GROWTH OF OAK SEEDLINGS WITH SPECIFIC ECTOMYCORRHIZAE IN URBAN STRESS ENVIRONMENTS[1]

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Abstract. Eleven-month old container grown seedlings of pin oak (*Quercus palustris*) and sawtooth oak (*Q. acutissima*) were outplanted on an earth-filled, steeply graded highway interchange near Atlanta, Georgia. The pin oak seedlings had either *Pisolithus tinctorius* (Pt) ectomycorrhizae or natural ectomycorrhizae (controls). The sawtooth seedlings had either Pt, *Thelephora terrestris* (Tt), or natural (controls) ectomycorrhizae. At the end of two growing seasons, pin oak seedlings with Pt ectomycorrhizae were larger than control seedlings. Pt ectomycorrhizae also increased survival and growth of seedlings of sawtooth oak in comparison to seedlings with Tt or control ectomycorrhizae.

Many of Georgia's cities have soils that are less than ideal for growing trees. Urban soils may be deficient in nutrients, heavily graded, contaminated by hydrocarbons from road runoff or landfill material, compacted by heavy foot or vehicle traffic, or full of construction debris (Grey and Deneke, 1978). Trees planted in poor quality soils will be more susceptible to insect and disease problems (Pirone, 1978), may require intensive maintenance, and often die within a few years of outplanting. Such site-related problems are expensive for typically underfunded municipal tree agencies. Treatments or practices that promote tree vigor on poor sites will increase the effectiveness of urban forestry programs.

The research reported here explores the potential value of inoculating seedlings with a particular species of ectomycorrhizal fungus, *Pisolithus tinctorius* (Pers.) Coker and Couch, prior to planting. Dramatic improvements in survival and growth of pine seedlings with abundant *P tinctorius* ectomycorrhizae over naturally infected control seedlings have been reported in numerous studies on diverse sites. See Marx et al. (1982) for a review of these studies.

We report here the effects of specific ectomycorrhizae on oak survival and growth in an urban setting. *P. tinctorius* (pt) and *Thelephora terrestris* Ehrh ex Fr. (Tt), a common fungus occurring naturally in nurseries, were tested against seedlings having erratic amounts of naturally occurring ectomycorrhizae. The fungi were applied to two species of oaks having value as urban trees, sawtooth oak (*Quercus acutissima*) and pin oak (*Q. palustris*). Pin oak is noted for its rapid growth and adaptability to urban stresses, and is widely planted in the Eastern U.S. (Pirone, 1978). Sawtooth oak, an import from Asia (Davis, 1973), can serve as an important source of mast for wildlife, especially deer (Hopkins and Huntley, 1979). Although it has been planted in Georgia since the 1920's, prolific fruit production makes it a poor choice where acorns are a nuisance. Marx (1979 a,b) inoculated white (*Q. alba*) and northern red oaks (*Q. rubra*) with Pt and Tt in a nursery, and Dixon and others (1981) reported that Pt ectomycorrhizae increased survival and growth of black oak (*Q. velutina*) seedlings after outplanting.

Procedures

In the autumn of 1978, approximately 4,000 acorns were collected, half from a single pin oak and half from a single sawtooth oak on the University of Georgia campus. Collecting from single trees reduced the genetic diversity in the seeds. Acorns were placed in cold storage (34°F) for the winter.

Ninety-eight gallons of vegetative inoculum of each of *P. tinctorius* and *T. terrestris* were

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prepared by methods described elsewhere (Marx and Bryan, 1975; Marx and Rowan, 1981). The potting soil was a 1:1 mixture of peat moss and vermiculite to which dried fungal inoculum was added in a ratio of 1:8. The planting mix was placed in 750 ml seedling containers. No inoculum was added to one third of the containers for the uninoculated control condition. One germinated seed was planted in each container in May, 1979, and placed in a greenhouse on the University of Georgia campus. In June, the seedlings were moved to a lathhouse at the University's Whitehall Experimental Forest for the rest of the 1979 season. The seedings were fertilized every 2 weeks with 50 ml of half-strength Miracle-Gro commercial plant food, and watered as needed. Ca, Fe, and Mg were added to the nutrient solution from August through the end of the growing season in September.

In October the root systems of the seedlings were examined to grade the degree of ectomycorrhizal development (Marx and Bryan, 1975). On sawtooth oak, development of Pt ectomycorrhizae was excellent , and that of Tt was satisfactory (Table 1). Pt ectomycorrhizae on the pin oak were adequate, but Tt development on the pin oak was insufficient for a field test. The pin oak Tt treatment was therefore excluded from the field trials. Most of the uninoculated controls had been naturally infected with wild mycorrhizal species. These controls represented the degree and type of inoculation one would expect from standard nursery conditions, and were considered acceptable.

The seedlings were outplanted in April, 1980 on a heavily graded ramp median at the interchange of Interstate 75 and State Route 5 north of Marietta, Georgia. The soil was essentially pure fill, and slope was as high as 20 percent. The planting area was subsoiled to a depth of 12 inches and all trees were planted in the trenches left by the subsoiler. The plots were arrayed as rows running from the top of the grade to the bottom.

The sawtooth oak plots consisted of 18 rows of 25 trees each. The eighteen rows were divided into six sets of three plots each, and within each set, the Pt, Tt, and control treatments were assigned at random.

The pin oak plots consisted of 6 rows of 20 trees each, and 12 rows of 10 trees each. The Pt and control treatments were alternated across the pin oak plots. Each plot was separated from the next by a distance of 15 feet.

The trees were measured while dormant in March 1981 and March 1982. Height was measured to the nearest 0.1 cm, and root collar diameter with calipers to the nearest 0.01 cm. At the conclusion of the study, root samples were

Table 1. Ectomycorrhizal development on container grown sawtooth and pin oak seedlings immediately prior to outplanting.

	Inocuated with		
Seedling no.	*Pisolithus tinctorius (Pt)*	*Telephora terrestris (Tt)*	*Naturally inoculated*
Sawtooth oaks			
1	60 + 5 = 65[a]	40[b]	10[b]
2	70 + 0 = 90	40	15
3	90 + 0 = 70	50	5
4	40 + 10 = 50	65	5
5	4 + 10 = 50	45	5
6	70 + 5 = 75	40	0
7	80 + 0 = 80	65	10
8	40 + 15 = 55	35	20
9	70 + 5 = 75	60	10
10	60 + 5 = 65	55	10
X	62 + 6 = 68	50	10
Pin oaks			
1	5 + 20 = 25[a]	----[c]	15[b]
2	60 + 0 = 60	----	20
3	5 + 10 = 15	----	20
4	20 + 5 = 25	----	20
5	40 + 5 = 45	----	10
6	10 + 20 = 30	----	10
7	50 + 5 = 55	----	20
8	30 + 0 = 30	----	10
9	40 + 10 = 50	----	10
10	10 + 10 = 20	----	10
X	27 + 9 = 36		15

[a] First number is percent of feeder roots with Pt ectomycorrhizae, the second number is percent of feeder roots with naturally occurring ectomycorrhizae, and the last number is the total ectomycorrhizal development.

[b] Since Tt and natural ectomycorrhizae appear the same to the unaided eye, only an estimate of percent feeder roots infected is possible. We must assume that a certain percent of ectomycorrhizae on the Tt seedlings are from natural sources.

[c] The development of Tt ectomycorrhizae on pin oak was so poor that these analyses were not undertaken and the condition was dropped.

taken from the outplanted trees to assure persistence of the tested ectomycorrhizal species. Drought and accidental mowing caused high mortality during the study, but sufficient trees remained for the statistical analyses described below.

Results and Discussion

Survival. Accidental mowing removed 37 percent of the sawtooth and 20 percent of the pin oaks. Among unmowed seedlings, survival by the end of the first year was 76 percent for the pin oaks, and 73 percent for the sawtooth oaks. By the second year, survival declined to 67 percent of the pin oaks and 51 percent of the sawtooth oaks.

A chi-square test of the effect of mycorrhizal treatments on survival was made, deleting all mowed trees. The survival rates are shown in Table 2. Pin oak survival was not influenced by mycorrhizal treatment. By contrast, Pt treatment improved survival of sawtooth oaks. In the 1981 season, seedlings with Pt ectomycorrhizae survived better than the controls. In the 1982 season, survival among seedlings with Pt ectomycorrhizae continued to be good, while survival declined sharply among seedlings with Tt ectomycorrhizae.

The exceptionally dry summers of 1980 and 1981 contributed to the low survival figures. All trees were healthy when outplanted, but they were not watered or fertilized after outplanting.

A random examination of seedling roots after the second growing season indicated that both Pt and Tt persisted on the specifically inoculated seedlings and had spread to newly formed roots.

Growth. Table 2 shows the average height and root collar diameter of the surviving trees for 1981 and 1982. There were only slight differences in the size of the seedlings in 1982, with the uninoculated sawtooth somewhat smaller than the Pt and Tt treated sawtooth oaks. The pin oak

Table 2. Survival rates and mean height and diameter of seedlings.[a]

Species	*1981*			*1982*		
and treatment	*Height*	*Diameter*	*Survival*[b]	*Height*[c]	*Diameter*[c]	*Survival*[b]
	cm	*cm*	*percent*	*cm*	*cm*	*percent*
Sawtooth Oak						
Pt	44.0	.42	82	59.5	.85	69
Tt	45.4	.42	73	49.8	.59	40
Control	41.5	.38	64	51.3	.62	47
Pin Oak						
Pt	35.9	.56	77	50.1	.96	68
Control	36.8	.57	75	46.1	.85	66

[a] *Height and diameter values include only seedlings surviving unmowed to March, 1982. Survival figures include only unmowed trees surviving in each year.*

[b] Pt significantly enhanced survival for sawtooth oak in 1981 (X^2 = 8.26, p .02) and in 1982 (X^2 = 15.35, p .001).

[c] Between 1981 and 1982, Pt treated sawtooth oak seedlings grew significantly more in height (F = 16.16, p .001) and diameter (F = 15.20, p .001) than Tt and control seedlings. Pin oak seedlings treated with Pt also grew significantly more in height (F = 11.28, p .01) and diameter (F = 14.20, p .005).

Pt and control conditions were virtually the same size. Growth the second season is the test of the treatment effect in this study.

Analyses of variance were performed on the means for each plot for the height and diameter growth scores—i.e., height 1982 minus height 1981, and diameter 1982 minus diameter 1981. For the sawtooth oak, the number of plots entering the analysis was 6 for Tt, and 5 each for Pt and control conditions. Due to mowing and mortality, one control plot had only a single tree, so it was removed from the analysis. An entire plot of Pt trees was mowed down in 1982, and so it was omitted from the analysis. The analysis of variance on mean height and diameter growth indicated that Pt ectomycorrhizae stimulated greater growth than either the control or Tt treatments. The control and Tt treatments were virtually identical.

The pin oak plots all had sufficient survival to be included in the design. The analysis of variance on the plot means for Pt and control conditions also shows a significant increase in growth among Pt-inoculated seedlings.

Growth for both pin oak and sawtooh oak was enhanced by Pt ectomycorrhizae. Inoculation with Tt was successful only on sawtooth oak, and it did not significantly improve growth over naturally occurring ectomycorrhizae (some of which was also *T. terrestris*) found on controls.

Conclusions

Pisolithus has been shown to improve survival of sawtooth oaks, and growth of both pin and sawtooth oaks planted on a heavily graded bypass interchange. Compared to seedings with naturally occurring ectomycorrhizae, as would occur under standard nursery conditions, the Pt-pin oak averaged 4 cm taller and 0.1 cm larger in diameter at the end of their third year. Pt-treated sawtooth oaks were about 8 cm taller than controls, and almost 10 cm taller than Tt seedlings. Pt-sawtooth oaks averaged 0.23 cm larger in diameter than controls. This enchancement of growth indicates improved vigor in the Pt trees, and improved tree condition is an important step toward more effective urban forest plantings.

Although these findings strictly apply only to heavily graded fill sites like the one in this study, similar results might be expected on other sites that are low in soil nutrients and moisture. Pt has been shown repeatedly to offer advantages over Tt on pine seedlings on such sites.

Since Pt vegetative inoculum is commercially available (Marx et al. 1982), oak seedlings could be tailored with Pt in nurseries. This study indicates such treatment of pin oak and sawtooth oak seedlings would be a worthwhile investment for planting on dry, infertile urban sites.

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