significant impacts in the first analysis while income, degree of interest in landscaping, house age, and occupational status of the head of household were significant in the latter analysis. These factors deserve careful attention in marketing plans of producers and marketers.

For each one percent reduction in price, quantity of sod demanded increased by 1.83 percent. Consumers are highly responsive to price changes. Thus, if costs are favorable, producers can stimulate sales and possibly enhance profits through price adjustments.

Increases in household income was found to have a positive impact on sod purchasers. Purchases were found to be responsive to changes in income beyond the $31,000 level. For changes in income at and beyond this level, 70% or more of the market adjustment was due to new consumers entering the market. The balance of the market adjustment resulted from former sod purchasers buying additional sod. These estimates provide useful information relative to targeting promotional activities and sales as well as insight into future opportunities for the industry as incomes and the general standard of living increase.

Literature Cited

1. Adrian, J.L., J.A. Yates and R. Dickens. 1981. Commercial turfgrass-sod production in Alabama. Ala. Agr. Exp. Sta. Bul. 529, pp. 48.

2. Capps, O., Jr. July 1983. Qualitative and censored response models. Amer. Agr. Econ. Assoc., Econometrics Refresher Course; Virginia Polytechnic Institute, Dept. of Agr. Econ. and Stat., pp. 18.

3. Deegan, J., Jr. and K.J. White. 1976. An analysis of nonpartisan election media expenditure decisions using limited dependent variable methods. Soc. Sci. Res. 5:127–135.

4. Lokey, C.M., Jr. 1984. "The marketing of turfgrass-sod in Alabama." Unpublished Masters Thesis, Department of Agricultural Economics, Auburn University.

5. Tobin, J. 1958. Estimation of relationships for limited dependent variables. Econometrics 26:24–36.

6. U.S. Bureau of the Census. 1971. Occupation classification system. U.S. Government Printing Office, Washington, D.C.

Influence of Stratification and Light on Germination of Sourwood (*Oxydendrum arboreum* (L.) DC.)[1]

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Abstract

Comparison of stratified and nonstratified seed demonstrated that at 25° C (77° F), as duration of stratification increased from 0 to 60 days, germination percentage also increased. However, an opposite effect occurred for seed exposed to alternating temperatures of 30/20° C or 25/15° C (86/68° F or 77/59° F). There were no significant differences observed in the final germination percentage between seed stratified for 30 days and nonstratified seed. Stratification hastened germination and decreased the light required for germination.

Index words: sorrel tree, propagation, seed, moist-chilling

Introduction

Viable seed, which do not germinate under conditions normally regarded as favorable for germination, are considered to be dormant (13). Three southern species of *Kalmia* (*K. hirsuta* Walt., *K. latifolia* L. and *K. cuneata* Michx.) exhibit seed dormancy. Three species of *Kalmia* whose native ranges are further north (*K. angustifolia* L., *K. polifolia* Wangenh., *K. polifolia microphylla* (Hook.)Rehd., var.) exhibit no seed dormancy (9). This suggests that seed dormancy is a means for preventing fall germination in southern latitudes, where seed are subjected to warm temperatures after their release from the capsule. If these seed were able to germinate, the tender seedlings would be susceptible to winter kill. The adaptation is not necessary for many northern species. By the time the seed disperse, conditions are not favorable for germination (9).

In many plant species, dormancy may be satisfied by cold-moist stratification (6, 8, 13, 15). *K. latifolia* L. seed are partially dormant. Moist-cold stratification for eight weeks will cause an increase in germination from 40–50% to 60–75% (9). Olson and Barnes (14) and Fordham (7) reported that sourwood seed do not have an inhibiting dormancy. Stratification has been found to substitute for a light requirement in some species that do not require stratification for germination (2, 4). The optimum temperature for germination may change as a result of stratification (1, 12) or light and temperature effects may be eliminated entirely (16). Stratification has also been found to decrease the germination interval in Fraser fir (*Abies fraseri* (Pursh) Poir.) (1) and *K. latifolia* L. (9). The following experiments were designed to study the effects of stratification on the light and temperature requirements of sourwood (*Oxydendron arboreum* (L.) DC.) seed for germination.

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[2]Graduate Research Assistant and Associate Professor, resp. Appreciation is extended to Drs. R.J. Downs and J. F. Thomas as well as Mr. C.M. Farrell for their assistance and guidance with studies conducted in the SouthEastern Plant Environment Laboratories (Phytotron).

Materials and Methods

General procedures. Sourwood seed were collected from random native populations in Yadkin County, NC. The capsules were crushed and then sieved through U.S. standard #25 (mesh opening 710 micrometers) and #35 (mesh opening 500 micrometers) sieves to separate the seed from the capsule debris. A General seed blower, model ER, custom-made by New Brunswick Steel Works was used to remove any flat, sterile seed. The potentially viable seed were air-dried and stored at 4° C (39.2° F).

The following experiments were conducted in the SouthEastern Plant Environment Laboratories (Phytotron) at N.C. State University. Owing to the small size of sourwood seed, they were measured on a volume basis rather than counted individually. Initially, sample lots of 100 seeds were counted and found to have an average volume of 0.06 ml. Seeds were pretreated with 70% Arasan (Tetramethylthiuram disulfide). Washed sand was used as the stratification medium (8, 11, 15). The sand was passed through a U.S. standard #30 sieve (mesh opening 600 micrometers). The particles which passed through the sieve were air dried. Ten ml sand and two ml water (5:1 by vol.) were mixed in a plastic Petri dish. Approximately 100 sourwood seeds were added to each dish. The Petri dishes were sealed with parafilm[3].

Experiment 1: Influence of stratification and temperature on seed germination. Seed were stratified for 0, 30, or 60 days by placing 12 Petri dishes containing seeds in a refrigerator at 4° C (32.9° F) on September 14, October 13, and November 11, 1983. The contents of all 36 Petri dishes were transfered to 9 cm (3.5 in) glass Petri dishes lined with germination blotters[4] (saturated with water) and placed in Phytotron germination chambers (5), on 11/11/83. Four dishes of each stratification treatment were placed in each of three germination chambers which were maintained at 30/20° C (86/68° F), 25/15° C (77/59° F) and 25° C (77° F). Petri dishes were removed from the chambers each day, maintained at room temperature and exposed to one hour of fluorescent light.

Germination was defined as the emergence of the radicle from the seed. Seed were observed daily under a dissecting microscope. Germination was recorded and germinated seed were removed from the Petri dish.

The number of germinated seeds was expressed as a total number of seeds germinated per Petri dish. Since the presence of sand made it impossible to count the potentially viable seeds, a germination percentage was not used. After performing an analysis of variance, Fisher's protected LSD was used to separate means.

Experiment 2: Influence of stratification and light on seed germination. Stratified seeds were prepared as for Study 1. After 30 days stratification, the seed were placed in 9 cm (3.5 in) glass Petri dishes lined with germination blotters. Two Phytotron C chambers were used (5). One controlled environment chamber was set for 30/20° C (86/68° F) and the other was set for 25/15° C (77/59° F). Chambers were illuminated with fluorescent light[5] for 9 hours in each 24 hour period. Twelve Petri dishes were placed in each chamber. The seed were exposed to 0, 1, and 9 hours fluorescent light in each 24 hour period. To accomplish the 9-hour light treatment, Petri dishes remained in the open inside the chambers. To accomplish the 1-hour light treatment, Petri dishes were maintained in black sateen bags and taken out of the bags for 1 hour per 24 hour period. For the 0-hour light treatment, Petri dishes remained inside black sateen bags. Seeds were sown on 3/22/84. Germination of seed exposed to 1 and 9 hours light was recorded daily. At 4 and 5 day intervals, dark treated seed were viewed in a dark room under a green safe light. Chambers were maintained at a relative humidity of 95 + or − 1.0%. Data were analyzed as in Experiment 1.

[3]Parafilm is a trade name of the American Can Co. for laboratory film.
[4]Certified seed testing paper from Western Seed Testing Service.
[5]Illuminance of 29.9 klx equivalent to 379 umol$m^{-2}s^{-1}$.

Results and Discussion

Experiment 1: Germination of seed exposed to alternating temperatures of 30/20° C (86/68° F) and 25/15° C (77/59° F) was significantly higher than germination of seed exposed to a constant temperature of 25° C (77° F) (Table 1). A decrease in germination interval[6] was found when seed were exposed to 30/20° C (86/68° F). When seed were stratified for 0 days and 30 days, there was no significant difference in the final number of germinated seeds (Fig. 1). Sixty days stratification significantly lowered germination. There was a decrease in germination interval when seed were stratified for either 30 or 60 days (Fig. 1).

There was a significant temperature by stratification interaction. When subjected to a constant temperature of 25° C (77° F), the number of germinated seeds increased as the

[6]Germination interval is defined as that period of time during which the maximum percent of seed capable of germination do germinate.

Table 1. Influence of temperature on total germination of stratified and nonstratified sourwood seeds[z].

Temperature (°C)	Total number seed germinated
30/20	43.2 a[y]
25/15	39.7 a
25	22.1 b

[z]Data are for a total number of seeds which germinated over 33-day period.
[y]Means within a column followed by the same letter are not significantly different at the 5% level using Fisher's LSD.

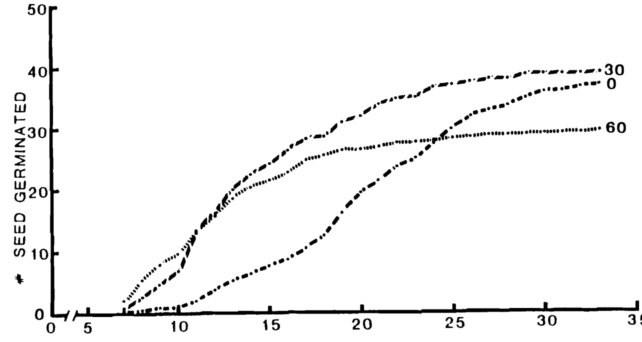

Fig. 1. Cumulative germination of sourwood seed stratified for 0, 30, or 60 days.

length of stratification increased from 0 to 30 to 60 days. At alternating temperatures of 30/20° C and 25/15° C (86/68° F and 77/59° F), the number of germinated seeds decreased as the length of stratification increased from 0 to 30 to 60 days (Fig. 2). Temperature treatments were compared within each level of stratification (Fig. 2). Significant differences occurred between temperature treatments at 0 and 30 days stratification. At 60 days stratification, temperature did not influence germination.

Higher germination was achieved when seed were exposed to alternating temperatures as compared to constant temperature. This is in agreement with results found in prior sourwood germination experiments (3). Between the alternating temperatures used (30/20° C, 25/15° C; 86/68° F, 77/59° F), there were no significant differences in final number of seeds germinated (Fig. 2).

When seed were stratified for 60 days, there was a decrease in germination as compared with seed stratified for 0 or 30 days. Stratification causes physiological changes to occur within the seed (8). These processes require energy and deplete the energy reserves within the endosperm (13). The decrease in germination after 60 days of stratification indicates that the energy reserves in the seed may have been depleted to an extent great enough to preclude germination.

When seed were stratified for 60 days there was no effect of temperature on germination. Since a decrease in germination due to excess stratification occurred, temperature effects may not have been apparent.

Stratification has been shown to decrease the germination interval of sourwood seed. This is important for two reasons. A grower may choose to germinate seed for two weeks rather than four, to decrease costs. Most stratified seed germinate during the first two weeks which results in uniform seedling stands that facilitate handling.

Experiment 2: The total number of germinated seed exposed to 30/20° C (86/68° F) and 25/15° C (77/59° F) was 73.7 and 66.8 respectively. This difference was not significant. There was a decrease in germination interval with seed exposed to 30/20° C (86/68° F) (Fig. 3). A significantly

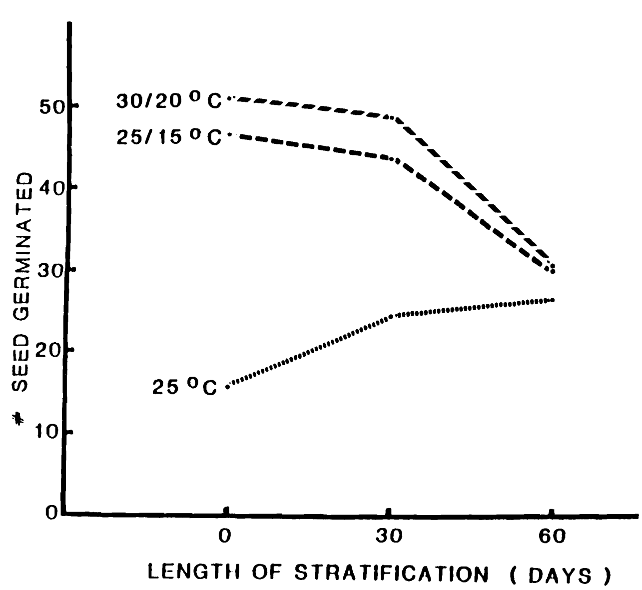

Fig. 2. Effect of the length of the stratification period and temperature on the germination of sourwood seed.

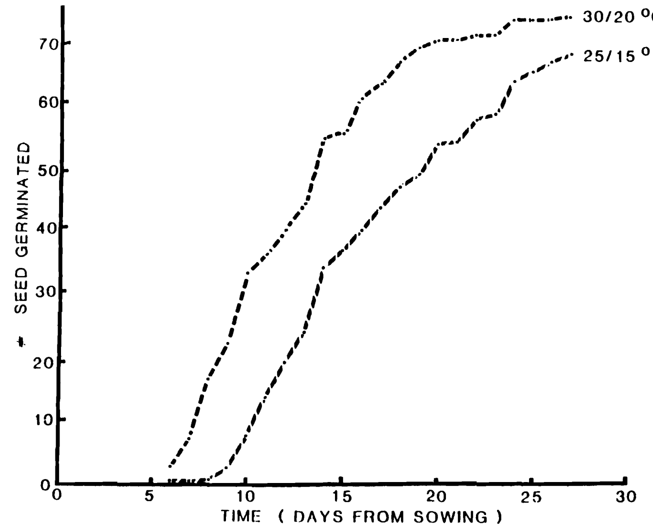

Fig. 3. Cumulative germination of stratified sourwood seed exposed to temperatures of 25/15° C or 30/20° C. (86/68° F and 77/59° F).

higher number of seed, exposed to 1-hour and 9-hours of light, germinated as compared to seed receiving no light (Table 2).

Results indicate that 1 hour of light is sufficient to achieve optimum germination when stratified seed are used. When stratified seed received no light, germination was significantly lower than when seed were exposed to light (Table 2). When nonstratified sourwood seed received no light, germination was negligible (3). Although lower than seed exposed to light, germination of stratified seed in darkness was sufficient so as not to be classified as negligible.

Significance to the Nursery Industry

The problems associated with the current production practices for sourwood in the North Carolina mountains are a low survival rate of seedlings harvested from the wild and unpredictability of seedling supply and uniformity. Development of a reliable means to produce this species from seed would increase the profitability of sourwood to the nursery industry.

Stratification of sourwood seed for thirty days decreases the germination interval which is important to the nurseryman. By stratifying the seed, optimum germination can be reached within a shorter period of time. This results in more uniform stands which facilitate routine handling of seedlings throughout the succeeding production process.

Table 2. Influence of the duration of light exposure on germination of stratified sourwood seeds[z].

Duration of light exposure (hrs)	Total number seed germinated
0	29.9 b[y]
1	95.1 a
9	86.7 a

[y]Data are for a total number of seed germinated over 27-day period.

[y]Means within a column followed by the same letter are not significantly different at the 5% level using Fisher's LSD.

When seed are stratified, one hour of light is sufficient for optimum germination and some germination occurs in darkness. For optimum germination, a grower may use non-stratified seed and supply three hours light (3), or use stratified seed and supply one hour light. If stratified seed are used, germination occurs to some extent even in darkness.

For practical application, further research into liner, container and field production would be useful to the grower.

Literature Cited

1. Adkins, C.R., L.E. Hinsley, and F.A. Blazich. 1984. Role of stratification, temperature, and light in Fraser fir germination. Can. J. For. Res. 14:88–94.

2. Barnhill, M.A., M. Cunningham, and R.S. Farmer. 1982. Germination characteristics of *Paulownia tomentosa*. Seed Sci. & Tech. 10:217–221.

3. Barton, S.S. and V.P. Bonaminio. 1984. Factors affecting the sexual propagation of sourwood (*Oxydendrum arboreum* (L.) DC.). M.S. Thesis, N.C. State Univ., Raleigh.

4. Cho, M.S., J.H. Jung and D.Y. Yeam. 1981. Studies on seed germination of rhododendron plants. J. Kor. Soc. Hort. Sci. 22:107–120.

5. Downs, R.J. and J.F. Thomas. 1983. Phytotron procedural manual for controlled environment research at the SouthEastern Plant Environment Laboratories. N.C. Agr. Res. Service Tech. Bul. 244 (revised).

6. El-Nabawy S., M. Abou Rewash, A.M. El-Hamady, I. Desonky and F. Khalil. 1980. Changes in growth active substances in pecan seeds as affected by stratification and GA treatments. Egypt. J. Hort. 7:33–43.

7. Fordham, A.J. 1960. Propagation of woody plants by seed. Arnoldia 20:33–40.

8. Hartmann, H.T. and D.E. Kester. 1975. Plant propagation, principles and practices, 4th. Prentice-Hall, Inc., Englewood Cliffs, N.J.

9. Jaynes, R.A. 1971. Seed germination of six *Kalmia* species. J. Amer. Soc. Hort. Sci. 96:668–672.

10. Jaynes, R.A. 1971. Selection and propagation of improved *Kalmia latifolia* cultivars. Proc. Intern. Plant Prop. Soc. 21:366–373.

11. Knox, C.A. and R.H. Smith. 1981. A method for rapid seed germination of pecan. Pecan Quarterly 15(3):23–24.

12. Lockley, G.C. 1980. Germination of chokecherry (*p. virginiana*) seeds. Seed Sci. & Tech. 8:237–244.

13. Mayer, A.M. and A. Poljakoff-Mayber. 1963. The germination of seeds. The Macmillan Co., N.Y.

14. Olson, D.F. and R.L. Barnes. 1974. *Oxydendrum arboreum* (L.) DC. sourwood, p. 566–567. In: C.S. Schopmeyer (Tech. Coord.). Seeds of woody plants in the United States. Ag. Handbook 450. U.S. Dept. of Ag. For. Ser., Washington, D.C.

15. Ponders, H.G., R.L. Shumack and C.H. Gilliam. 1981. Liners-the first step in shade tree production. Amer. Nurseryman 153(11):10, 11, 54–64.

16. Stearns, F. and J. Olson. 1958. Interaction of photoperiod and temperature affecting seed germination in *Tsuga canadensis*. Amer. J. Bot. 45:53–58.

Effects of Container Size, Root Pruning, and Fertilization on Growth of Seedling Pecans[1]

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Abstract

Seedling pecan top growth was greater in 38 l (#10) containers and shallow 19 l (#5) containers when compared to deeper 19 l (#5) containers and 11 l (#3) containers; however, all trees were large enough to bud by July of the first growing season. Root pruning at transplanting did not affect top growth, but increased root branching and total root growth. Increased rates of a complete fertilizer increased root growth, but did not affect top growth.

Index words: *Carya illinoinensis*, container production, fertility

Introduction

Demand for container-grown pecans (*Carya illinoinensis*) has increased substantially in recent years. Trees are typically produced by budding or grafting the desired cultivar onto 1- or 2-year-old seedlings with at least one additional growing season required before marketing. Although kinked and circling roots occur and production costs are higher, container-grown pecans can be transplanted year round and with greater success than bare root trees (1). In general, root pruning induces branching and creates a more desirable root system although conflicting results have been obtained with pecan (1, 2, 4, 7). Container size and shape have also been shown to influence the growth of several woody species (3). This study evaluated the effects of container size and shape, root pruning, and fertilization rate on growth of pecan seedlings prior to budding with the objective of minimizing the time required to reach the budding stage.

Materials and Methods

Experiment 1. 'Elliott' pecans were stratified for 6 weeks at 6.7° C (44° F) in closed plastic bags filled with moist peat moss. Pecans were sown January 27, 1983, in 3.8 l

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