Germination Requirements of Lotebush (*Ziziphus obtusifolia* var. *obtusifolia*)

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Abstract

Optimum average temperatures for germination of lotebush (*Ziziphus obtusifolia* var. *obtusifolia*) seeds in the laboratory were 20° to 30°C. Although some germination occurred without light and without a cold treatment, both of these factors tripled germination when they were present. Aging was unnecessary to obtain optimum germination. Best emergence in the field occurred when average soil temperatures ranged from 22.4° to 27.1°C. These field temperatures are most common in early spring and early fall. Litter enhanced germination in late spring and summer. Timing of precipitation is a limiting factor during the warmest months.

Lotebush (*Ziziphus obtusifolia* var. *obtusifolia*), a spiny shrub in the Rhamnaceae family, occurs in Texas, Arizona, New Mexico, and northern Mexico. Because of its ability to resprout from both crown and roots, along with its resistance to herbicides (Scifres and Kothmann 1976), lotebush has the potential to increase its cover on Texas rangeland after the release of competition from other woody vegetation by brush control treatments (Carter 1958, Box and White 1969). Moreover, since lotebush spreads by movement of seeds and requirements for germination are unknown, its ecological potential may be seriously underestimated.

Temperature is not only a general environmental factor which affects the germination process, but may be a method for breaking the dormancy of some seeds. Seeds of many plants are shed in autumn and are exposed to cold temperatures during the winter while they may also be exposed to moist conditions in the soil or under leaf litter. Schopmeyer (1974) reported that *Ziziphus jujuba* seeds needed to be stratified for 60 to 90 days at 5°C in moist sand for maximum germination to occur.

Light, important for breaking the dormancy of some seeds, is usually most abundant only on the soil surface. Seeds can be characterized by their light requirements as those which: (1) germinate after a brief illumination; (2) germinate only in continuous light; (3) germinate only in darkness; or (4) are indifferent to light during germination (Crocker 1948, Schopmeyer 1974, Mayer and Poljakoff-Mayber 1975). Percentage of creosotebush (*Larrea tridentata*) seeds which germinate is greater in darkness than in light (Barbour 1968), whereas, germination of big sagebrush (*Artemisia tridentata*) seeds exposed to full light was greater than when seeds were in the dark (Weldon et al. 1959).

The indurante stone in each lotebush fruit has two cells, and each contains a seed resembling an apple (*Malus pumila*) seed (Lundell 1969). Common methods used to scarify seeds are mechanical abrasion (Schopmeyer 1974, Mayer and Poljakoff-Mayber 1975), passage through the digestive tracts of birds and herbivores (Mayer and Poljakoff-Mayber 1975), and fire (Cushwa et al. 1968). Other methods include acid, boiling water (Quick and Quick 1961, Schopmeyer 1974, Mayer and Poljakoff-Mayber 1975), and exposure to alternating low and high temperatures which cause the seedcoat to contract and expand (Mayer and Poljakoff-Mayber 1975).

This study was designed to determine (1) the optimum temperature for germination of lotebush seeds (removed from the stones) in the laboratory, (2) whether a cold treatment and a period of aging was necessary for optimum germination, (3) whether light enhanced germination, and (4) whether seeds needed to be scarified to germinate. Various experiments were also conducted to determine how the stone enclosing the seeds might be decomposed either artificially or naturally. The effect of three mulch treatments on germination of lotebush seeds was evaluated in the field.

Methods

This study involved two phases. First, a series of laboratory investigations was conducted to determine the temperature, light, scarification, and after ripening requirements for germination of lotebush seeds. A series of alternating temperature regimes, simulating diurnal fluctuations in temperature, was used in a controlled environmental growth chamber.

Seeds collected during the summer of 1976 were given a preliminary 3-week cold treatment in the stones under dry conditions at 5°C (Willemsen 1975) before laboratory experiments were initiated in spring, 1977. Following the cold treatment, the seeds in stones were stored at room temperature. Later collections in June, 1977, and July, 1978, were also given a 3-week cold treatment, except where otherwise noted, before being used for germination studies in fall, 1977 and 1978. Seeds were collected at sites near Post and Colorado City, Texas, from at least 10 plants at each location. Seeds from all plants and the two locations were tested as one composite sample.

The second phase of the study involved planting lotebush seeds at Lake Ransom Canyon (Fig. 1), Lubbock County, Texas. Plots were located on Mobeetie sandy loam soil (a coarse-loamy, mixed, thermic Aridic Ustochrept) on a footslope position below the caprock escarpment. Slope was 3 to 5%. Scattered lotebush plants were present on the study area.

Laboratory Studies

Initially, temperature requirements for germination of lotebush seeds were evaluated using a 17°C night (15 hr) temperature and day (9 hr) temperatures of 15°, 20°, 23°, 25°, 27°, 30°, 32°, 35°, and 40°C. Germinations under a constant temperature of 15°C was also tested.

Each temperature regime was evaluated with 1 to 4 replications (depending on trends and variability in germination) of 60 randomly selected seeds which were placed on filter paper in Petri dishes containing 20 seeds each. The seeds were kept moist with distilled water. An open beaker of water (500 ml) was kept in the growth chamber, to maintain a high humidity. Warm white flourescent lights were automatically timed to shine during the period with the higher alternating temperature. After exposing the seeds to each temperature combination of 10 days, the length of radicles

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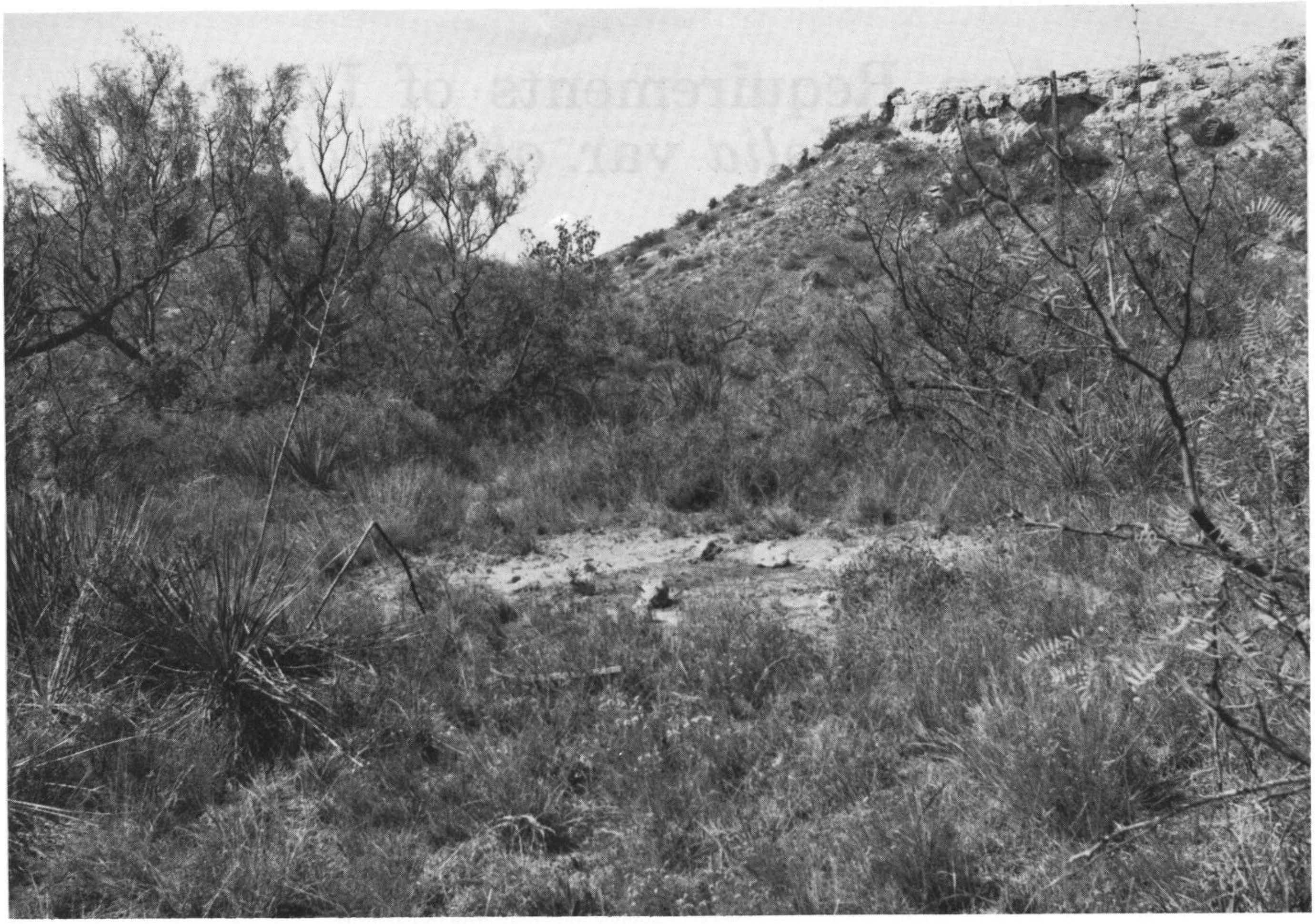

Fig. 1. *Photograph of general study area near Lubbock, Texas, with study plot in foreground.*

of germinated seeds was measured. Seeds were considered germinated if the radicles were at least 2 mm long.

After optimum germination temperatures were established, additional experiments were designed to compare the germination of stratified (3-week cold treatment) vs unstratified seeds that had been removed from the stones. Also, some Petri dishes were wrapped in aluminum foil to simulate a treatment of continuous darkness while other treatments were exposed to the 9 hours of light.

Methods of scarification included steeping fruits (seeds in stone) (Quick and Quick 1961) by placing 50 of them in 1.0 liter of distilled water at 85° C until the water reached room temperature. Other fruits (in stones) were boiled vigorously in 1.0 liter of water for 3 minutes and then rinsed in cold water before being placed in the growth chamber (Quick and Quick 1961; Clemens et al. 1977). Another group of fruits was moistened and then alternately frozen and thawed four times each. Fifty fruits were burned over a direct flame at 427° C for 1 min. A final group of 50 fruits was soaked for 45 min in concentrated sulfuric acid before being rinsed and placed in the growth chamber (U.S. Forest Service 1948). Seedcoats were not broken by any of these methods. Hand removal of seeds from the stones was necessary for this research.

Field Studies

Field experiments were initiated in spring, 1978, using three mulch treatments to simulate soil disturbances which could result from various brush control treatments. The purposes of mulching were to reduce evaporational losses from the soil and to provide a variety of temperatures in the seed zone (Springfield 1971), with the assumption that temperature is an important variable in germination of lotebush seeds.

Plots were randomly chosen on nearly level, sunny locations. A clean seedbed was prepared by removing the grasses and forbs with a hoe. The soil was smoothed with a rake to reduce microvariations in topography which could have a signfiicant influence on soil temperature. Each of the four plots was 1 m^2 and was subdivided into three sections. Ten lotebush seeds were planted in each subdivision of the plots at a depth of 1 cm in the spring, summer, and fall. Each plot was watered at a rate of 3.8 liters/day for 3 consecutive days following seeding (Meagher 1943). Thus moisture was not limiting during any month and the seeds could germinate when the combined range of temperatures was adequate (Hubbard 1956, Adams 1962).

Planting dates were May 25, July 3, July 17, August 10, September 17, and October 10. Dry, mown Bermudagrass *(Cynodon dactylon)* was used as the mulching agent. Within each plot, the treatments with bare soil, 3,370 kg/ha of mulch, and 5,620 kg/ha of mulch were applied randomly. Six iron-constantan thermocouples per plot (two per subdivision) were buried 1 cm below the soil surface. Soil temperature was monitored using a potentiometer that was attached to the thermocouples on each of 4 days during each trial. Temperatures were recorded at approximately 8:00 a.m. and 4:00 p.m. (CST) on each of those days. After 2 weeks, the number of emerged lotebush seedlings for each treatment was recorded.

Chi-square analysis was used on the laboratory data (number of seeds that germinated) to determine differences between treatments. Field data (number of seeds that germinated) were analyzed using a 3×6 factorial randomized block design (Snedecor and Cochran 1967). Duncan's new multiple range test was used to separate means ($P<0.05$).

Results and Discussion

Laboratory Studies

Lotebush seeds (removed from stones) germinated in the presence of light over the daytime temperature range of 20° to 40° C. Seeds germinated equally well over the range of 20° to 32° C but percentage germination dropped significantly at 35° C (Table 1). Although there was no difference among treatments within the 20° to 32° C range, the highest germination percentage tended to occur at 30° C (Table 1). No seeds germinated at 15° C.

Average radicle lengths for seedlings were not significantly different over the temperature range of 25° to 35° C (Table 1). These data indicate that seedlings which germinate in the range of 25° to 35° C will be most vigorous and have the best chance for survival. Available moisture after germination would probably be the principal factor affecting seedling survival.

Table 1. Effects of average growth chamber temperatures on germination and radicle length of lotebush seeds.[1]

Temperature	Seeds germinated (%)[2]	Mean radicle length (mm)
15	0 d	0 d
20	52 a	9 bc
23	53 a	5 cd
25	55 a	13 ab
27	55 a	13 ab
30	62 a	15 a
32	45 ab	11 ab
35	37 b	14 ab
40	27 c	4 cd

[1]Means within a column followed by the same letter are not significantly different ($P<0.05$).
[2]Analyses were based on number of seeds that germinated per replication of 60 seeds.

Chi-square analysis of the difference in percentage germination of stratified and unstratified seeds at 32° C was highly significant ($P<0.01$). Only 15% of the unstratified seeds germinated, whereas 45% of the stratified seeds germinated.

The Chi-square value comparing seeds receiving light vs. those in total darkness of 30° C was also highly significant ($P<0.01$). Germination percentage was 62% from seeds placed in the light, compared to 18% for those in the dark.

When lotebush seeds were not removed from the fruits, no seeds germinated at 30° C, regardless of the scarification treatment (steeped, boiled, frozen and thawed, burned, or soaked in sulfuric acid). However, the hard stones in the fruits were softened somewhat by the acid treatment and the repeated freezing and thawing.

No scarification was required for germination, if the seeds were removed from the fruits. However, the freezing and thawing of fruits in the field might open the way for fungi and other microorganisms to break down the hard case enclosing the seeds. Also, germination could conceivably occur merely because of physical deterioration from several successive years' cycles of freezing and thawing.

After-ripening did not improve lotebush seed germination. Seeds collected during the previous year germinated equally as well as seeds placed in the growth chamber 3 weeks after they were collected.

Field Studies

The greatest number of lotebush seedlings emerged when the seeds (extracted from fruits) were planted on May 25 and September 17, compared to other planting dates (Table 2). The next best dates for emergence were August 10 and October 10.The fewest seeds germinated after plantings on July 3 and July 17.

Planting dates and mulch treatments interacted significantly indicating that mulch treatments were beneficial during the warm periods—May, early July, and August (Table 3). During the cool months, September and October, mulch treatments reduced lotebush seed germination and seedling emergence.

Table 3. Percentage seedlings emerged (based on 40 seeds/treatment) after planting lotebush seeds under three mulch treatments on various dates near Lubbock, Texas.

Planting date (1978)	Mulch treatment[1]	Average soil temperature (° C)	Seedling emergence (%)[2]
May 25	None	29.3	15 fgh
	Moderate	27.9	38 cd
	Heavy	27.1	60 ab
July 3	None	37.7	0 i
	Moderate	36.5	5 hi
	Heavy	34.8	13 gh
July 17	None	32.9	0 i
	Moderate	31.9	8 ghi
	Heavy	31.0	10 ghi
August 10	None	34.5	5 hi
	Moderate	33.3	8 ghi
	Heavy	31.4	18 efg
September 17	None	22.4	65 a
	Moderate	21.4	45 bc
	Heavy	20.7	25 def
October 10	None	22.1	30 cde
	Moderate	21.1	15 fgh
	Heavy	20.1	5 hi

[1]Mulch treatments None = 0 kg/ha
Moderate = 3,370 kg/ha of Bermudagrass hay
Heavy = 5,620 kg/ha of Bermudagrass hay
[2]Values within a column followed by the same letter are not significantly different ($P<0.05$).

Mulch cover moderated the daily fluctuation between minimum and maximum soil temperatures. Average minimum soil temperatures ranged from 20.5° C in May to 24.3° C in July and 12.8° C in October. Average maximum soil temperatures were 35.7° C in May, 48.4° C in July, and 29.4° C in October. The September planting date was followed by a period of cool, rainy weather. Thus, the average maximum soil temperature for September was only 26.2° C. Examination of the average soil temperatures (average maximum temperature + average minimum temperature/2) (Fig. 2) indicates that lotebush seedling emergence was greatest when the average soil temperature was between 22.4° and 27.1° C (Table 3).

More lotebush seedlings emerged following planting on September 17 during cool, rainy weather than at other dates. Out of

Table 2. Seedling emergence (%) based on plantings of 120 lotebush seeds on various dates.

Planting date	Soil temperature (° C) Maximum	Minimum	Average[2]	Seedlings emerged (%)
May 25	35.7 d	20.5 d	28.1 d	38 a
July 3	48.4 a	24.3 a	36.3 a	6 c
July 17	40.5 c	23.4 b	31.9 c	6 c
August 10	42.3 b	23.8 b	33.1 b	10 bc
September 17	26.2 f	16.8 e	21.5 e	45 a
October 10	29.4 e	12.8 f	21.1 e	17 b

[1]Means within a column followed by the same letter are not significantly different ($P<0.05$).
[2]Maximum + Minimum/2.

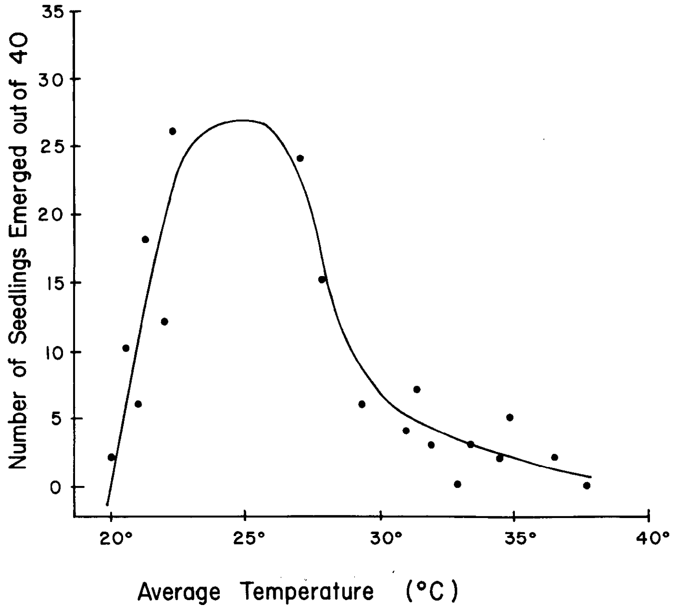

Fig. 2. *Number of lotebush plants that emerged on field plots in relation to average (maximum and minimum/2) daytime temperature.*

120 seeds, a total of 54 seedlings emerged, 26 of which emerged from the bare soil (Table 3) which had an average temperature of 22.4° C. Both mulch treatments lowered germination (Table 3).

The second highest number of seedlings (45) emerged from the 120 seeds planted on May 25. Although a few seedlings were present on the bare soil, the plots with the heavier mulch application supported the most seedlings—24. Litter enhanced emergence by insulating the soil and lowering the average soil temperature to 27.1° C. By contrast, the bare soil had an average temperature of 29.3° C, which limited germination in the field but which approaches the upper end of the optimum temperature range based on laboratory studies.

Plots seeded on October 10 and August 10 planting dates supported 20 and 12 seedlings, respectively, after 2 weeks. In October, more seedlings were growing on the warmer, bare soil (22.1° C).

Although the average soil temperatures were nearly identical in September and October, the total number of seedlings that emerged was significantly ($P<0.05$) different between the dates (Table 2). This difference in numbers of plants that germinated between these plantings may indicate that average field temperatures below 21.5° C are not favorable for germination. In August, most seedlings emerged from beneath the heavier mulch treatment which cooled the soil to 31.4° C.

Seven seedlings each emerged following planting on July 3 or July 17. No seedlings emerged from the bare soil which averaged 37.7° C for July 3 and 32.9° C for July 17. The heavier mulch cover reduced soil temperature to a greater extent and, thus, supported more seedlings than the plots with light mulch cover. Soil temperature averaged 34.8° C for July 3 and 31° C for July 17 beneath the 5,618 kg/ha layer of mulch.

Greatest germination (63%) of lotebush seeds occurred when average soil temperatures were within the range of 22.4° C to 27.1° C, although 25% and 18% germination occurred at average temperatures of 20.7° and 31.4° C (Table 3). Thus, these data indicate that the optimum temperature range in the field for lotebush seed germination is more narrow than that indicated from laboratory studies. The optimum range of temperatures for germination of lotebush seeds is most prevalent in early spring and early fall. Mulch during these seasons is detrimental to seedling emergence. By contrast, mulch is beneficial during the late spring and summer months when average soil temperatures are above 31° C.

Generally, low percentage lotebush seed germination and seedling emergence could be expected during the summer because of extremely high maximum soil temperatures unless there was a period of cool, rainy weather. Seedlings emerging under such conditions would probably be shortlived unless soil moisture remained optimum throughout the summer.

A cold treatment was necessary to obtain maximum lotebush germination. Thus it seems likely that whatever seeds germinate from a particular year's seedcrop, most would not do so until at least the following spring.

Literature Cited

Adams, L. 1962. Planting depths for seeds of three species of *Ceanothus.* U.S. Dep. Agr. Forest Serv. Res. Note PSW-194. 3 p. Pacific Southwest Forest and Range Exp. Sta., Berkeley, Calif.

Barbour, M.G. 1968. Germination requirements of the desert shrub *Larrea divaricata.* Ecology 49:915-923.

Box, T.W., and R.W. White. 1969. Fall and winter burning of South Texas brush ranges. J. Range Manage. 22:373-376.

Carter, M.G. 1958. Reclaiming Texas brushland range. J. Range Mange. 11:1-5.

Clemens, J., P.G. Jones, and N.H. Gilbert. 1977. Effect of seed treatments on germination in Acacia. Aust. J. Bot. 25:269-276.

Crocker, W. 1948. Growth of Plants—Twenty Years' Research at Boyce Thompson Institute. Reinhold Publ. Corp., New York. 459 p.

Cushwa, C.T., R.E. Martin, and R.L. Miller. 1968. The effects of fire on seed germination. J. Range Manage. 21:250-254.

Hubbard, R.L. 1956. Effect of depth of planting on the emergence of bitterbrush seedlings. U.S. Dep. Agr. Forest Serv. Res. Note C-113. 6 p. California Forest and Range Exp. Sta., Berkeley, Calif.

Lundell, C.L. 1969. Flora of Texas. Vol. II. Texas Res. Foundation, Renner, Texas 417 p.

Mayer, A.M., and A. Poljakoff-Mayber. 1975. The Germination Seeds. 2nd ed. Pergamon Press, New York. 192.

Meagher, G.S. 1943. Reaction of pinyon and juniper seedlings to artificial shade and supplemental watering. J. Forest. 41:480-482.

Quick, C.R., and A.S. Quick. 1961. Germination of *Ceanothus* seeds. Madrono 16:23-30.

Schopmeyer, C.S. 1974. Seeds of woody plants in the United States. U.S. Dep. Agr. Handbk. 450. 883 p.

Scifres, C.J., and M.M. Kothmann. 1976. Site relations, regrowth characteristics, and control of lotebush with herbicides. J. Range Manage. 29:154-157.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical Methods. Iowa State Univ. Press, Ames, Iowa. 593 p.

Springfield, H.W. 1971. Winterfat seedlings emerge best from shallow seeding, moderately dry soil. J. Range Manage. 24:395-397.

U.S. Forest Service. 1948. Wood Plant Seed Manual. U.S. Dep. Agr. Misc. Pub. 654. 416 p.

Weldon, L.W., D.W. Bohmont, and H.P. Alley. 1959. The interrelation of three environmental factors affecting germination of sagebrush seed. J. Range Manage. 12:236-238.

Willemsen, R.W. 1975. Effect of stratification temperature and germination temperature on germination and the induction of secondary dormancy in common ragweed seeds. Amer. J. Bot. 62:1-5.