For lots A–C, it appears that any treatment that creates a weak area or opening in the seed coat will improve germination and emergence. This suggests that acid scarification improved emergence by removing a physical barrier (i.e. the hard seed coat that is impermeable to water) rather than by removing a chemical inhibitor from the seed. This is similar to what has been observed for seed of some other species (6) although with seeds of *Panicum coloratum*, acid scarification destroys a germination inhibitor (9).

In addition to promoting total emergence, cutting or filing the seed also hastened emergence in lots A–C. One week after sowing, these treatments clearly promoted emergence relative to the control (Table 4). Nearly all of the cut or filed seed that emerged during the experiment did so during the first week. In contrast, only 5–10% of the non-scarified seeds had emerged by this time. With lot D, cutting the seeds improved emergence after one week but filing had no effect.

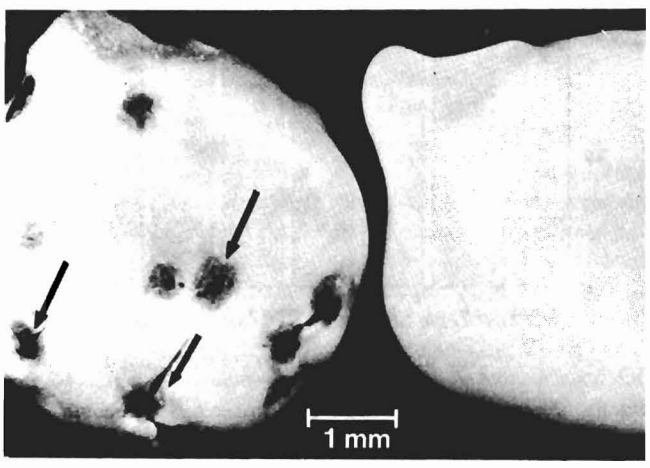

Fig. 2. Photograph of acid-scarified (180 min) (left) and non-treated (right) seeds of *L. texensis* (18×).

Table 4. Percent seedling emergence of *L. texensis* seeds (lot A) subjected to several different treatments.

Time after emergence	Treatment					
	Control	Hole[z]	1 freeze-thaw cycle	3 freeze-thaw cycles	Room Temp. H_2O	hot H_2O
1 week	0 c[y]	80 a	3 c	3 c	5 c	23 b
1 month	13 c	80 a	15 c	13 c	18 c	38 b

[z]hole created in seed coat using a small nail.

[y]percentages within a row with common lower case letters are not significantly different at the 5% level of probability (n = 40).

Because lot A seemed to benefit most from scarification, a variety of treatments that have been reported to promote germination of hard-seeded species was evaluated for this seedlot. Piercing the seed coat with a nail strongly promoted emergence after one week and after one month compared to the control (Table 4). This further supports our conclusion that scarification works by creating small channels for water uptake. A single, small pore in the seed coat apparently is sufficient for adequate imbibition. The hot water treatment increased emergence, but to a much lesser extent than the nail treatment. A similar observation was noted with *Sapindus drummondii* seed where a hot water treatment improved emergence relative to the non-treated control, but less so than other scarification treatments (7). Soaking the seeds of *L. texensis* in room temperature water for 24 hours had no effect on emergence (Table 4). Likewise, freezing and thawing of the seed had no effect on emergence. Apparently the freeze-thaw action was insufficient for creating channels for water uptake.

Based upon the results of this study, it appears that any treatment that creates a small weakening or opening in the seed coat of *L. texensis* will be useful for increasing seedling emergence. Although sulfuric acid scarification is an effective treatment for improving emergence, it is hazardous to use. The mechanical scarification treatments used in this study were very effective in promoting emergence, but are too laborious to be practical on a large scale. It is possible, however, that mechanical scarifiers can be developed or adapted (e.g. like those used for alfalfa and clover) which will be useful for promoting emergence and hence facilitating the commercial production of transplants of *L. texensis*.

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Herbicide Use In Propagation: Effects on Rooting and Root Growth of Stem Cuttings[1]

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Abstract

Two experiments were conducted to determine the effects of several preemergence applied herbicides on rooting, root quality and subsequent root growth of selected woody cuttings. In the first experiment *Ilex* x *attenuata* Ashe 'Fosteri' rooting percentage, primary root numbers and root ratings were suppressed with Surflan (oryzalin). In the second experiment, the long-term effects of herbicide use in propagation were monitored for 13 months after potting. Suppression of one or more rooting variables occurred with the 3 species, *Abelia* X *grandiflora* 'Sherwoodii', *Buxus microphylla* var. *koreana*, and *Ilex crenata* 'Compacta', 8 weeks after cuttings were placed in propagation. Thirteen months later, Surflan treated boxwood exhibited root and shoot growth suppression while 'Compacta' holly exhibited suppressed root growth.

Index words: weed control, injury

Herbicides used in this study: Ronstar (oxadiazon), 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one; Goal (oxyfluorfen), 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; Prowl (pendimethalin) N-(1-ethylpropyl)-3,4-dimethyl 1-2,6 dinitro-benzenamide; Surflan (oryzalin), 4-(dipropylamino)-3, 5-dinitro-benzenesulfonamide, Eptam (EPTC), S-ethyldipropylthiocarbamate; Casoron (dichlobenil), 2,6-dichlorobenzonitrile, and Princep (Simazine), 6-chloro-N,N′-diethyl-1,3,5-triazine-2,4-diamine.

Species used in this study: Sherwood abelia (*abelia* x *grandiflora* (Andre)Rehd. 'Sherwoodii'); Korean boxwood (*Buxus microphylla* var. *koreana* Nakai); Foster's holly (*Ilex* x *attenuata* 'Foster's #2'); Compacta Japanese holly (*Ilex crenata* Thunb 'Compacta'); blue rug juniper (*Juniperus horizontalis* Moench 'Wiltoni').

Significance to the Nursery Industry

Limited information is available on the use of herbicides in the propagation of woody nursery crops. This study shows that potential exists for the safe use of herbicides, depending on the crop and herbicide. Surflan (oryzalin) and Surflan based herbicides were more likely to suppress rooting than other herbicides tested. Ronstar (oxadiazon) was the safest for use in propagation with the species tested. Each producer should conduct a test on a small-scale before treating an entire crop.

Introduction

Many growers propagate by sticking cuttings in small containers (rose pots) then placing them under mist in greenhouses or outdoor groundbeds. Weed control in these areas is a problem currently addressed by hand weeding. Use of herbicides to control weeds in these areas would be beneficial; however, limited information is available on how herbicide effects rooting and subsequent root growth of woody cuttings.

Cohen (3), Ahrens (1) and Fretz (5) evaluated propagation of cuttings taken from stock plants previously treated with herbicides. No reduction of rooting or root quality occurred when herbicides were applied at the recommended rate; however, materials such as Eptam (EPTC), Casoran (dichlobenil) and Princep (simazine) reduced rooting at 3 and 4 times normal use rates (5). Research has also shown Surflan to suppress root growth of woody plants (6). Johnson (7) reported suppressed rooting and root quality when herbicides were broadcast over the top of cuttings during propagation. Defoliation of some species was also observed.

In commercial production where many growers stick cuttings directly into individual pots; pots are filled with media, placed in flats, and the flats are moved to the propagation house 1–2 days prior to sticking the cuttings. During this time the pots are watered to thoroughly wet the medium. Application of preemergence herbicides to the pots before sticking the cuttings may avoid direct herbicide injury reported by Johnson (7). The objective of this study was to determine if pre-propagation application of preemergence applied herbicides would affect rooting and subsequent root growth of selected woody plants.

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