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Effect of Water Bath Temperature and Stratification on Germination of Pecan Seed

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Abstract. **Parameters were defined to germinate pecan [*Carya illinoinensis* (Wangenh.) C. Koch] seeds in aerated water followed by container planting. Germination was not affected by the ratio of seeds to water in the germination containers. Highest germination rates with the greatest uniformity in germination were obtained with a water bath temperature of 32 °C. Stratification up to 188 days increased the rate of germination, but the largest response was between no stratification and 56 days (6.5 days vs. 2.3 days to reach 50% germination, respectively). Seeds that were germinated in a water bath, then planted in containers, achieved 50% emergence in 4.7 days compared to 12.4 days for direct-planted seed. Emergence was more uniform when seeds were germinated in water before planting compared with seeds that were directly planted in containers (7.0 days vs. 9.5 days between 10% and 90% emergence, respectively). Also, by germinating the seeds before planting, nonviable seeds were eliminated, resulting in 100% emergence compared to 76% emergence when planted directly.**

Nonstratified pecan seeds germinate slowly and nonuniformly. Removal of the shell reduced the time required for germination, and improved germination uniformity (Sparks and Pokorny, 1967). van Staden and Dimalla (1976) concluded that pecan seeds do not have a dormancy period, and will germinate at any time that environmental conditions are favorable. They reported that the shell is freely permeable to water and gases, but retards germination by mechanically restricting radical elongation. When nonstratified seeds were germinated at 30 to 35 °C, germination was relatively rapid and uniform. However, other work has shown that stratification can substantially reduce the time to germination, improve the uniformity of germination, and increase growth of the seedlings (Knox and Smith, 1981; Madden et al., 1977; Madden and Tisdale, 1975; Sparks et al., 1974). Nonstratified seeds required ≈30 to 60 d, but stratified seeds only 6 to 20 d, to reach 50% emergence (Madden and Tisdale, 1975; Sparks et al., 1974). Stratification usually did not affect the percentage of seeds that germinated (Madden and Tisdale, 1975). Wolstenholme (1974) reported that pecan germination was more rapid and uniform as germination temperature increased from 20 to 30 °C if seeds were stratified for 0 or 17 d. However, if seed were stratified 100 d the effect of temperature on germination was virtually eliminated.

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Germination of pecan seeds usually ranges between 70% and 90%. This can substantially increase production costs of container-grown trees, since up to 30% of the containers must be discarded. Therefore, the objective of this study was to develop a system to germinate seeds before planting, thus allowing elimination of nonviable seeds. Our second objective was to reduce the time to seedling emergence and improve uniformity of emergence.

Materials and Methods

Preliminary studies indicated that the ratio of seeds to water [ratios tested ranged from 1:1 to 1:4 (v/v) seeds : water] did not affect the rate, uniformity, or percentage of seed that germinated (data not shown). In the studies reported here, the ratio of seeds : water was about 1:3 (v/v). Rigid plastic containers for bathing the seeds in water were 12 cm in diameter and 24 cm tall. Water temperature was maintained with aquarium heaters that oscillated about 2 °C from the set temperature. Water was aerated in each container from a compressed air source. The air was distributed with tygon tubing and an aquarium air stone was attached to the end of the tubing to diffuse the air at the container bottom. Water was changed daily in each container to remove any possible growth inhibitors leached from the seeds (Knox and Smith, 1981).

'Giles' seeds were stored dry (≈3% seed moisture) at 4.5 °C until they were placed in stratification. To initiate stratification, seeds were hydrated 24 h in water then placed in moist vermiculite at 4.5 °C. Unless stated otherwise, treatments in each study were replicated three times with 100 seeds per replication in a completely randomized design. Data were analyzed using trend analysis.

Effect of water temperature on germination. Stratified (89 d at 4.5 °C) seeds were germinated at three temperatures: 22, 27, and 32 °C. Germinated seeds were counted and removed daily for 11 d. Total germination percentage was calculated, as well as the number of days to reach 10%, 50%, and 90% germination, and the time elapsed between 10% and 90% germination, based on the number of seeds that germinated (not total seed).

The experiment was repeated using the same treatments and conditions as described above, except that seeds were stratified 158 d.

Stratification duration. Seeds were stratified for 0, 56, 105, 143, 165, or 188 d. Stratification treatments were arranged such that all treatments were completed at the same time. Several seeds that were stratified ≥143 d germinated while in stratification, and therefore were eliminated from the study. However, if these had been retained, germination would have been faster in those treatments.

Seeds were germinated at 32 °C. Germinated seeds were counted and removed daily for 10 d. Cumulative germination percentage was plotted to compare stratification treatments.

Effects of pregerminating seeds vs. direct planting. Seeds were stratified 81 d, then either planted in 5.5-cm-diameter × 14-cm-tall cone-shaped containers (Stuewe and Sons, Corvallis, Ore.) or germinated at 32 °C, then planted in containers. The container medium was a soilless mix (Metro-mix 300; Scotts-Sierra Horticultural Products Co., Marysville, Ohio). Containers were maintained in a laboratory at a constant 22 °C, and 100 seeds were included in each treatment. Seeds were checked daily, and germination was recorded in the aerated water, and emergence in the containers. Cumulative germination and seedling emergence were plotted to compare how rapidly the seedlings emerged and the percentage of containers with live seedlings.

Results and Discussion

Effect of water temperature on germination. Percentage germination of seed stratified 89 d was greater at 32 °C than at 22 or 27 °C. The number of days to reach 10%, 50%, or 90% germination was curvilinearly related to bath temperature, and 32 °C resulted in the fastest rate of germination (Table 1). Uniformity of germination was best at the highest temperature (interval between 10% and 90% germination decreased linearly).

When seed were stratified for 158 d, germination percentage was greater at 27 and 32 °C than at 22 °C (Table 1). The time to reach 10%, 50%, or 90% germination was negatively related to water temperature. Also germination uniformity was improved as bath temperature increased (interval between 10% and 90% germination decreased linearly).

A temperature of 32 °C increased the germination percentage >10% compared to 22 °C, and increased both the rate and uniformity of germination compared with 22 or 27 °C. Similarly, van Staden and Dimalla (1976, 1977) and van Staden et al. (1976) reported optimum germination in soil at 30 to 35 °C. Wolstenholme's (1974) results agree with those

Table 1. The effect of water bath temperature on germination of 'Giles' pecan seed after stratification at 4.5 °C for 89 or 158 d.

Water temperature (°C)	Germination (%)	Days to 10% germination	Days to 50% germination	Days to 90% germination	Days between 10% and 90% germination
		Seeds stratified 89 d			
22	65	3.2	4.8	8.4	5.1
27	77	2.2	3.3	5.9	3.8
32	85	1.8	2.7	5.1	3.3
Significance $P > F$					
Linear	0.011	0.001	0.002	0.001	0.017
Quadratic	0.366	0.013	0.066	0.049	0.182
		Seeds stratified 158 d			
22	79	2.2	3.9	6.3	4.1
27	94	1.5	2.8	4.7	3.2
32	92	1.2	2.2	3.8	2.6
Significance $P > F$					
Linear	0.001	0.003	0.007	0.008	0.024
Quadratic	0.001	0.118	0.318	0.254	0.4309

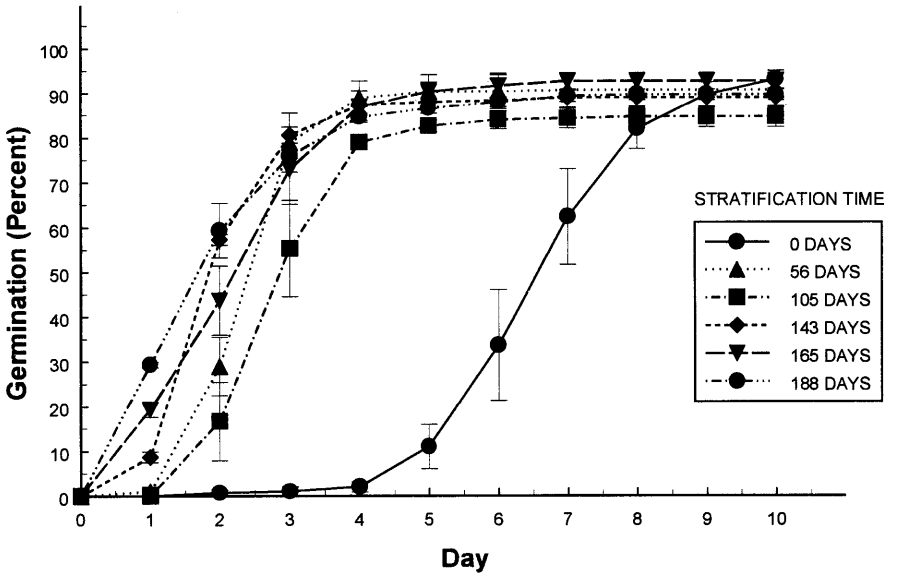

Fig. 1. The effect of time of stratification at 4.5 °C on cumulative germination of 'Giles' pecan seeds in aerated water at 32 °C. Vertical bars are standard errors of the mean.

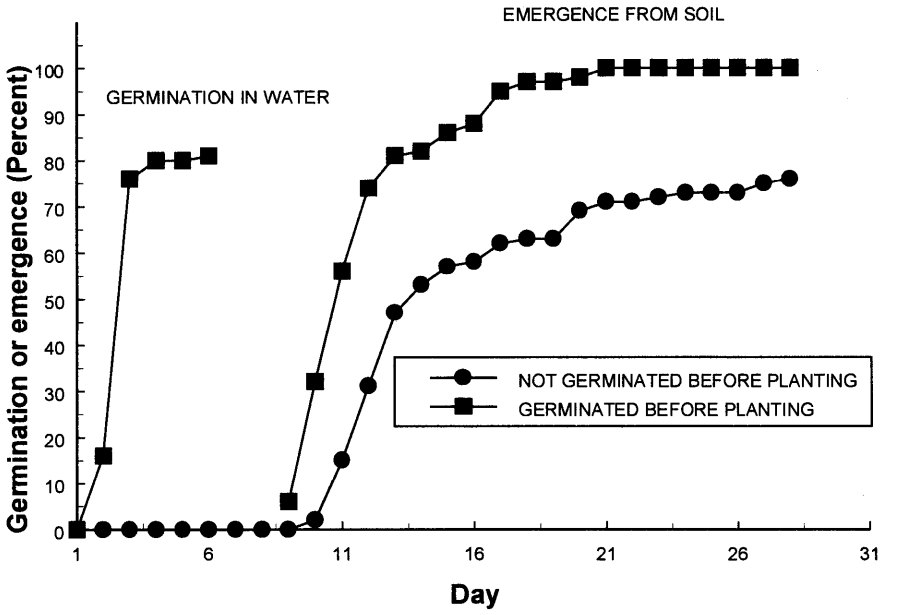

Fig. 2. Comparison of (**a**) cumulative germination of pecan seeds bathed in aerated water at 32 °C, (**b**) subsequent seedling emergence when planted in containers after germination, and (**c**) seedling emergence when seeds were planted directly in containers. Temperature in the containers was 22 °C.

of van Staden and Dimalla (1977) and van Staden et al. (1976) if seeds were not stratified or stratified for 17 d. However, he reported little effect of temperature on germination if seed were stratified 100 d.

Stratification duration. Stratification did not affect the final germination percentage, but did reduce the time to germination (Fig. 1). Increasing the stratification time increased the rate of germination, but the largest difference was between seeds that were not stratified and those that were stratified for 56 d or more.

van Staden and Dimalla (1976, 1977) and van Staden et al. (1976) reported that stratification was not necessary to achieve rapid and uniform germination when seeds were germinated at 30 to 35 °C. However, our data demonstrate that the rate of germination and uniformity could be improved by stratification even when the germination temperature was 32 °C.

Sparks et al. (1974) concluded that 'Stuart' pecans should be stratified at least 70 d. Madden and Tisdale (1975) and Madden et al. (1977) reported that northern cultivars generally have a longer stratification requirement than southern cultivars. They reported 112 d of stratification were required for 'Riverside' (southern cultivar) and 126 d for 'Major' (northern cultivar). Our results indicate that seeds should be stratified at least 56 d, and that longer periods of stratification will further increase the speed and uniformity of germination.

Effect of pregerminating seeds vs. direct planting. Bathing seeds in aerated water resulted in rapid germination (Fig. 2). A total of 81% of the seeds germinated when bathed in water vs. 76% when planted directly in the containers. Germinating the seeds in water then planting the germinated seeds in containers resulted in faster seedling emergence than planting the seeds directly in the containers. Another major advantage of germinating seeds in water then planting them in containers is that nonviable seeds can be eliminated, resulting in a perfect stand. Thus expenses associated with containers and media are not wasted on nonviable seeds. In this example, containers and media could be reduced by 24% if seeds were first germinated in water.

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