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Pisolithus Tinctorius Mycobiont Inoculations as a Factor in Performance of Containerized and Bare-Root Shortleaf Pine Seedlings on Lignite Minesoils in Panola County, Texas

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PISOLITHUS TINCTORIUS MYCOBIONT INOCULATIONS AS A FACTOR IN PERFORMANCE OF CONTAINERIZED AND BARE-ROOT SHORTLEAF PINE SEEDLINGS ON LIGNITE MINESOILS IN PANOLA COUNTY, TEXAS

by

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PISOLITHUS TINCTORIUS MYCOBIONT INOCULATIONS AS A FACTOR IN PERFORMANCE OF CONTAINERIZED AND BARE-ROOT SHORTLEAF PINE SEEDLINGS ON LIGNITE MINESOILS IN PANOLA COUNTY, TEXAS

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Dean of the Graduate School

PREFACE

The continental United States harbors about 243 billion tons (oil equivalent) in established coal reserves (Crabbe and McBride, 1978) -- this amounts to some 31 percent of the world's known deposits. Significant deposits of lignite occur in 30 Texas counties with total reserves estimated at approximately 5 billion tons (Fisher, 1965). Due to the seemingly helium-filled inflation rate for petroleum, coal is the only fossil fuel whose extraction can, and will be increased. Of primary importance, fully one-third of these deposits can be excavated by surface mining methods, assuming current technologic and economic conditions -- reserves of lignite recoverable by open-pit mining in the "piney woods" expanse of East Texas are approximately 1.6 billion tons (Fisher, 1965).

The two final decades of the twentieth century will undoubtedly witness thousands of acres of American landscape deeply disturbed by surface mining to expose massive coal seams. This is inevitable, for regardless of environmental and sociological constraints on its use, coal represents the only abundant energy resource capable of meeting the nation's projected needs.

Surface mining results in substantial environmental damage during and after coal extraction. In addition to disruption of the ecosystem, surface mining leaves sites in such condition that productive post-mining land use is discouraged. Herein lies the greatest challenge to research, education and industry -- to economically and productively reclaim mine spoil to the highest possible use for ourselves and posterity. One catalyst for ensuring that this challenge is met may be governmental regulation.

Efforts to establish national standards for mining and reclamation began in Congress in 1971. The 90th Congress held hearings on implementing mining standards, but no bill was reported out of committee. This scenerio was repeated in the 91st Congress. In 1973 the House of Representatives passed a bill to regulate all strip mining, but Congress adjourned without the Senate completing consideration of the bill. A referendum in the Senate to reconsider the bill in 1974 failed by one vote. The 93rd Congress drafted new legislation to regulate surface mining industries, but a successful vote in Congress was thwarted by veto of President Ford because of what he felt would be adverse economic impacts of the measure. President Ford again vetoed a similar bill passed by the 94th Congress in 1975 -- an attempt to override the veto failed the two-thirds majority needed by only three votes. Legislation finally enacted by Congress and signed into law by President Carter in 1977 was originally introduced by the 95th Congress in early 1976 (Mink, 1976).

Full implementation of the Surface Mining Control and Reclamation Act of 1977 (Public law 95-87) is targeted for mid-1980 when individual states will have filed their programs. This tact was taken as the law states, "Because of the diversity in terrain, climate, biological, chemical, and other physical conditions in areas subject to mining operations, the primary governmental responsibility for developing, authorizing, issuing, and enforcing regulations for surface mining and reclamation operations subject to this act should rest with the states." The Texas Surface Mining and Reclamation Act established a permit process for coal, lignite, and uranium mines. The surface mining act in Texas is presently administered by the Texas Railroad Commission, which is empowered to declare areas unsuitable for mining, to reject inadequate applications, and to deny or condition permits if applicant's reclamation plan is unsuitable (Hossner et al., 1980). The law further stipulates that these state actions fall under the purview of the Office of Surface Mining in the Interior Department.

Coal is very likely the energy source that will fuel the future; and strip mining will be the primary means of its acquisition. Legislation is now in place to help ensure that a quality environment is restored as our tomorrows are energized. This present research was an effort to aid in that endeavor to responsibly reclaim the land.

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INTRODUCTION

To date little information is available concerning reforestation of East Texas lignite minesoils. Also little is known about how shortleaf pine (*Pinus echinata* Mill.) will perform as a reclamation species. However, shortleaf pine's well-understood silvics, coupled with the fact that it is indigenous to many of the mining sites seem to promise its fitness (see Figures 1 and 2), especially if the many advantages can be realized from planting trees as containerized seedlings.

Most importantly, the symbiosis called "mycorrhiza" may hold the critical key to successful reforestation on harsh environments in East Texas. New techniques for "tailoring" specific mycorrhizae are being perfected -- inexpensive, protractive, and having no documented collateral counteractive effects, these techniques show tremendous promise. However, the science of choosing and tailoring specific mycorrhizae to a tree species is young, and too little is known, for example, concerning inoculation procedures for containerized planting stock, and particularly for shortleaf pine.

The primary purpose for this study was to investigate the performance of shortleaf pine seedlings planted on East Texas lignite minesoil as containerized seedlings,

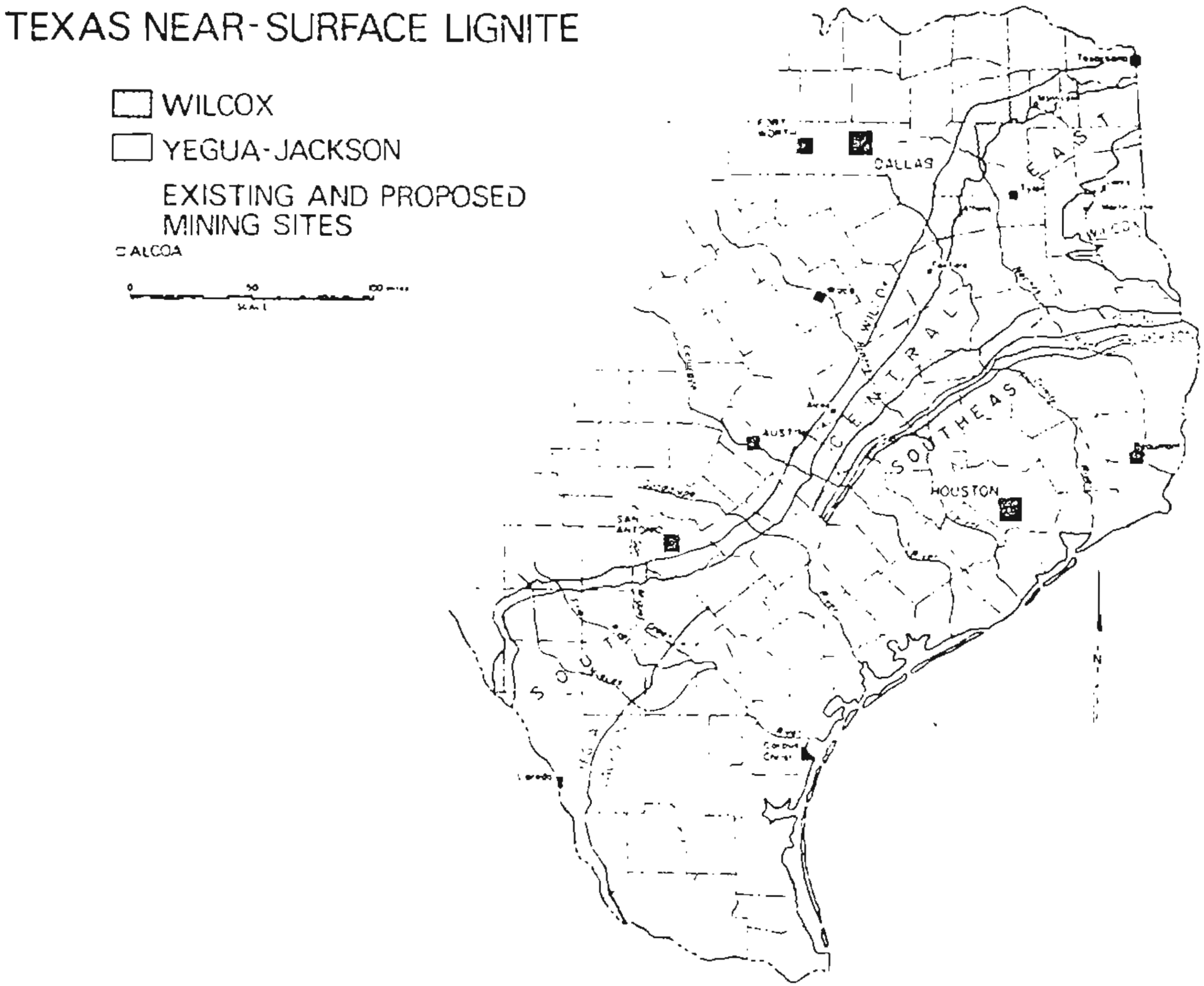

Figure 1. Texas near-surface lignite. Adapted from Kaiser (1974) by White (1978).

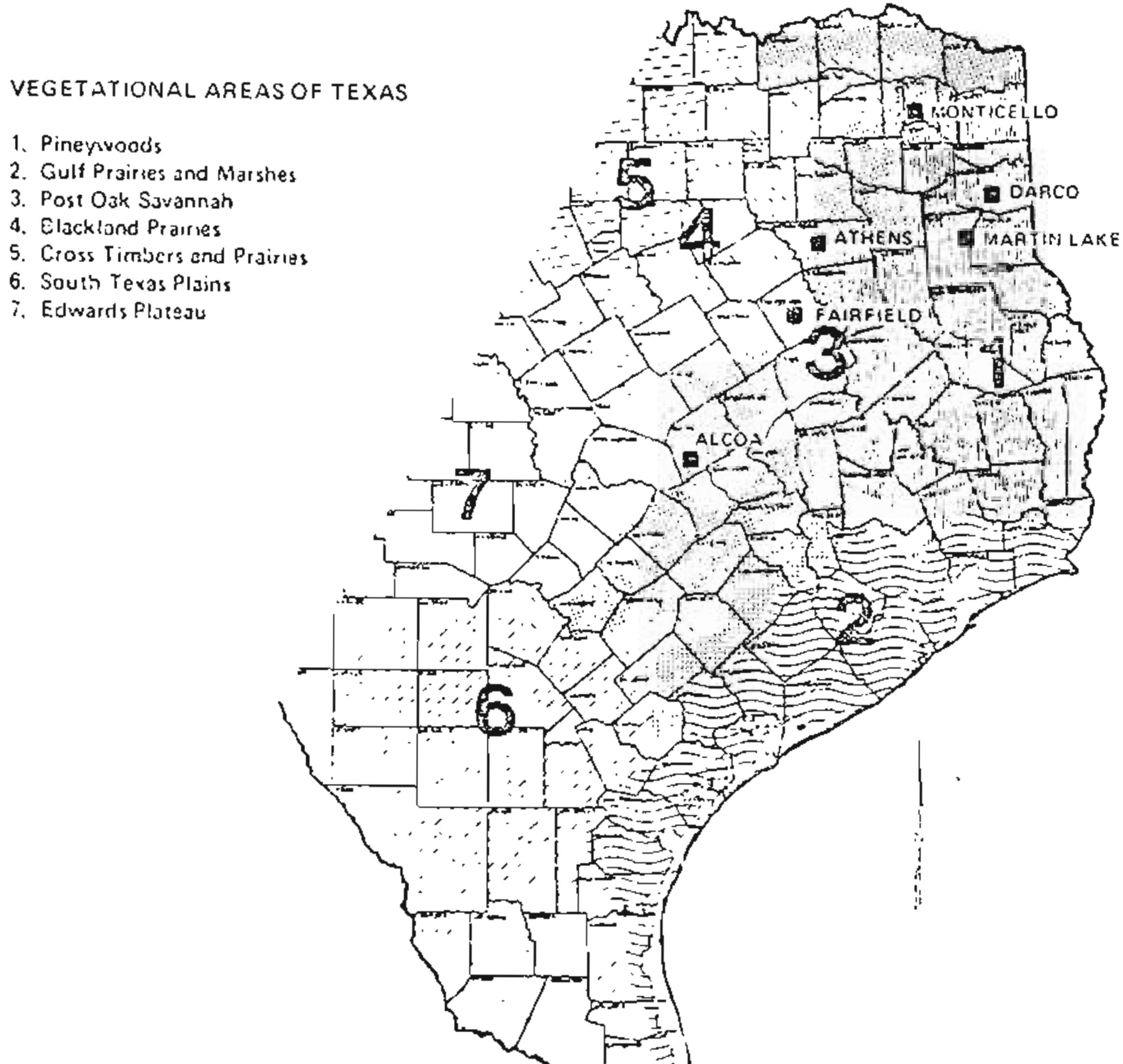

Figure 2. Vegetational areas of Texas. Adapted from Gould (1962) by White (1978).

having received inoculation with the fungus Pisolithus tinctorius (Pers.) Coker and Couch[1] to produce a uniquely tailored mycorrhiza on root systems. Hopefully, results of this study will enable future reclamationists to better prepare pine seedlings to cope with many varied harsh conditions experienced on East Texas lignite minesoil.

Mycorrhizae

The theory that tiny rootlets of trees can and do exist in a symbiotic relationship with certain fungi was first postulated by a German botanist, A.B. Frank, in 1885. He called the association a "mycorrhiza" (μυκοσ-fungus; ριζα - root). Frank's work was predicated on speculations by C. Vittadini in 1842 that tree rootlets are nourished by certain fungal mycelia which mantle them.

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[1] Micheli was first to describe this gasteromycete as Lycoperdoides album tinctorium radice amplissima in 1791. Subsequently, nearly 60 different generic names have been applied to it, including Scleroderma, Polysaccum, Lycoperdon, Pisocarpium, Durosaccum genera. Pilat (1958) listed seven sub-species of P. tinctorius based on the shape of basidiocarp, and shape and color of peridioles. Coker and Couch (1928) concluded that differences in basidiocarp form, especially concerning the presence or absence of a conspicuous, simple, or complicated stalk, and surface color of the peridium are of little taxonomic value. Marx and coworkers (Marx and Bryan, 1975; Marx et al., 1976) found in mycorrhizal synthesis tests with pine, a single isolate of P.tinctorius may produce stalked or nonstalked basidiocarps from 1 to 18 cm in size, and basidiospores and peridioles may vary from bright yellow to dark brown in color.

To date thousands of scientific and review papers and even great tomes have been written concerning mycorrhizae and their influences (see Kelly, 1950; Lobanow, 1960; Harley, 1969; Hacskaylo, 1971; Marks and Kozlowski, 1973). From this oeuvre of mycorrhizae publications much insight and some controversy has arisen. For example, mycorrhiza has been described as a symbiotic relationship (Frank, 1885), a compound organ (Riffle and Boosalis, 1979), a microbial coenosis (Dominik, 1961), a symbiotic biotrophy (Lewis, 1973), and a mutual parasitism (Hacskaylo, 1959), depending primarily on the author's view of the reciprocal functions of fungus and higher plant. The fungus is often called "fungal symbiont" or "mycobiont" -- the root tissues of higher plants are rather uniformly termed "host".

For purposes of this paper, a mycorrhiza may be defined as the symbiotic relationship between fungi (mycobionts) and a rootlet of a vascular plant (host). This definition is adopted with realization that the relationship does produce a unique organ on root systems in form and function (compound organ), and that participants do prey upon one another for life-sustaining needs (mutual parasitism).

Virtually all vascular plants depend on mycorrhizae as the most metabolically active parts of their root system. Most woody plants require mycorrhizae to survive and seldom thrive without an abundance of them. There is a strong interdependence between mycobiont and host for survival in natural ecosystems, as each organism derives physiological and ecological benefits from the other.

The obligate nature of this biotrophic habit is strikingly well illustrated by failures in attempts to introduce trees to soils lacking proper mycobionts (see Briscoe, 1959; Trappe and Strand, 1969; Vozzo and Hacskaylo, 1971; Mikola, 1973), and by unsuccessful culturing of mycobionts in absence of a suitable host (Gerdemann, 1968; Palmer, 1971). Several studies have demonstrated that even certain host plants that may be considered only facultatively mycotrophic exhibit much better growth when their root systems are mycorrhizal (Clark, 1969; Harley, 1969; Khan, 1972; Kleinschmidt and Gerdemann, 1972). Traditionally, fungi have been classified as either basically parasitic or saprophytic, but recent speculations assert that many fungi cannot complete their life cycles without entering into a mycorrhizal relationship -- this suggests a unique third class of fungal organisms which might be designated "mycorrhizal".

The ubiquitous nature of the mycorrhizal habit is best illustrated with studies by Maeda (1954) and Gerdemann (1968). Over 200 families of vascular plants, representing some 1,000 genera were shown to be unanimously mycorrhizal. Notable exceptions were aquatic plants in general, and terrestrial plants when their root systems were formed in saturated soils (Maeda, 1954; Konoe, 1962; Mejstrik, 1965).

Mycorrhizae have been classified into two major groups according to infection anatomy:

1) endo-mycorrhizae in which the mycobiont penetrates the host cell wall, forming characteristic organs that host cells digest, and

2) ecto-mycorrhizae in which the mycobiont invades the host only intercellularly. Since most tree species of commercial importance, including those of families Pinaceae, Fagaceae, Betulaceae, Salicaceae, and Tiliaceae form ecto-mycorrhizae, further discussion will center on this form.

Thousands of mycobiont species have been identified -- many genera in higher Basidiomycetes, Ascomycetes, and zygosporic Endogonaceae are included. Many of these mycobiont species associate with only a single host genus or even only a few species (subgenus) of hosts, while others are nonspecific in this respect (see Trappe, 1962, 1971; Smith, 1971; Chilvers, 1973; Gerdemann and Trappe, 1974). Basidiomycetes form most ectomycorrhizae. Over 2,100 species of ectomycorrhizal fungi have been estimated to exist on North American trees alone (Marx, 1975), and as many as three different mycobionts have been isolated from a single pine mycorrhizal rootlet, which is usually termed a "short root" (Dominik, 1961; Zak and Marx, 1964; Marx, 1977).

Ectomycorrhizae are fairly consistently coherent in anatomy (Figure 3). Ectomycorrhizae are characterized primarily by the following:

1) a mantle of fungal tissue shrouding host rootlets with a nimbus of hyphae radiating out into soil, and

2) "Hartig-net" development which is the pattern of fungal penetration between rootlet cortical cells -- in well developed ectomycorrhizae, mycobiont tissue completely enclose outer cortical cells, separating them one from the other. Some maintain that total Hartig-net development is mandatory before a rootlet may be termed ectomycorrhizal.

Ectomycorrhizal roots are usually extremely truncated. They may be unforked (monopodial), but usually they are bifurcate (dicotomously branched) or coralloid (multi-forked). Their color is determined by hyphae in the mantle and ranges through shades of black, brown, gold, red, yellow, and white.

The spate of fungi ready to form mycorrhizae encompasses a broad spectrum of physiological and ecological

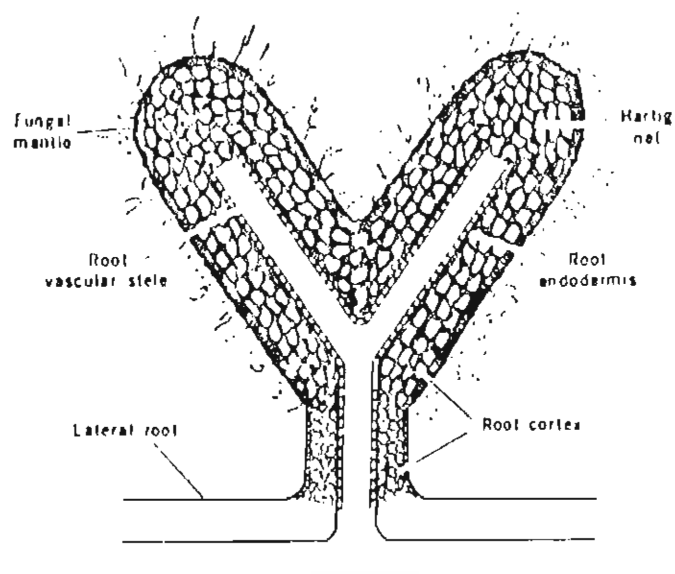

Figure 3. Diagram of typical ectomycorrhiza including the Hartig-net, fungal mantle, and external hyphae. Adapted from Ruehle and Marx (1979).

traits. Specifically, differences among mycobiont species include temperature and moisture responses (Moser, 1958; Hacskaylo et al., 1965; Mexal and Reid, 1973), phosphorus solubilization and uptake (Bowen, 1973; Mejstrik and Krause, 1973), nitrogen utilization (Lundeberg, 1970; Bowen, 1973), production of enzymes, metabolites, and antibiotics (Lindeberg, 1948; Slankis, 1973; Marx, 1970), and resistance of hyphae to decomposition (Meyer, 1970). Mycobiont differences are often expressed in habitat preferences, successional changes in mycobionts with aging of host, and seasonal fluctuations in propensity for mycorrhiza-forming activity by different fungi (Dominik, 1958, 1961; Mikola, 1965; Anderson, 1966).

The potential for functional differences among mycobiont species is magnified by interactions with similarly diverse hosts. Differential growth response of host taxa to various mycobionts has been frequently recorded (Laiho, 1970; Bowen, 1973; Mikola, 1973). Select mycobionts apparently have adapted to certain harsh conditions, such as coal spoil banks in Pennsylvania (Schramm, 1966), and host species in association with these fungi exhibit remarkable vitality, which can be attributed only to mycorrhizae (Moser, 1958; Marx and Bryan, 1971).

Ectomycorrhizal infections are initiated by spores or hyphae of mycobionts invading growing tip areas of host feeder roots. The propagules are stimulated into vegetative growth by exudates from the root, rich in biochemical energy and nutrients. Hyphae quickly shroud root tips forming mantles; then root cortices are invaded and become interlaced with hyphae growing intercellularly. Secreting pectinase, hyphae usually completely dissolve and themselves replace middle lamellae between cortical cells, thus forming Hartig-nets.

Typically ectomycorrhizae exhibit far larger diameters than uninfected rootlets and usually form branches in various patterns dependent on physiological interactions of mycobiont with host (Harley, 1969; Slankis, 1973). However, direct connection with mycobiont hyphae that grow out individually or as fascicled strands or rhizomorphs to soil beyond normal rhizospheres is probably the key operative feature of mycorrhizae. This strategically diffuse distribution of hyphae in upper soil layers functions as extension of root systems to absorb and translocate water and nutrients from solum to host (Mosse, 1959; Harley, 1969; Bowen, 1973). As many as 200 to over 2,000 individual hyphae may emerge from a single mycorrhiza, and each hypha may extend over 2 meters (Trappe, 1962). Thus, mycobiont hyphae dramatically increase absorbing surface of host root systems, but probably more importantly, extended hyphae are well distributed throughout the soil body -- Burgess and Nichols (1961) determined that a single milliliter of soil can contain as much as 4 meters of mycorrhizal hyphae.

Mycobiont hyphae often are capable of functioning more efficiently than plant roots, in many respects, due to better physiological adaptations for substrate exploitation. Fungi may exude auxins, vitamins, cytokinens, enzymes, and other compounds which directly influence root tissue and ion uptake (Miller, 1971; Bowen, 1973; Muira and Hall, 1973; Slankis, 1973). Some net effects of this efficiency include:

1) mycorrhizae are larger and more branched;

2) they live and function longer; and

3) they respire at greater rates than plant roots (Harley, 1969). Root symbionts may be deeply involved in synthesis, transfer and stimulation of growth hormones within host plants, but the degree of such involvement is unknown (Kormanik et al., 1977).

Plant root initiation, growth, and extension are highly consumptive of metabolic energy -- herein may be one of the most beneficial features of mycorrhizae. Mycobiont hyphae more efficiently invade soil, and rootlet longevity is increased by mycorrhizae. Ectomycorrhizae persist and apparently function from several months to as long as 8 years (Orlov, 1968; Harley, 1969).

Ectomycorrhizae exhibit greater respiration rates than plant roots (Harley, 1969; Schweers and Meyer, 1970). Harley (1971) determined that although the ectomycorrhizal mantle comprised only about 4% of the biomass of a 55-year-old pine, it evolved over 25% of CO_2 produced by the entire root system. His figures were exclusive of hyphae which grow away from mycorrhizae into soil; thus, these results may be considered conservative.

Rhizospheres of higher plant roots are markedly altered with formation of mycorrhizae, which produce what has been termed "mycorrhizospheres" (Trappe and Fogel, 1977). Mycobionts readily incorporate host-exuded photosynthates -- Vancura and Hovadik (1965) found that in mycorrhizal plants, root exudates were strikingly impoverished of sugars both quantitatively and qualitatively. Indeed, Marx et al. (1977) found that decreases in exudes of sucrose due to high soil fertility significantly reduce susceptibility of loblolly pine roots to ectomycorrhizal infection.

Mycorrhizospheres may be further characterized by their pathogen-inhibiting nature. Zak (1964, 1965) first postulated that mycorrhizae may act as barriers to invasion of pine roots by pathogenic fungi and aphids. Exudates of a fungal symbiont may stimulate or inhibit microorganisms, including other mycobionts. In a series of studies, Marx and Davey (Marx, 1969a, 1969b, 1973;

Marx and Davey, 1969a, 1969b) found that certain mycobionts protect pine roots against *Phytophthora cinnamoni*, the littleleaf pathogen. Bilan (1970) lists five ways in which mycorrhizal fungi protect roots:

1) They form mechanical barriers against invasion of pathogens.

2) They produce antibiotics that repel or inhibit pathogens.

3) They stimulate self-protective chemical reactions in host roots.

4) They create an environment which is favorable to microbial populations antagonistic to pathogens.

5) They consume root exudates required by pathogens.

No mycobionts are known to be nitrogen fixers. However, studies have shown that nitrogen-fixing organisms are components of and are probably stimulated by mycorrhizospheres (Rambelli, 1973; Silvester and Bennett, 1973). Trappe (1962) has found hyphae of a mycorrhizal fungus encrusted with *Azotobacter* bacteria.

Safir et al. (1971) have demonstrated that mycorrhizal infection increases water transport from soil through roots to host plant leaves. Other experiments indicate that mycorrhizal seedlings resist drought conditions better than nonmycorrhizal ones, for a given host species (Shemakhanova, 1962; Bowen, 1973). Although tolerance of low water potentials between mycobionts varies markedly, all ectomycorrhizal fungi do grow in solutions of much higher osmotic pressure than that which plasmolyzes rootlets of nonmycorrhizal plants (Shemakhanova, 1962; Mexel and Reid, 1973). Simonsberger and Koberg (1967) reported a completely severed spruce shoot kept green and apparently normal for eight months by attached mycorrhizal mycelia solely supplying adequate moisture and nutrients. Such transport of water by mycobiont hyphae well may be important to plants of limited root penetrations, and plants growing on loose, droughty soil but with reachable water tables.

Fungal tissues act as nutrient sinks (Harley, 1969; Stark, 1972). Studies with radiotracers for virtually all essential nutrients confirm mycobiont uptake and translocation of ions to hosts; and the necessity of mycorrhizal association to achieve a thrifty supply of nutrients to plants has been similarly determined (Gerdemann, 1969; Clark, 1969; Harley, 1969; Trappe and Strand, 1969; Gilmore, 1971; Hayman and Mosse, 1972; Daft and Nicolson, 1972; Kleinschmidt and Gerdemann, 1972; Bowen, 1973; Jackson et al., 1973). High respiration rates and diverse enzyme systems of mycobionts indicate strongly active ion uptake (Theordorou, 1968; Harley, 1971; Barlett and Lewis; 1973), but Harley (1978) has questioned some aspects of this inference. Stark (1972) found that sporocarps of mycorrhizal fungi commonly contain substantially greater concentrations of N, P, K, Na, Cu, and Zn than pine needles, on a dry weight basis. Also, fungi act as stores for nutrients to prevent leaching from soil profiles.

Often N, K, Ca, Mg, Fe, Cu, Mn, Na, Si, Zn, Al, and B are present in greater concentrations in mycorrhizal plants than in nonmycorrhizal ones. In other cases, the opposite is true, or no significant difference is encountered (Kormanik et al., 1977). Differential uptake of mineral nutrients, however, is not normally reflected in plant growth (Gray and Gerdemann, 1973). High levels of soluble phosphorus in soil seemingly depress mycorrhizae development, and low levels adversely affect plant growth. Thus, mycorrhizal plants grown in soils with low available phosphorus concentrations show heavy mycorrhizae development and grow much better than those that are nonmycorrhizal (Kormanik et al, 1977).

Studies with radioisotopes of carbon (^{14}C - labeled) have demonstrated that mycobionts acquire photosynthates quite readily from their chlorophyllous host (Melin and Nilsson, 1957; Reid and Woods, 1969; Ho and Trappe, 1973). Mycobionts can utilize photosynthates from hosts in a variety of forms (Vancura and Hovadik, 1965; Slankis et al., 1964). Except for simple carbohydrates and thiamin, it is not known, however, which of these products are essential (Hacskaylo, 1973).

Excluding orchidaceous mycobionts, the great majority of mycorrhizal fungi exhibit little or no saprophytic ability (Gerdemenn, 1968; Harley, 1969). They generally fruit only when in association with a host; and many do not grow at all, even in the most sophisticated culture media, without their host (Gerdemann, 1968; Laiho, 1970; Hacskaylo, 1973).

East Texas Lignite Minesoil

The extensive lignite deposits in Texas were developed by three geologic depositional processes -- fluvial, deltaic, or lagoonal. East Texas lignite occurs as a component facies of ancient fluvial depositions (Kaiser, 1974; Berg, 1980).

Most commercial lignite deposits in East Texas are found as constituent parts of the geological taxum known as the Wilcox group; lignite in Panola County is a fluvial deposit in the Calvert Bluff formation of that group (Kaiser, 1974). This seam, as are many in East Texas, is characterized by a 1-2 meter thick lignite bed overlain by 8-10 meters of unconsolidated, heavily-weathered, often varved silt and clay. This regolith, which is called "overburden", supports a soil mantle which may be typically sandy.

To expose extractable coal, overburden is stripped away to be redeposited in long parallel ridges as is illustrated in Figure 4 . Generally, no attempt is made to stockpile _in situ_ topsoil; these spoil banks represent a structureless agglomeration of substrate, coal partings, soil, and some unweathered rocks. Following removal of lignite, spoil banks are contoured into a gently rolling topography by heavy earth-moving equipment (Figure 5), with primary emphasis on controlling erosion and minimizing stream sediment load. Virtually little or no attention is ascribed to directing placement of spoil bank components in regard to resulting plant growth medium. It is this recontoured spoil bank material that is called "minesoil".

East Texas minesoils generally are clay loams with high concentrations of exchangeable cations, particularly calcium and magnesium, but with low concentrations of nitrogen and phosphorus. Soil reaction (pH) is usually high (pH 5.5 - 7.0) with isolated acid "hotspots" (pH 2.5 - 5.0) resulting from hydrolyzation of sulfates in lignite, most prevalently from bonecoal which is the stratum of lignite stripped from immediately above commercial seams. Minesoil characteristically is high in combustible carbons (2-8%), but this results from included coal partings; humus is effectively diffused to trace

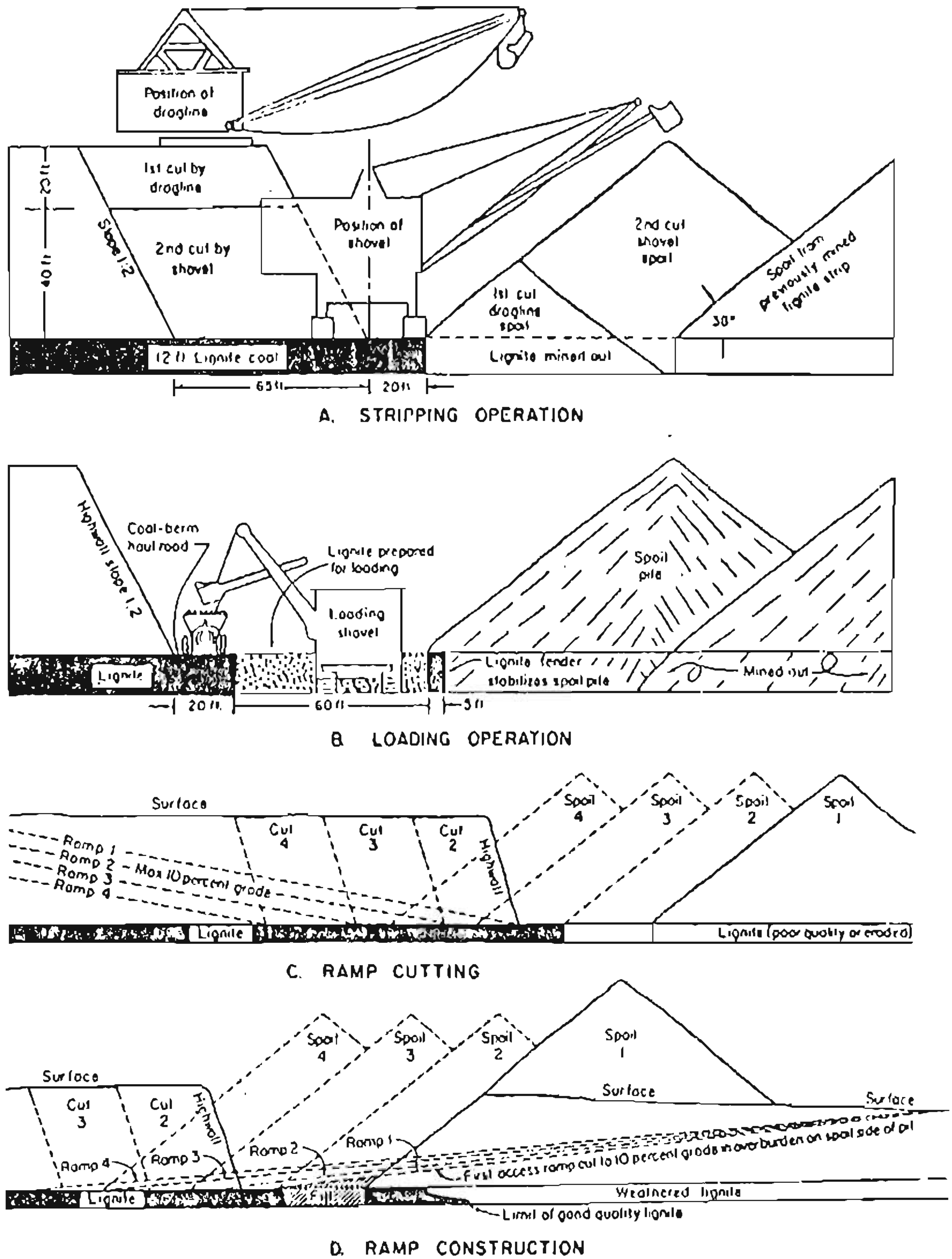

Figure 4. Representative stripping method in open-pit mining of lignite. Modified from Van Sant and Ellman (1959) by Fisher (1965).

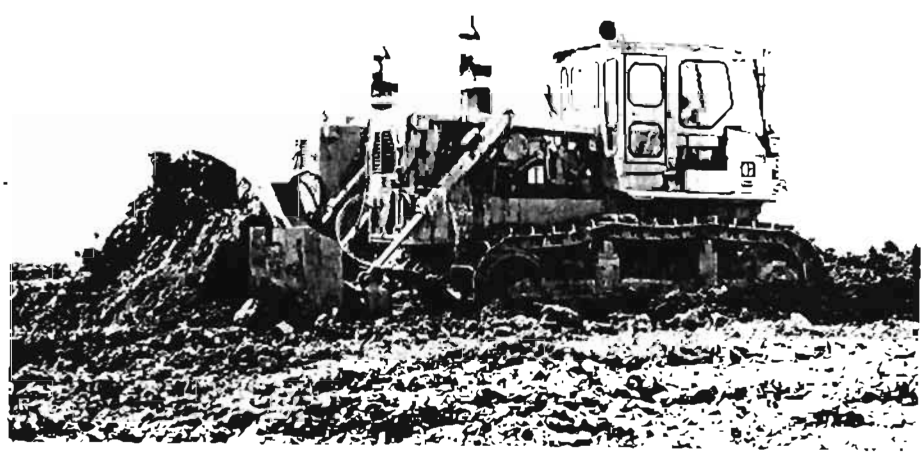

Figure 5. Typical heavy earth-moving equipment used to recontour spoil banks at Martin Lake.

amounts. No micro-nutrient concentrations have been found growth-limiting, and no chemical toxicities have been clearly demonstrated (Angel, 1973; Bryson, 1973; Cook, 1977).

STUDY OBJECTIVES

I. To compare performances of containerized shortleaf pine seedlings which have received one of three types of fungal inoculation treatments with *P. tinctorius*.

   A. Seedling inoculation treatments included the following:

      1. Cultured vegetative mycelia in vermiculite medium.

      2. Basidiospores carried in a vermiculite medium.

      3. Direct seedcoat inoculation with basidiospores.

      4. Control (no inoculation treatment).

   B. Seedling performance parameters monitored after eight-month's growth by the following:

      1. Quantification of mycorrhizal infections on treatments by total root system counts of ectomycorrhizal short roots.

      2. Ultrastructural examination of fixed ectomycorrhizal short roots from the containerized cultured mycelia treatment by light and transmission electron microscopy, to characterize the nature of shortleaf pine/*P.*

tinctorius mycorrhizae.

3. Growth measurements.
    a. Survival.
    b. Total height.
    c. Root collar diameter.
4. Biomass accumulation determinations.
    a. Root gram dry weight.
    b. Shoot gram dry weight.
    c. Total gram dry weight.
    d. Root/shoot ratio.
5. Root measurements.
    a. Total root system displacement volume.
    b. Root measurements and counts by orders.
6. Foliage chemical analyses.
7. Lateral roots chemical analyses.

II. To ascertain seedling performance parameters for 1-0 nursery-grown bare-root shortleaf pine seedlings as follows:

A. Total root system counts of ectomycorrhizal short roots.

B. Biomass accumulation determinations.
1. Root gram dry weight.
2. Shoot gram dry weight.
3. Total gram dry weight.
4. Root/shoot ratio.

C. Root measurements.

1. Total root system displacement volume.

2. Root measurements and counts by orders.

D. Foliage chemical analyses.

E. Lateral roots chemical analyses.

III. To analyze soil chemical and physical properties for field plots at the Martin Lake lignite strip-mine in Panola County, Texas, and for soil used in containers.

IV. To compare performance of shortleaf pine seedlings which have been inoculated with _P. tinctorius_ and planted on mined and unmined plots at the Martin Lake stripmine.

A. Seedling inoculation treatments included the following:

1. Containerized seedlings inoculated as outlined in I.A.

2. Nursery-grown 1-0 bare-root seedlings root inoculated with the following:

a. Cultured vegetative mycelia in vermiculite medium.

b. Basidiospores carried in a vermiculite medium.

c. Control (no inoculation treatment).

B. Seedling performance parameters monitored for first growing season by the following:

1. Growth measurements.
    a. Survival.
    b. Total height.
    c. Root collar diameter.
2. Foliar analyses.

LITERATURE REVIEW

Mikola (1969) demonstrated that at the time of tree planting a parallel introduction of mycorrhizal symbionts is essential if afforestation of a site (particularly with Pinus species) is to succeed. However, there are many areas of the world where tree species and their symbiotic fungi do not occur naturally together, or a suitable vector is not available to deliver mycobionts to hosts. Reports of forestation attempts that were either near or total failures until ectomycorrhizal infection occurred on tree roots include: the high Andes of Peru (Marx, 1976), Puerto Rico (Vozzo and Hacskaylo, 1971), Africa (Gibson, 1963), Australia (Bowen et al., 1973), Asia (Oliveros, 1932), subalpine areas of Austria (Moser, 1963), former agricultural soils of Poland (Dominik, 1961), oak shelterbelts in the steppes of Russia (Imshenetskii, 1967), and former treeless areas of the United States (Hatch, 1937). In all cases the remedy proved to be inducement of symbiotic root infection either by introducing pure cultures of mycobionts, or soil containing ectomycorrhizal fungi, or by manipulating soil containing low levels of indigenous symbiotic fungi to encourage ectomycorrhizal development. An interesting note -- failure in afforestation with normally endomycorrhizal trees due to a deficiency of appropriate mycobionts has not been reported (Marx, 1975).

Only limited research has been conducted to determine what microorganisms are present in fresh coal spoils and how, and at what rate they increase. Fungi, bacteria, and other microorganisms which are necessary for nitrification or accumulation of nitrates, nitrogen fixation by symbiotic (leguminous) and nonsymbiotic bacteria, and mycorrhizal relationships are presumed low or completely lacking in recently mined soils (Grandt and Lang, 1958). Marx (1975) states that "the surface material (of coal spoil banks) is nearly a biological desert in comparison to the biological status of the original profile." Vimmstedt (1969), in contrast, reported that readily-dispersed organisms in stripmine spoil, such as bacteria, fungi, and arthropods, do re-establish themselves soon after a source of food (organic matter) is provided.

Wherever natural or artificially seeded pines on coal spoils has resulted in successful seedling establishment, those seedlings invariably have been found to be mycorrhizal when examined (Schramm, 1966). Harley (1969) reported that sources of mycorrhizal infections are not carried in tissues of host embryos and that propagules are not commonly found on the seedcoat. Spores or other propagules vectored by water, air currents, animals, etc. have been found by Robertson (1954) to be the probable inoculants on mine spoils.

Virtually no soil mass is as unstable and as vulnerable to incontrovertible geomorphic processes as fresh mine spoils. Minesoil surfaces quickly succumb to the slightest erosive actions of wind or water -- the results are massive stream sedimentation, hugh land slumps, cavernous gulleys, rills, valleys and hammocks. Contouring spoil banks to a gently rolling topography, allowing for controlled runoff, mediates some of these effects, but rapid establishment of vegetative cover is essential for arresting most erosion processes; and establishment of a closed forest canopy amounts to complete stabilization of sites. Unfortunately, indications are that the dynamics of natural vectoring systems for ectomycorrhizal mycobionts probably operate too slowly and inefficiently to cope with immediate needs for plant establishment necessary on fragile newly-placed minesoils.

A study conducted by Ponder (1979) with black walnut (Juglans nigra L.) indicated that grading coal spoil banks to approximate original contours of the land operated to introduce endomycorrhizal fungi to the site. However, no such results have been reported for any ectomycorrhizal mycobionts.

The most incisive work conducted to date relating mycotrophy to stripmine revegetation was reported in a classic paper by Schramm (1966). He concluded in his studies of plant colonization on anthracite spoils in Pennsylvania that early ectomycorrhizal development was essential for seedling establishment of *Betula lenta* L., *B. populifolia* Marsh, *Pinus rigida* Mill., *Populus tremuloides* Michx., *Quercus rubra* L., and *Q. velutina* Lam. Schramm suggested and offered strong evidence for the argument that evergreen species (pine) should be utilized for revegetation of coal spoils. He also noted that the majority of surviving seedlings, and especially those growing well, were heavily ectomycorrhizal; seedlings, which were either naturally or artificially seeded, that did not have ectomycorrhizae were chlorotic and soon died.

Schramm (1966) found on *Pinus* that the principle ectomycorrhizal mycobiont was *Pisolithus tinctorius*. He carefully traced mycelial strands of *P. tinctorius* from ectomycorrhizal hosts as far as 5 meters through large spoil waste volumes to bases of basidiocarps. This was possible because mycelial strands were unique in their brilliant gold-yellow color and large size. Ectomycorrhizae formed by *P. tinctorius* also were yellow-gold in color and prolifically branched.

Schramm (1966) further reported that most vigorously growing seedlings had formed ectomycorrhizae with *P. tinctorius*; and in most cases it was the first fungal symbiont on seedling roots. Other species of ectomycorrhizal fungi infected tree roots and produced basidiocarps usually only after litter had accumulated under seedling canopies.

Shramm's work strongly inferred that only a few ectomycorrhizal fungi, but principally *P. tinctorius*, are capable of ecologically adapting to soil conditions on anthracite wastes. Prompted by these results, Marx (1975) made observations and found *P. tinctorius* basidiocarps and its unique, gold-yellow ectomycorrhizae and mycelial strands to be the predominant, if not the only, mycobiont infecting roots of *Pinus virginiana* Mill., *P. taeda* L., *P. resinosa* Ait., and several *Betula* species on coal spoils in Indiana, Pennsylvania, Ohio, Virginia, West Virginia, Kentucky, Tennessee, and Alabama, as well as *Pinus echinata* and *P. taeda* L. on strip-mined kaolin wastes in Georgia. Parenthetically, Marx (1975) found over 3,000 *P. tinctorius* basidiocarps under planted loblolly pine in an area of less than ½ acre in Fabius, Alabama. *Pisolithus tinctorius* has also been reported on coal spoils in West Germany associated with *Betula*, *Populus*, and *Salix* (Meyer, 1968); in Missouri on *Pinus banksiana* Lamb. (Lampky and Peterson, 1963); and in Indiana and Tennessee associated with various

Pinus species (Hile and Hennen, 1969).[2]

Based on Schramm's observations and these other reports, the premise seems well established that certain species of ectomycorrhizal fungi are more beneficial to tree seedling growth than others, especially under certain harsh conditions. Also, it appears that *P. tinctorius* may be more beneficial to establishment of *Pinus* species on coal minesoils than other ectomycorrhizal fungi. Furthermore, nursery-grown pine seedlings planted on adverse sites, such as stripmine spoils, may die or remain stunted for many years because fungal mycorrhizal symbionts common to nurseries are not adapted to harsh conditions experienced on transplant sites (Marx and Bryan, 1970, 1975).

Some of the earliest work done to "synthesize" a specific mycobiont/host ectomycorrhiza was performed by Bryan and Zak (1961). Shortleaf pine seedlings were inoculated with *P. tinctorius* in aseptic culture -- it was confirmed that *P. tinctorius* had successfully, and efficiently produced the desired ectomycorrhiza.

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[2] *Pisolithus tinctorius* has been confirmed to occur naturally in 33 countries of the world and in 38 states in United States. It has been found associated with various tree species in nurseries, urban areas, orchards, and forests, in addition to stripmine spoils. Experiments have proved it can form ectomycorrhizae on 30 species of *Pinus* including *P. echinata*; it has been reported occurring naturally on nine additional species of *Pinus* (Marx, 1977).

Such successes, coupled with a desire to appropriate the many advantages associated with _P. tinctorius_ ectomycorrhizae, led to research to develop methods to "tailor" pine seedlings with _P. tinctorius_ mycorrhizae for planting on coal minesoil and other sites. This necessitated development of practical, and inexpensive inoculation techniques.

Trappe (1977) has outlined the possible methods for host inoculation with a specific mycobiont:

1) Spontaneous inoculation - In some areas seedlings may be naturally inoculated by mycelia or spores vectored by soil, wind, water, or any of several types of biota.

2). Soil humus - Introducing propagule-bearing humus from area known to harbor the mycobiont has been employed successfully around the world.

3) Mycorrhizal seedlings and roots - Mycobionts have been introduced successfully by transplanting mycorrhizal seedlings, and by incorporating freshly excised mycorrhizal root systems.

4) Fungal sporocarps, spores, and sclerotia - Although direct applications of basidiospores of a few ectomycorrhizal fungi have proved to be effective inoculum, for reasons yet unknown, attempts with other species have failed to produce mycorrhizae.

5) Pure mycelial cultures - Techniques for inoculation

with pure cultures of selected mycobionts have been developed, but it is a common experience of mycorrhiza researchers all over the world that many mycorrhizal fungi grow poorly or not at all in pure-culture methods tried so far.

Research to develop techniques for tailoring tree seedlings with mycorrhizae formed by P. tinctorius and other mycobionts has been spearheaded by Dr. Donald H. Marx and his coworkers at the U.S. Forest Service Institute for Mycorrhizal Research and Development in Athens, Georgia. Inoculation procedures utilized in the present study were essentially adaptations of techniques developed and reported by that Institute's workers.

Marx (1970) found that P. tinctorius could be cultured practically, in volume, and mycelia used successfully to infect Pinus species with ectomycorrhizae. Fungal inocula were 4-month-old cultures grown at 25°C in 1-liter volumes of vermiculite-peatmoss substrate at pH 5.5, moistened with 500 mℓ of modified Melin-Norkrans (MMN) liquid medium. Experiments were conducted in a plant-growth room which had been fumigated and sterility checked; the room was electronically air-conditioned and filtered. P. tinctorius formed typical ectomycorrhizae and produced basidiocarps with 14 of 18 Pinus species tested, including shortleaf pine.

Marx (1975) also demonstrated that direct application of *P. tinctorius* basidiospores resulted in desired ectomycorrhizae on *Pinus* roots. Basidiospores were obtained from mature basidiocarps (those with exposed, dry spores). Spores were separated from fruiting bodies by crushing basidiocarps on a 0.84 mm mesh screen in a closed plastic bag. Quantities of spores were determined with a haemocytometer; there were approximately 1.1 billion basidiospores per gram. Spores were mixed with distilled water 10g/500cc) and washed into soil around 2-month-old loblolly pine seedlings growing in plots which had been fumigated with methyl bromide. Ectomycorrhizal development from basidiospores of *P. tinctorius* was sporadic and first detected about six weeks after soil infestation.

Marx and his coworkers (1979) have reported some special considerations associated with use of *P. tinctorius* basidiospores:

1) Basidiospore collections are often contaminated with other microorganisms (yeasts, bacteria, and fungi) and insects.

2) Viability of basidiospores cannot be easily determined; the only reliable means is to form ectomycorrhizae with them.

3) Basidiospores are not as effective as vegetative inoculum in forming ectomycorrhizae on pine seedlings.

4) Basidiospores rarely form ectomycorrhizae on all seedlings in inoculated soil,and, with few exceptions, the overall development of ectomycorrhizae on seedlings at the end of the growing season is less than that formed by vegetative inoculum.

5) With minimum competition, such as on fresh coal minesoil, basidiospores very effectively form ectomycorrhizae and stimulate seedling growth (Marx et al., 1978).

Inoculations with P. tinctorius mycelia and basidiosproes on a variety of host species have been field tested on multifarious sites, often with near panacean effectiveness. Production of nursery stock pine seedlings tailored with P. tinctorius ectomycorrhizae has become quasi-operational in many sections of the country (Marx et al., 1976; Marx et al., 1978; Marx and Artman, 1978). Survival and growth of outplantings of these inoculated seedlings, on even extremely severe sites caused by erosion and disturbance, has often been phenominal (Berry and Marx, 1978; Marx et., 1977).

Revegetation of coal minesoils with pine seedlings inoculated with P. tinctorius has shown great promise. Rice and his coworkers (1979) found that mycelial inoculations in the field on one-year-old loblolly pine seedlings planted on minesoils in Kentucky survived and grew better than nursery-inoculated plants. Survival of field-inoculated trees was also significantly better than non-inoculated controls. No differences among treatments with respect to foliar concentrations of N, P, K, Fe, and Mn were observed -- levels of Ca and Mg were higher in nursery-inoculated seedlings. Importantly, overwinter survival of nursery inoculated seedlings was extremely poor compared with controls.

In a six year study on bituminous stripmine spoils in Pennsylvania, Medve and his coworkers (1977) used mascerated roots containing P. tinctorius to inoculate Pinus species. A significant increase in treatment growth was registered, with no significant difference in survival. The Pinus species had 90-100% mycorrhizal roots. An interesting note -- almost 60% of the volunteer woody plants invading study plots were found in subplots inoculated with mascerated roots.

Marx and Artman (1979) found that nursery-grown seedlings of loblolly pine and shortleaf pine with ectomycorrhizae formed by P. tinctorius survived and grew significantly better than seedlings with Thelephora terrestris, a mycobiont common in Southeastern tree nursery beds, after three years on an acid coal spoil in Kentucky and four years on an acid coal spoil in Virginia. Seedlings with P. tinctorius ectomycorrhizae on the Kentucky mine had significantly higher concentrations of foliar N and lower

S, Fe, Mn, and Al. Susceptibility to winter injury on both spoils was less on seedlings with *P. tinctorius* fungal symbiont. The ability of *P. tinctorius* to persist and spread to new roots stimulated seedling growth on these acid spoils and lack of persistence and spread of *T. terrestris* accounted for poor seedling survival and growth.

In addition to usual problems associated with tree seedling planting, coal minesoils in East Texas invariably have adverse physical characteristics, detrimental chemical peculiarities, lack of organic matter, and periodic droughty conditions. Davidson and Sowa (1974a; 1974b) have demonstrated that many of these detriments may be circumvented, ameliorated or eliminated on coal minesoils by planting container-grown seedlings rather than bare-root seedlings. Balmer (1974) and Mann (1977) have pointed out that although per unit cost of containerized seedlings is higher compared with nursery-grown planting stock, containerized seedlings survive and grow better initially, thus expensive seed is used more efficiently; also planting is safer and less expensive; better use can be made of fertilizers and pesticides; and the planting season is greatly extended. An excellent review of the "state of the art" for growing containerized southern pines has been prepared by Barnett (1974) in which he affirms that, although not a panacea, containerized seedlings offer the best available solutions to problems of forestation of difficult sites.

Certain practices often used in growing container stock, such as artificially-maintained high levels of certain soil nutrients, and utilization of sterile soil media can effectively discourage ectomycorrhizae development on tree seedling roots; and this can be responsible for increasing transplanting shock, especially under adverse field conditions (Marx and Barnett, 1974). Unfortunately, only limited published information is available on ectomycorrhizae development on containerized seedlings. Hartigan (1969) reported that mycobiont inoculation of Monterrey pine grown in polyurethane foam greatly increased seedling growth in a greenhouse. Such inoculation was deemed necessary because seedlings were to be outplanted in Australian soils devoid of indigenous fungal symbionts.

Marx and Barnett (1974) infested three different types of planting media in containers (3 X 15 cm Japanese Paperpots) with various application rates of mycelia or basidiospores of P. tinctorius before planting loblolly pine seeds. The best ectomycorrhizae development was achieved with mycelial inoculation in a soil medium having low fertility -- the type of soil mixture and its fertility strongly affected ectomycorrhizae development.

In considering cultural treatments applied to containerized seedlings, one cannot overlook the important role that phosphorus nutrition plays in production of quality seedlings with good mycorrhizae development. Heilman and Ekuan (1980) have confirmed that phosphorus deficiency is a cause of poor growth and poor mycorrhizae formation in greenhouse-grown containerized seedlings. They also showed that pH balance must be maintained to prevent acid conditions and fixation of phosphorus in the soil medium.

PROCEDURES, MATERIALS, AND STUDY AREA

Cultured Mycelial Inoculant

Preparation of mass cultures of *P. tinctorius* vegetative inoculum began in early October, 1977. Basically this process involved the following steps:

1) location and harvesting of an East Texas source of fresh, uncontaminated *P. tinctorius* hyphae;

2) preparation of pure cultures of fungus on petri plates; and

3) initiating mass cultures with pure samples of petri cultures.

Initially, a single fresh "green" basidiocarp of *P. tinctorius* was collected adjacent to a 20-year-old slash pine (*Pinus elliotti* Engelm.) plantation in Houston County, Texas. The basidiocarp was newly-formed; the periderm was intact, and no insect or disease damage was visible which would compromise the integrity of this sporophore. The entire fruiting body was pliant and not dry. This sample was collected in a polyethylene bag to guard its high moisture content, and it was temporarily stored in the bag at 5°C in darkness.

It is interesting to note how growth habits of sporocarps of *P. tinctorius* located in Houston County reflect ecological preferences of this mycobiont species. Several fruiting bodies were found growing on the southwest side of the pine plantation in sandy soil which recently had been plowed deeply to near the plantation boundary. Sporophores were found exclusively in an area three to seven meters from the plantation margin and only in fresh tillage with no competing vegetation; no fruiting bodies could be found in the forest stand itself (Figure 6). This growth habit suggests that P. tinctorius can adapt to dry, sterile soils (deep sand), yet it probably competes poorly with other fungi, including other mycobionts.

Preparation of petri cultures began with sterilization of 9mm petri dishes in a forced-air oven at 160°C for 12 hours. An enriched Melin-Norkrans' (Norkrans, 1949) nutrient solution (MN nutrient solution) was used for growing the fungus. In the formulation, glucose was substituted for sucrose and the modified nutrient solution was referred to as MMN (Marx, 1969a):

Ingredient	MN Nutrient Solution	MMN Medium
$Ca\ Cl_2$	0.05g	0.05g
$Na\ Cl$	0.025g	0.025g
$KH_2\ PO_4$	0.5g	0.5g
$(NH_4)_2\ HPO_4$	0.25g	0.25g
$Mg\ SO_4 \cdot 7H_2O$	0.15g	0.15g
$Fe\ Cl_3$ (1%)	1.2 ml	1.2 ml
Thiamine HCl	25 μg	100 μg
Malt extract		3g
Glucose	2.5 g	10g
Bacto-agar (optional)		15g
Distilled water	to 1,000 ml	to 1,000 ml.

Figure 6a. Basidiocarp of P. <u>tinctorius</u> growing near a 20-year-old slash pine plantation in Houston County, Texas.

Figure 6b. P. <u>tinctorius</u> basidiocarps growing in deeply plowed sand adjacent to the plantation.

Of course, this formulation may be prepared as either a liquid or agar medium by adding or not adding bacto-agar. Nutrient salts were dried in a vacuum oven at 55^{o}C for 12 hours before weighing. After autoclaving for 30 minutes at 121^{o}C, reaction of both agar and liquid formulations was pH 6.2-6.4. Approximately 30 ml of MMN agar medium was used for each petri culture.

To initiate petri cultures of P. tinctorius, the basidiocarp first was washed with tap water, then surface-sterilized with a chlorine solution (household bleach/distilled water 1:1 v/v). The fruiting body was carefully dissected to reveal peridioles in the soma of the gleba. A single peridiole was extracted at a time and placed at the center of a petri agar plate. Petri cultures were then incubated for 30 days at 23^{o}C in darkness. Only 9 of 55 cultures were not successfully inoculated in this fashion, and no contamination of any culture was noted.[3]

All inoculation work was performed under completely sterile conditions utilizing a filtered, positive air pressure transfer hood, and an ultraviolet lamp. An open petri

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[3] Efforts to initiate pure petri plates of P. tinctorius using mature basidiospores were never successful. Such attempts produced highly contaminated cultures with no clearly distinguishable colonies of pure P. tinctorius.

plate was allowed to stand under the hood throughout inoculation procedures -- no contamination was noted on this plate after 30 days of incubation.

After 30 days most petri agar plates were covered with a cinnamon-brown bloom of fungal hyphae (Figure 7a). Nominally about 20 days are required for colonies to grow to the edge of petri plates.

Mass mycelial inoculum containers were Kerr 2-quart wide-mouth, self-sealing canning jars with lids modified to allow some gas transfer but no microbial or other contamination. Lid sealing disks were drilled at the center to allow a Retco KF-04-04 PS hydraulic coupling to be fitted. General Electric (GE) Hi-Temp Instant Gasket, a silicon-based liquid sealing compound, was used to seal hydraulic fittings to jar lid disks. A length of approximately 8 cm of Tygon tubing (7 mm I.D.) was placed over each hydraulic fitting, and the open end was plugged to a depth of about 4 cm with sterile cotton.

The growth medium for each mass mycelial inoculum system was 1450 cc dry grade 2 vermiculite mixed with 50 cc finely divided peat moss, and 750 mℓ liquid MMN nutrient solution. Each complete system was autoclaved for 30 minutes.

Under sterile conditions, each mass culture system was inoculated with 10 disks (8 mm dia.) of mycelium agar cut from one petri culture. The disks were cut from edges of

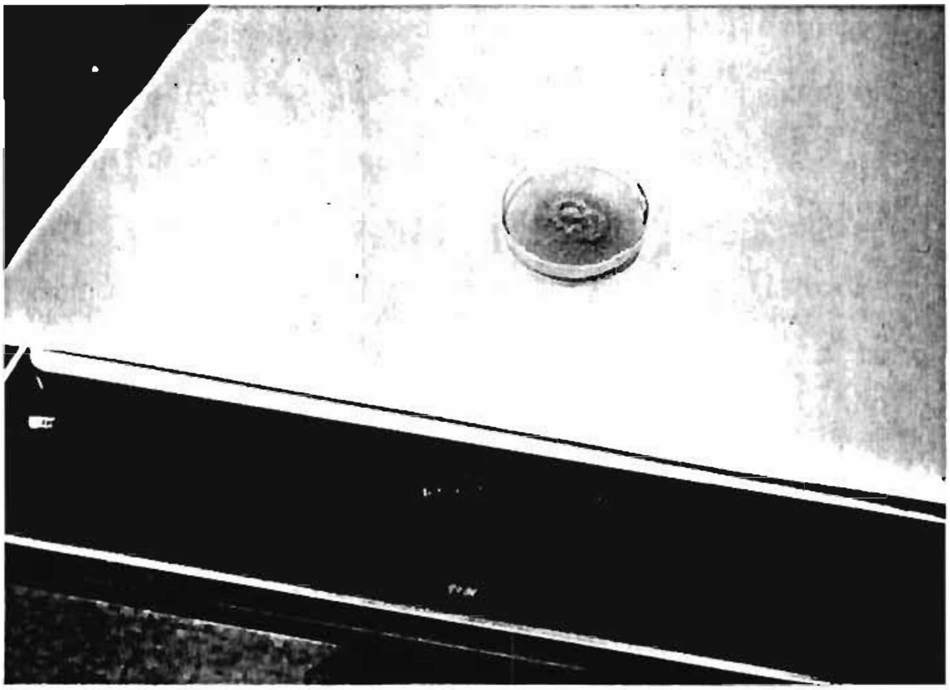

Figure 7a. P. tinctorius hyphae growing on petri cultures of MMN agar, 30 days after inoculation with a peridiole.

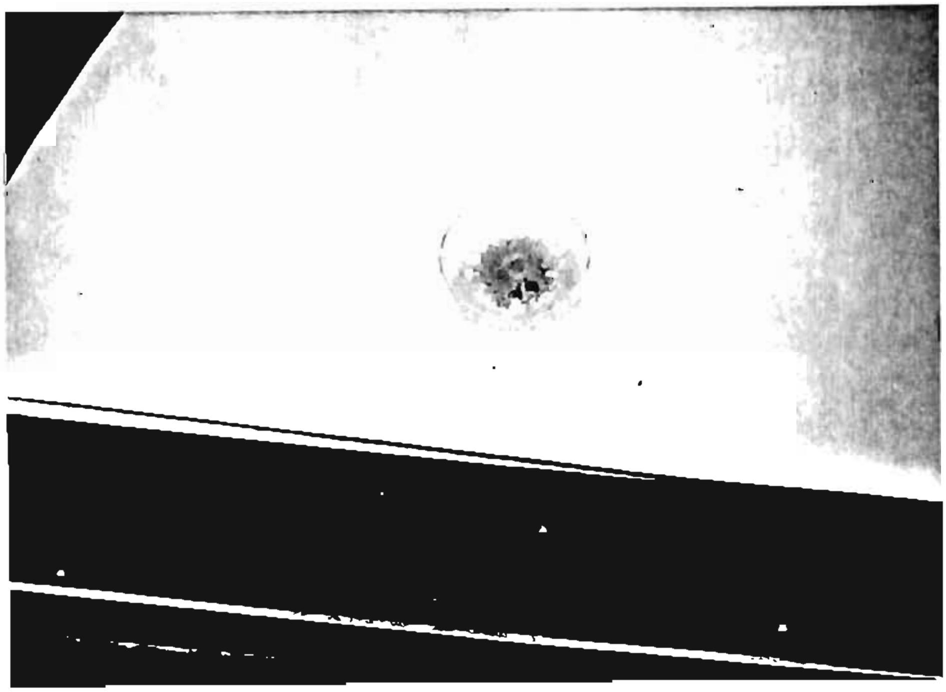

Figure 7b. Petri agars of P. tinctorius with 8 mm discs removed to inoculate mass cultures.

petri plates where hyphae were considered most actively growing (Figure 7b). Container lids were tightly sealed, and a polyethylene bag was placed over tops of containers and firmly secured with elastic bands (Figure 8a). Thirty-two containers of mass culture were prepared in this fashion. Also, mycelial discs, 8 mm in diameter, were removed from petri cultures and stored on MMN agar plants in sealed test tubes at 5^{o}C (see Marx and Daniel, 1976) -- these isolates were used to inoculate subsequent systems of mass cultures.

The mass cultures of P. *tinctorius* were grown in an incubation chamber in darkness, at 25^{o}C, for 5 months (Figure 8b). Following this period, distinctive mycelia of P. *tinctorius* permeated the complete volume of cultures. Microscopic examination comfirmed that individual particles of vermiculite were permeated with hyphae. No contamination was found in any incubated containers.

To prepare mass inoculum for use, the mycelium, vermiculite/peatmoss system was removed from jars, passed through a 5 mm mesh screen, and held with two layers of cheesecloth while being leached with approximately 8 liters of cool running tap water. Excess water was removed by squeezing. Leached inoculum was placed in plastic bags and refrigerated at 5^{o}C for 24 hours until used. Marx (1975)

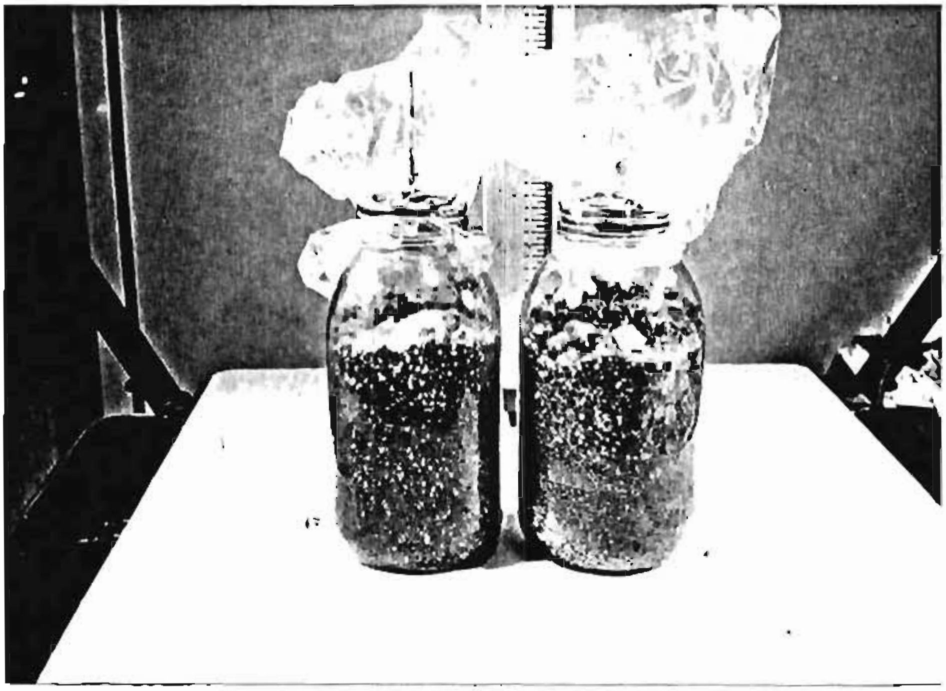

Figure 8a. System for mass culturing P. tinctorius vegetative inoculum.

Figure 8b. Mass inoculum systems under incubation.

reported that tests had indicated that nonassimilated nutrients must be leached from inoculum. When nonleached inoculum was added to fumigated soil, saprophytic microorganisms, which naturally colonize soil, reproduced rapidly and significantly increased damping-off of seed as well as reduced inoculum potential of the fungal symbiont.

Basidiospores

Basidiospores of P. tinctorius were obtained from mature sporocarps (those with exposed, dry spores) collected in mid-October, 1977, from the area in Houston County, Texas, described above. Ten mature basidiocarps 8 to 15 cm in diameter were harvested from a 10 m^2 area (Figure 9).

Spores were removed by crushing basidiocarps on a 2 mm mesh screen over a soil pan. Remnants of basidiocarps retained on the screen were discarded. Well over 35 g (fresh weight) of basidiospores were collected from 10 sporocarps. Spores were stored dry in small plastic film storage bags, over a dessicant in large sealed jars (Figure 10). The jars were kept in darkness at $5^{\circ}C$.

Containerized Seedlings

Styroblock-8[R] containers were used. Each block contained 80 planting cavities 15.2 cm deep with top diameters of 3.9 cm (volume 130 cm^3). Each cavity had 3 large side ribs interspaced with 3 small ribs to provide some control

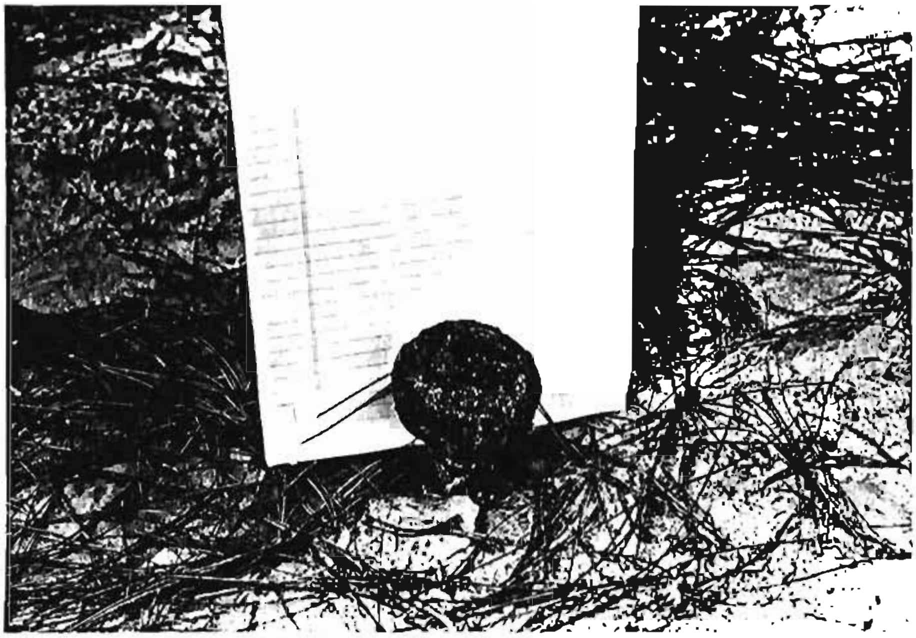

Figure 9a. Mature basidiocarp of P. tinctorius.

Figure 9b. Mature basidiocarps of P. tinctorius -- note differences in growth forms.

Figure 10. Basidiospore storage in heavy plastic bags, over a dessicant, and in a closed jar -- note heavy mesh screen used for spore extraction.

over root-binding. A large bottom hole (dia. 1.1 cm) provided drainage for each cavity. Planting medium was easily sloughed through this drain hole, and it probably should have been plugged somewhat with small pieces of aspen excelsior -- the drain holes were not plugged in this study.

The basic growing medium used in the styroblock containers was triple-steamed sandy loam soil obtained from an undisturbed area on the Martin Lake mine in Panola County, Texas. That area was mapped as a Bowie fine sandy loam by the Soil Conservation Service (1975). A complete sample analysis of this soil is given in Appendix Tables 1 and 2.

Shortleaf pine seeds were prepared first by stratification in a moist peatmoss/burlap medium at 0-5°C for 60 days. Seeds then were soaked in 1% H_2O_2 for 20 minutes, and temporarily stored at 5°C in distilled, sterile (boiled) water until planted. Floating seeds were discarded.

Treatment groups for the containerized seedlings aspect of this study included the following:

1) Soil medium inoculated with *P. tinctorius* cultured vegetative mycelia;

2) Soil medium inoculated with *P. tinctorius* basidiospores carried in vermiculite;

3) Direct seedcoat inoculation with *P. tinctorius* basidiospores; and

4) Controls (no inoculation treatment).

<u>Containerized cultured mycelial inoculation</u>. Five styroblocks, each with 80 planting cavities (400 total planting spaces), were filled with soil medium mixed 2:1 v/v with *P. tinctorius* cultured mycelial inoculum (see Marx and Barnett, 1974; Ruehle and Marx, 1977). Three shortleaf pine seeds were planted in each planting space.

<u>Containerized basidiospore/vermiculite inoculation</u>. Five styroblocks were filled with soil medium mixed 2:1 v/v with dampened vermiculite to which *P. tinctorius* basidiospores had been added at the rate of 10g (11 billion spores) per 30ℓ of dry vermiculite (see Marx, 1976a). Three seeds were planted in each planting space.

<u>Containerized seedcoat basidiospore inoculation</u>. Five styroblocks were filled with soil medium mixed 2:1 v/v with vermiculite. Then 40g of seed (approx. 3,800) were taken from the sterile water soak, blotted on a paper towel, and placed in a plastic bag, to which was added 2.5g (2.75 billion) *P. tinctorius* basidiospores. The bag was shaken until all the seeds were thoroughly coated with spores (see Theodorou, 1971; Theodorou and Bowen, 1973). Three of these seeds were planted in each planting space.

<u>Containerized control</u>. Five styroblocks were filled with soil medium mixed 2:1 v/v with vermiculite. Three seeds (<u>not</u> dusted with spores) were planted in each planting space.

All styroblocks (20 replicates) were planted on June 1, 1978. The styroblocks were placed in a greenhouse on the campus of Stephen F. Austin State University (SFASU), Nacogdoches, Texas. They were positioned in a randomized block design to minimize possible effects that a variable greenhouse environment might have on the experiment (four treatment groups: five statistical blocks).

After germination, seedlings were thinned to one per planting space in each styroblock. Seedlings were sprinkled with distilled water as was deemed necessary to maintain the moisture content in the growing medium at or near field capacity. Approximately 30 ml of a commercially available water-soluble N-P-K fertilizer (23:19:17), diluted in distilled water to 2,500 ppm, were added to each cavity 3 weeks after seed germination and every 3 weeks thereafter. Also 6 weeks after germination a soluble-iron (chelated iron 10%)/micronutrient solution was added to each cavity in one application. Pesticides were added as appeared necessary.

The seedlings remained under greenhouse regime for 5 months until November 1, 1978. At that time, all styroblocks were moved to a screenhouse on the SFASU campus for a period of winter hardening-off. The styroblocks were positioned in the screenhouse in the same randomized-block arrangement used in the greenhouse.

To reduce the possibility of root freezing, styroblocks in the screenhouse were placed in an insulating bed of triple-steamed pine bark. To assist in maximizing the hardening-off process, the rate of watering was reduced approximately 50%, and fertilizer treatments were terminated. No pesticide treatments were necessary during the screenhouse phase. However, clear plastic mulch material was tacked around three-fourths of the screenhouse perimeter to reduce the severe dessicating effects of winter winds -- it was suspected that this dessication rate was a function of the relatively small soil volume contained in styroblock cavities. The seedlings remained under screenhouse régime until late February, 1979 (4 months) -- at that time they were 8 months old.

At the conclusion of the screenhouse phase, total height and root collar diameter of each live seedling were measured, and survival percentage for each styroblock was noted (Appendix Table 3). Total height was measured throughout this study by pulling firmly on the shortleaf pine seedling, which is often characterized by a "crook" above and/or below the root collar, and measuring vertically from root collar to tip of terminal bud. Root collar diameters were measured in thousandths of an inch with a micrometer caliper and converted to millimeters.

Ten seedlings were selected randomly from each treatment group. The soil medium was carefully dissolved from each plant root system in a stream of tap water. For these seedlings the following parameters were measured and recorded (Appendix Table 4):

1) Total count of ectomycorrhizal short roots per primary lateral root,

2) Total volume of root system by water displacement,

3) Total top height,

4) Total main root length,

5) Position and length of primary lateral roots, and

6) Length of secondary lateral roots.

Ectomycorrhizal short roots were identified with the aid of a 10X hand lens using techniques described by Anderson and Crodell (1979). Considering that each seedling was grown in an approximately equal volume of soil in styroblocks, total ectomycorrhizal short root count was considered the best comparative measure of ectotrophy development. Additionally, samples of ectomycorrhizal short roots having typical bifurcate, cinnamon-brown morphology of P. tinctorius were collected from 10 seedlings which represented the cultured mycelial inoculation treatment. These ectomycorrhizal short roots were prepared for ultrastructural examination.

From among remaining seedlings in each styroblock, ten were selected randomly. Soil medium again was carefully dissolved from each plant root system in a stream of tap water. Root systems were excised from stems at the root collar, and tops and roots were placed in a drying oven for 48 hours at $60^{o}C$. Gram dry weight of roots and shoots were measured separately, and seedling total gram dry weight and root/shoot ratio were calculated (Appendix Table 5). Oven-dried foliage and lateral roots of each of these 200 containerized seedlings were analyzed chemically (Appendix Tables 6 and 7).

Nursery-grown Seedlings

In November, 1978, 1-0 bare-root nursery-grown shortleaf pine seedlings were obtained from the U.S. Forest Service. Seedlings had been grown from an East Texas seed source. They were carefully bundled with kaolin clay to retard root drying, and had been stored under refrigeration since lifting. In grading seedlings to uniform size and quality, it was surmised that they had been exceptionally well handled by the Forest Service. Graded seedlings were heeled-in at a nursery on the SFASU campus until planting.

Ten nursery-grown seedlings were selected randomly, and the six root measurement parameters listed above for containerized seedlings were recorded for these bare-root plants (Appendix Table 8).

Fifty additional nursery-grown seedlings were selected randomly. Gram dry weights of roots and shoots were determined as described above for containerized seedlings (Appendix Table 9). Oven-dried foliage and lateral roots were chemically analyzed (Appendix Tables 10 and 11).

Treatment groups for the 1-0 nursery-grown bare-root seedlings aspect of this study included the following:

1) Basidiospore/vermiculite inoculation. Mature basidiospores of *P. tinctorius* were mixed with dampened vermiculite at the rate of 10g spores per 30ℓ dry vermiculite. Just prior to planting, root systems of seedlings were placed in a plastic bag containing the basidiospore/vermiculite mixture and thoroughly shaken to insure adequate coating.

2) Cultured mycelial inoculation. Cultured mycelial mass inoculum was mixed 1:2 v/v with distilled water to form a slurry. Just prior to planting, the root system of seedlings were dipped in this slurry.

3) Nursery stock control. Just prior to planting, root systems of seedlings were placed in a plastic bag containing vermiculite and shaken.

Field Tests on Minesoil

The field phase of this study was conducted at the

Martin Lake Steam Electric Station lignite stripmine in Panola County, Texas -- located approximately 3.5 miles west of the Beckville community, as accessed by FM 124. The facility is owned and operated under permit by the Texas Utilities Generating Company (TUGCo). Lignite is transported by truck and rail to electrical power generators located adjacent to mining operations where it is used to fire steam boilers. Use of lignite in this manner is termed "mine-mouth utilization."

The lignite seam, which averages 1-2 meters thick, lies at a depth of 8-15 meters. The overburden is removed with a five-million-pound dragline hoisting a 70-cubic-yard effective capacity bucket. Each pit opening is 30-35 meters wide and extends 4000-4500 meters. Spoil banks are laid down in a "herringbone" fashion northeast to southwest. The spoil contains little or no consolidated rock. Sulfur content of the brown coal averages less than 1 percent, thus production of acid mine drainage in the spoil material is minimal (see Braley, 1951; Limstrom, 1948, 1960; Rogers, 1951; Fisher, 1965).

Following retrieval of the lignite seam, spoil banks are contoured to a gently rolling topography with heavy earth-moving equipment. Resulting minesoil is usually sprigged with coastal bermudagrass (*Cynodon dactylon* var. *coastal* (L.) Pers.), fertilized, and often irrigated.

Five plots, each measuring 10 by 40 meter (0.04 hectare), were delineated and fenced on the Martin Lake mining permit area. Three plots were established on the reclaimed mined area designated AI. These three plots may be coordinated on the TUGCo AI AREA COMPOSITE map (File: no. ML-76-111-8) as follows:

PLOT	DITCH	POSITION
Mined # 1	AI-15	90+25
# 2	AI-15	100+25
# 3	AI-15	120+00.

Two plots were established off the mine proper on neighboring "typical" unmined areas, coordinated as follows:

PLOT	LOCATION
Unmined # 1	Approx. 0.5 mi. east of the AI permit area on the Relocated North Sand Hills Road
# 2	AI-61; 90+75.

These plot locations are sketched in Figure 11, and the plots are illustrated in Figures 12 and 13 . Native soils on these areas as mapped by the Soil Conservation Service (1975) were as follows:

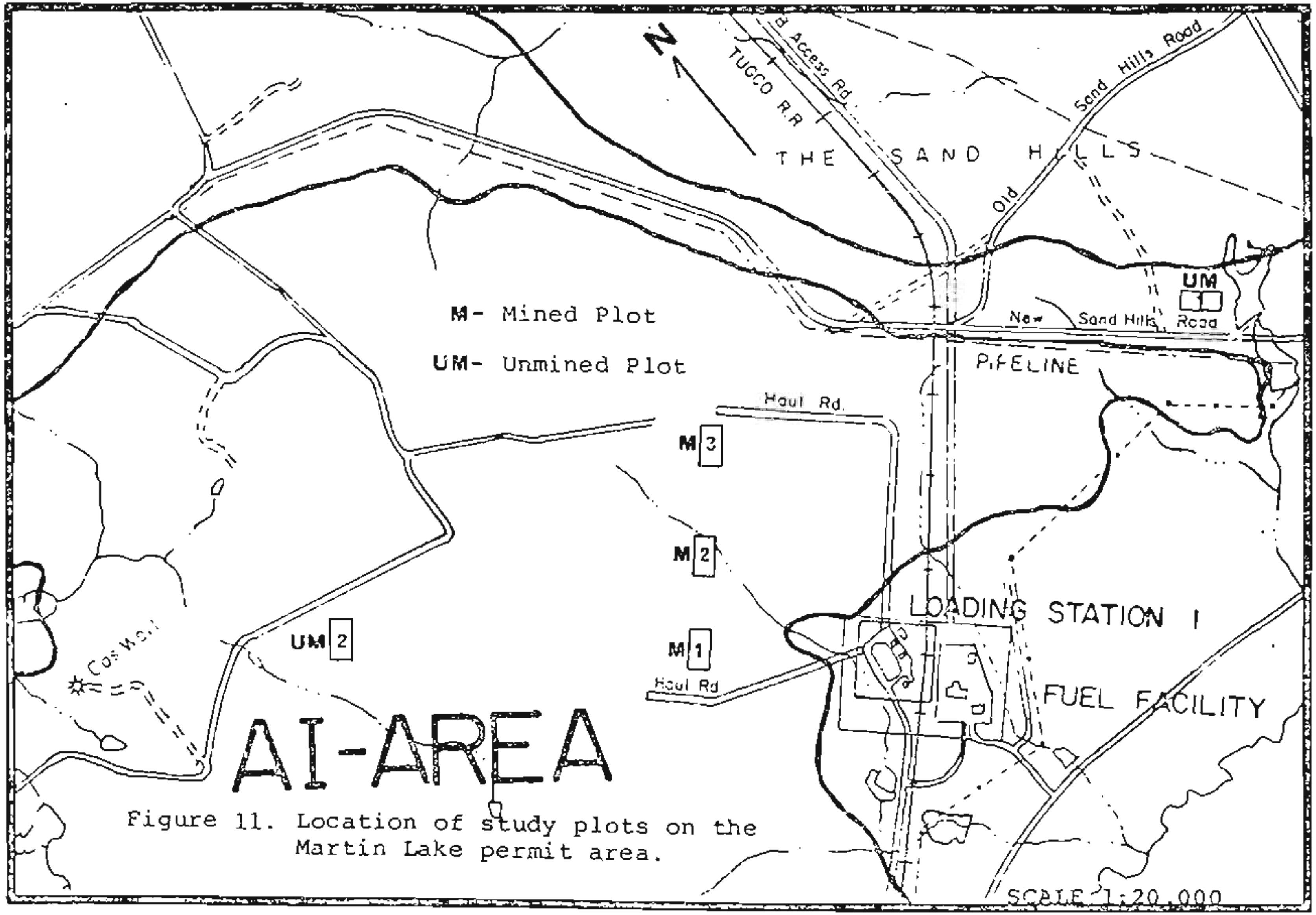

Figure 11. Location of study plots on the Martin Lake permit area.

Figure 12a. Mined plot #1 at Martin Lake -- note dragline on horizon and lush coastal bermudagrass growth on the reclaimed minesoil.

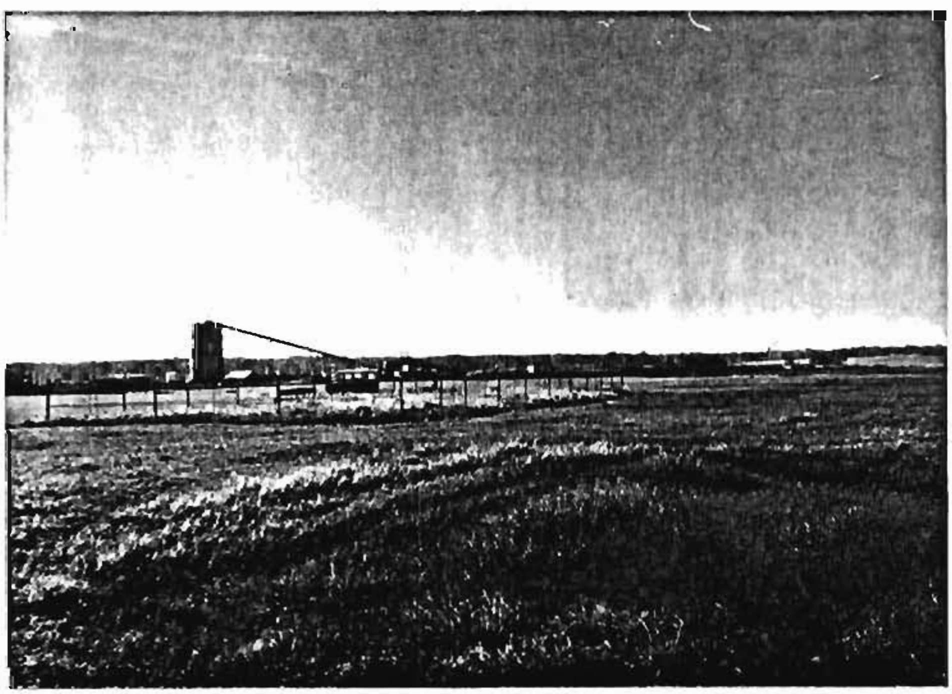

Figure 12b. Mined plot #3 -- the fuel station complex is in the background.

Figure 13a. Unmined plot #1 at Martin Lake -- note the stands of shortleaf pine around the area.

Figure 13b. Unmined plot #2 -- note the shortleaf pine regeneration in the background.

PLOT		SOIL
Mined	# 1	BO - Bowie fine sandy loam
	# 2	KU - Kullit fine sandy loam
	# 3	SAC - Sacul fine sandy loam
Unmined	# 1	BO - Bowie fine sandy loam
	# 2	SAF - Sacul fine sandy loam.

In early March, 1979, each field plot was planted with 6 rows of shortleaf pine seedlings. Rows contained 5 seedlings each, of the following treatments:

1) Containerized cultured mycelial inoculation,
2) Containerized basidiospore/vermiculite inoculation,
3) Containerized seedcoat basidiospore inoculation,
4) Containerized control,
5) Bare-root basidiospore/vermiculite inoculation,
6) Bare-root cultured mycelial inoculation, and
7) Bare-root nursery stock control.

To lessen possiblility of contamination, in each row, the 5 seedlings of a treatment were planted as a group, 1 meter apart -- a space of 2 meters was left between treatment groups. Rows were planted at a spacing of 2 meters apart. A total of 1050 shortleaf pine seedlings were planted, with 210 seedlings per plot.

Immediately following planting, each seedling's root collar diameter and total height were measured and recorded (Appendix Table 12). Also, with completion of planting of a plot, composite soil samples from each row were collected for analyses (Appendix Tables 1 and 2). A single composite consisted of 6 auger samples of soil to a depth of 25 cm from the areas between treatment groups in a row, bagged together. A total of 30 composite soil samples was collected, including 6 composites from each plot.

In November, 1979, following the first-year growing season which may be considered the "establishment" period for shortleaf pine, each surviving seedling's root collar diameter and total height again were measured and recorded, and growth was calculated (Appendix Table 12). Composite samples of needles from the 5 surviving seedlings per treatment group in a row were collected for foliar analyses (Appendix Table 13). Although a total of 210 composite foliage samples (42 per plot) may have been collected, only 161 actually were, due to some treatment groups in some rows suffering 100% mortality.

Laboratory Techniques

Methods and procedures employed for analyses of soils and plant tissues in this study may be described as "standard" techniques used in the SFASU School of Forestry soil testing laboratory (see Watterston, unpublished).

Foliar Analyses

Samples were dry-ashed in a muffle furnace at 500° for 48 hours. Concentrations of cations -- potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), zinc (Zn), and copper (Cu) -- were determined by atomic absorption procedures using a Jarrell-Ash Atomic Absorption/Flame Emission Spectrophotometer (see Jackson, 1958; Jarrell-Ash, 1966; Isaac and Kerber, 1971). Phosphorus (P) concentrations were measured colorimetrically on solutions of molybdophosphic acid complexes using a Coleman Universal Spectrophotometer with analyses at a wavelength of 600 mμ (Truog and Meyer, 1929). Total nitrogen (N) content was found using the macro-Kjeldahl method with Winkler modification (Bartholomew and Clark, 1965).

Soil Analyses

Samples were dried at 105° for 48 hours and sieved through a 2 mm mesh screen. Exchangeable cations (K, Ca, Mg, Na, Mn, Zn, Cu) were extracted with 1 *N* ammonium acetate (NH_4OAc). Available phosphorus was extracted with 0.002 *N* sulfuric acid (H_2SO_4). The concentrations of exchangeable cations and available phosphorus, and total nitrogen content were determined using the procedures described above. Concentrations of sulfates (SO_4) were found by employing turbidimetric techniques described by Jackson (1958), using a Coleman Universal Spectrophotometer. Soil reaction (pH) was measured with a Beckman glass electrode in a 1:2 v/v soil-water suspension -- the technique used was developed by Berg (1969) for oxidizable materials such as acid-producing sulfates in coal spoils. Cation exchange capacity (CEC) was determined by direct distillation of adsorbed ammonium (U.S.D.A., 1967).

Organic matter (OM) content in soil samples was measured by loss-on-ignition in a muffle furnace at 500°C for 48 hours (Black, 1965). Textural analyses were by the Bouyoucos method (Black, 1965).

Ultrastructure Analysis

Short roots excised from 8-month-old containerized cultured mycelium inoculation treatment seedlings were prepared for transmission electron microscopic examination initially by rapidly washing in distilled water to remove adhering soil and vermiculite particles. Short roots were cut to a length of approximately 2 mm. A simultaneous glutaraldehyde (1,5 pentanedial -- $OCH(CH_2)_3CHO$) and osmium (OsO_4) fixation technique was used, outlined as follows:

1) The 2 mm portions of short roots were placed in

a 2.5% buffered (pH 7-Sorensens phosphate buffer, 0.2M) glutaraldehyde solution for 15 minutes.

2) This solution was replaced with equal portions of buffer-glutaraldehyde and 2% osmium. The short root samples remained in this system for 2 hours, under refrigeration.

3) Samples were then washed for 10 minutes each in 3 changes of distilled water.

4) Fixation of the short roots was completed by staining in aqueous uranyl acetate ($UO_2(C_2H_3O_2)_2 \cdot 2H_2O$), in which they were left overnight (12 hours) at room temperature.

The dehydration schedule for fixed short root portions was as follows:

1) 25% ethyl alcohol - 15 minutes
2) 50% ethyl alcohol - 15 minutes
3) 75% ethyl alcohol - 15 minutes
4) 95% ethyl alcohol - 15 minutes
5) 100% ethyl alcohol - 15 minutes
6) 100% ethyl alcohol - 10 minutes
7) Acetone - 10 minutes
8) Acetone - 10 minutes.

Dehydrated short root portions were embedded in Spurr's plastic which had been prepared to a "hard" consistency by varying the DER-736 component. The embedding schedule used was as follows:

1) 30% plastic/70% acetone - 1 hour
2) 70% plastic/30% acetone - 1 hour
3) 100% plastic - 1 hour
4) 100% plastic under vacuum - 1 hour
5) 100% plastic at $70^{o}C$ - 12 hours.

For sectioning, a Sorvall MT2-B "Porter-Blume" microtome equipped with glass knives was used. Thin sections, about 100 Å, were collected on copper grids.

Post-staining was accomplished by a 15-minute exposure of mounted sections to a saturated solution of uranylacetate (0.5%) in 50% ethanol, followed by soaking on a drop of lead citrate $(Pb_3(C_6H_5O_7)_2 \cdot 3H_2O)$ for 3.5 minutes.

Specimens were examined on a Hitachi HS-9 transmitting electron microscope. Initial magnifications of electron micrographs were 2000-10,000 diameters with later photographic enlargement.

RESULTS AND DISCUSSION

Ectomycorrhizae Development

Development of ectomycorrhizae on 8-month-old containerized shortleaf pine seedlings was generally quite good for all treatments, including controls. Although Marx and Barnett (1974) have reported extrême difficulties in generating ectomycorrhizae on containerized seedlings of several *Pinus* species, the present results affirm that bountiful ectomycorrhizae may be formed on containerized shortleaf pine by infestation with either vegetative mycelia or mature basidiospores of *P. tinctorius*. Ectomycorrhizae development illustrated in Figure 14 is typical of results for all containerized treatments.

Only one major form of ectomycorrhizal short roots was found on all containerized treatments. This form was a dark cinnamon-brown in color, usually monopodial but often bifurcate, and 2-5 mm in length. Most ectomycorrhizae were positioned in the top 50 mm of root systems, and predominately emerging from secondary laterals. All morphological traits were typical for *P. tinctorius* ectomycorrhizae on *Pinus* species.

The overall mean for total number of ectomycorrhizal short roots formed in the 130 cm^3 volume of styroblock

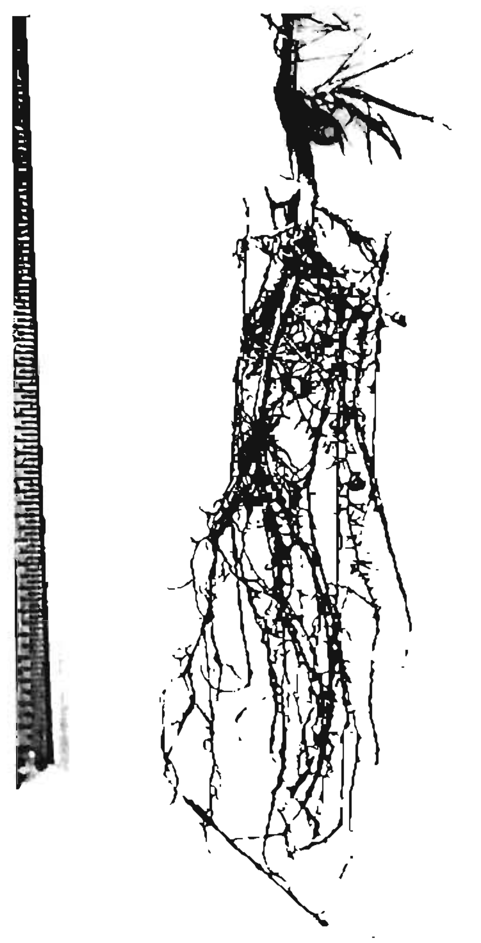

Figure 14. Ectomycorrhizal root system of an 8-month-old shortleaf pine seedling from the basidiospore/vermiculite inoculation treatment.

planting cavities was 2126.7 ± 92.3 The basidiospore/ vermiculite inoculation treatment produced best development, significantly better than the cultured mycelial inoculation which produced fewest ectomycorrhizae (Table 1). It should be noted that reduced ectomycorrhizae development for the cultured mycelial inoculation may have resulted somewhat from poor root aeration due to potting-mix compaction. High moisture content in the vermiculite/ mycelium inoculum produced a soil "puddling" effect when styroblock cavities were filled with potting-mix. This phenomenon was not experienced with other treatments.

Although extreme precautions were employed throughout the infestation phase of this study, obviously containerized control seedlings became inoculated with P. tinctorius propagules. This may have occurred in the greenhouse from spores concentrated in the air; or due to limited research space, perhaps adequate treatment isolation was not allowed. But, ectomycorrhizae produced on root systems of containerized control seedlings were identical morphologically to other treatments.

By means comparison, total number of ectomycorrhizal short roots produced by the basidiospore/vermiculite inoculation was 37.5% greater than the seedcoat basidiospore inoculation, but this difference was statistically non-significant.

Table 1. Total number of mycorrhizal short roots for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN COUNT ± STANDARD ERROR (#)	TUKEY'S COMPARISON (0.05)
Cultured Mycelial Inoculation	1724.5 ± 97.47	(2)
Basidiospore/Vermiculite Inoculation	2556.3 ± 113.24	(1)
Seedcoat Basidiospore Inoculation	1859.6 ± 57.87	(1,2)
Containerized Control	2370.2 ± 104.28	(1,2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	4769518.0	1589839.0	4.35*
Residual	36	13156834.0	365467.6	
Total	39	17926352.0		

* Significant at the 0.05 level of probability.

Ultrastructure of Ectomycorrhizal Short Roots

Many researchers have reported difficulties with fixation techniques that would allow studies on ultrastructure of ectomycorrhizal tree roots, using transmission electron microscopy (see Moore and MacAlear, 1961; Palade, 1952; Robertson, 1954). Most problems center around outer tannin-rich cell zones of host tissues. Tannin particles are partially crystalline and their hardness presents technical difficulties in embedding and sectioning of specimens for fine-structure observation. Fortunately, simultaneous glutaraldehyde-osmium fixation with embedding in Spurr's plastic yielded good results in this study, and would be recommended for future studies of mycorrhizae on southern pine species.

Figure 15 illustrates one lobe of a bifurcate shortleaf pine ectomycorrhizal short root. A mantle of fungal hyphae shrouds the entire root, and the epidermal layer of host cells has broken into discontinuous sections -- in many areas mantle has actually formed between host epidermis and the first layer of cortical cells. In some areas, wedges of hyphae can be seen forcing between outer cortical cells. This penetration is both a mechanical and an enzymatic process (Norkrans, 1950). Cell walls between cortical cells in young roots consist mainly of cellulose and a middle lamella of pectin and incrusted lignin--

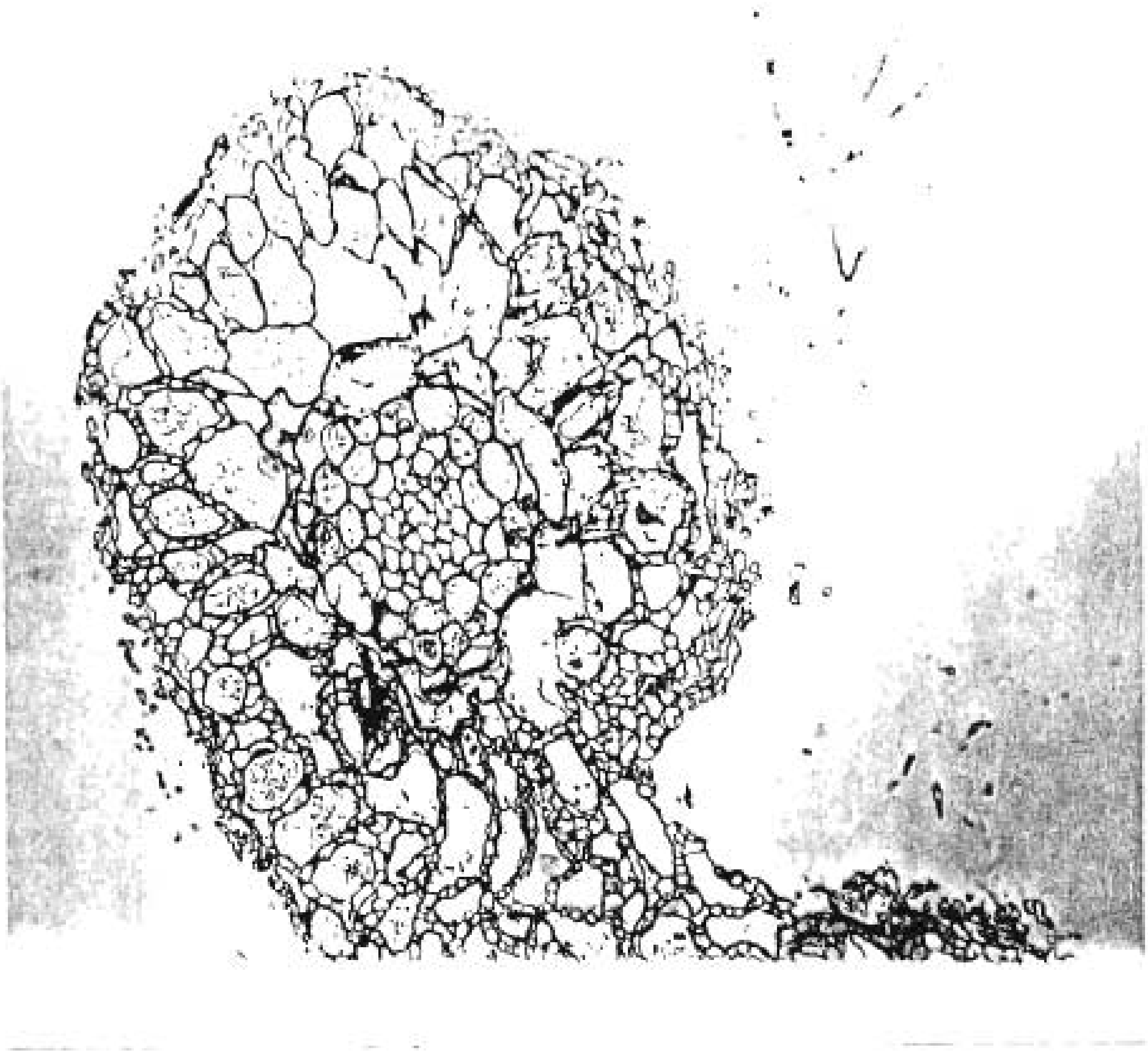

Figure 15. Cross-section (1.0 μ thickness) light micrograph of one lobe of a bifurcate ectomycorrhizal short root from an 8-month-old containerized shortleaf pine seedling which had been inoculated with mycelia of *P. tinctorius*. ca x 800.

mycorrhizal fungi are capable of secreting pectolytic enzymes for dissolving middle lamellae.

In Figure 15 , Hartig-net development is clearly illustrated. The invading fungus has lysed middle lamellae and separated cortical cells to form a system of hyphae which has a large contact surface with the host. Note that no hyphae elements have entered the pith area. All hyphae are inter-cellular, and no penetration of host cells is visible. Various stages of development of Hartig-net are evident throughout the root cross-section.

Large, densely-staining host epidermal cells are shown in Figure 16. These cells form a single-layer-thick tissue "stretched" over the root surface, and epidermal cells lock into one another in a "jigsaw puzzle" fashion. When invading mycobiont hyphae pierce between epidermal cells, each appears to "snap loose" from the other leaving a relatively large invasion portal for fungi to enter the host cortex. Figure 16 illustrates "relaxed" epidermal cells near a lesion point -- hyphae are not visible. Deeply stained materials are polyphenolic compounds or tannin particles. It is considered that the ability of a fungus to form ectomycorrhizae depends, in part, on its tolerance of these noxious compounds (Hofsten, 1969). Often hyphal and epidermal cells in the mantle region appear to be necrotic.

Figure 16. Large, densely-staining epidermal cells of a shortleaf pine root near an infection portal formed by mycobiont hyphae. ca. x 11,500.

When an opening does form in the host epidermis, mycobiont hyphae flood through into the cortex in a wedge-like fashion as shown in Figure 17. At this stage in ectomycorrhizae development, mycobiont hyphae are highly vacuolate and few organelles are visible -- those few hyphae rich in endoplasm are adjacent host cortical cells. Relative to vacuolate hyphae, this tends to indicate low metabolic activity, which may result from incomplete symbiotic relationship with the host. Portions of large host cortical cells visible also reveal a predominantly vacuolate condition. A thin layer of tannin, which seems to be bounded by a membrane, ribbons each cortical cell and crýstals of tannin are scattered throughout -- these crystals may be artifacts of sectioning. A small volume of cytoplasm, with few organelles, apparently exists as a shell around each cortical cell in this area of hyphal invasion just below the epidermis. At this stage the association is clearly an infection process (Hofsten, 1969).

In the Hartig-net region, deep in the host cortex, a more symbiotic relationship was established. Figure 18 illustrates typical Hartig-net development. Host cortical cells appear to possess a much larger volume of cytoplasm which is rich in mitochondria (indicating high metabolic activity) and other organelles. Cortical cells are highly

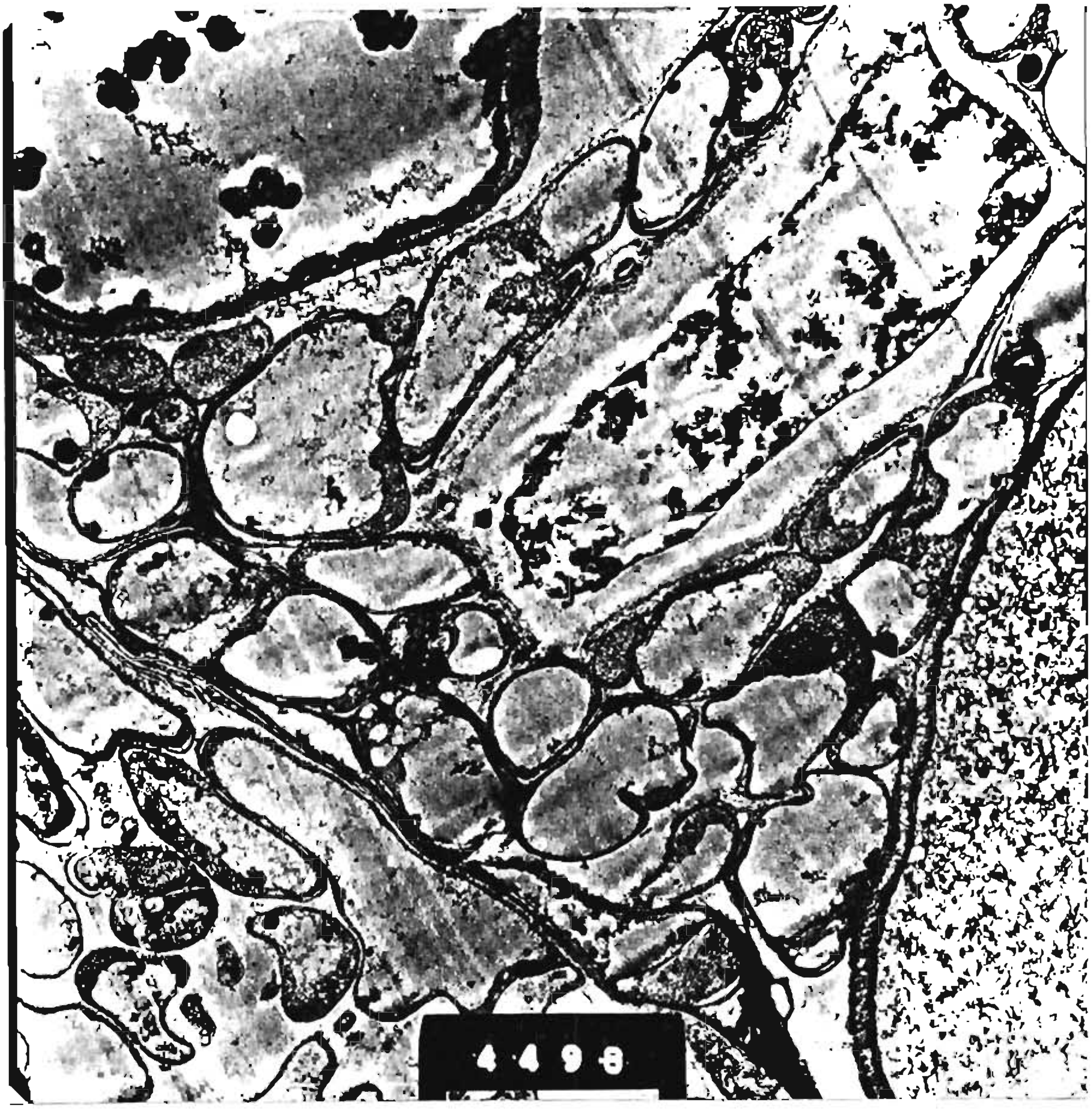

Figure 17. Electron micrograph of mycobiont hyphae invading the first layer of host cortical cells in an ectomycorrhiza of an 8-month-old containerized shortleaf pine seedling which had been inoculated with mycelia of P. tinctorius. ca. x 7,200.

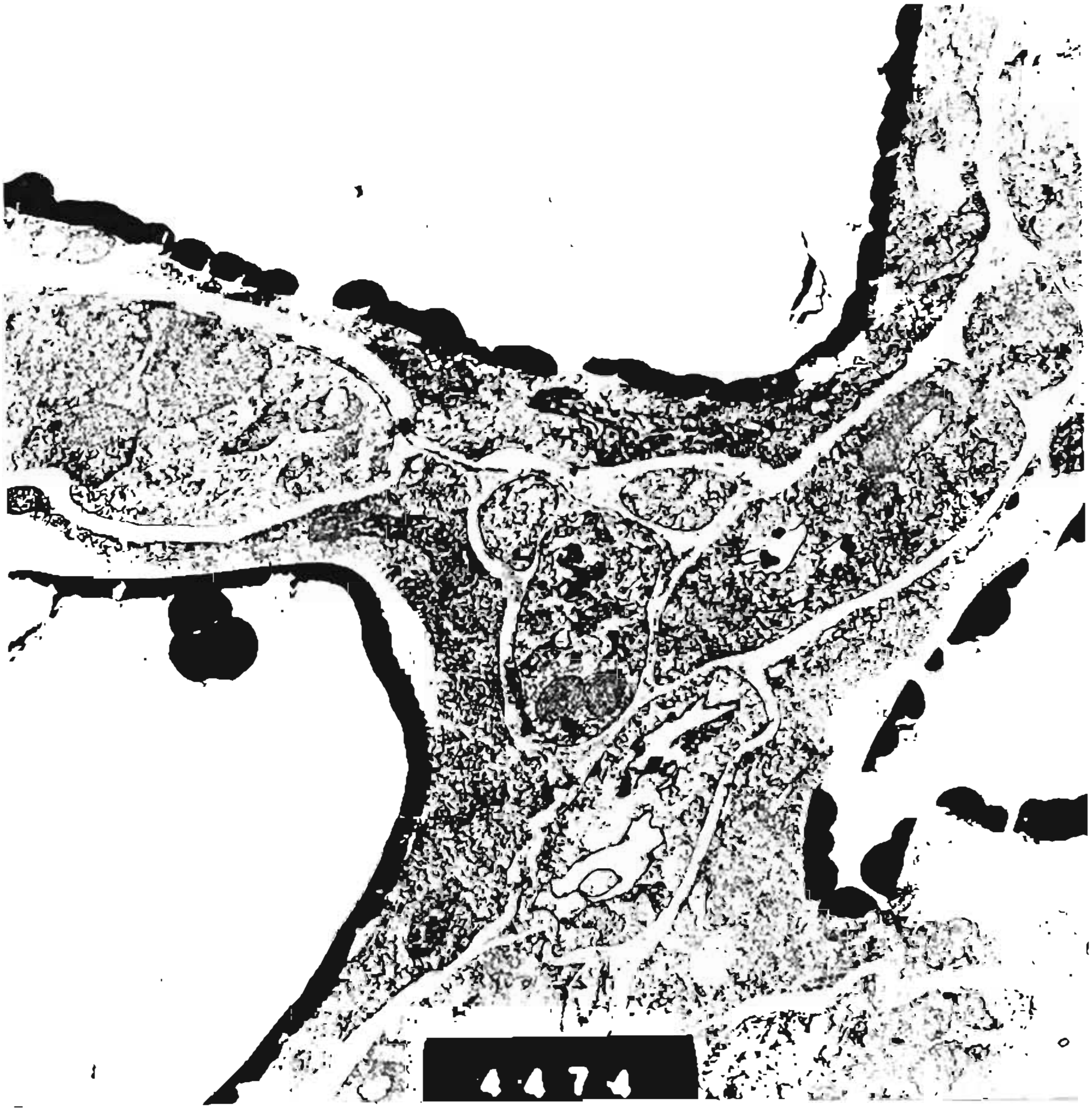

Figure 18. The Hartig-net region of an ectomycorrhizal root from an 8-month-old containerized shortleaf pine seedling which had been inoculated with mycelia of P. tinctorius. ca. x 11,500.

vacuolate, and a dense ribbon of polyphenolics has been laid down. Intimately associated hyphal elements appear to be very active metabolically -- nuclei and mitachondria appear throughout the cytoplasm. Clearly, the two partners are existing in a state of physiological balance.

Careful scrutiny was given to hyphal elements to ascertain taxonomic characteristics. Figure 19 shows a hyphae with diagnostic attributes typical of P. tinctorius. A barrel-shaped dolipore septum, which is peculiar to Basidiomycetes, is the prominent feature in this electron micrograph. The pore is plugged with electron-dense material, and a pore cap is observed around the septum.

On the other hand, Figure 20 reveals a section through a hypha that possesses a simple septum with two associated large Woronin bodies -- these features are characteristic of Ascomycetes or Fungi Imperfecti -- definitely not P. tinctorius. Note that the pore is plugged with electron-dense material. Obviously if P. tinctorius has successfully infected root systems of the 8-month-old containerized seedlings by inoculation with cultured mycelia, it has done so in conjunction with at least one other mycobiont species, probably from a naturally-vectored propagule.

Containerized Seedlings Evaluation

The styroblock containerization system used in this

Figure 19. Section through a hyphal element in the mantle of an ectomycorrhiza formed on an 8-month-old containerized shortleaf pine seedling which had been inoculated with mycelia of *P. tinctorius*. ca. x 39,000.

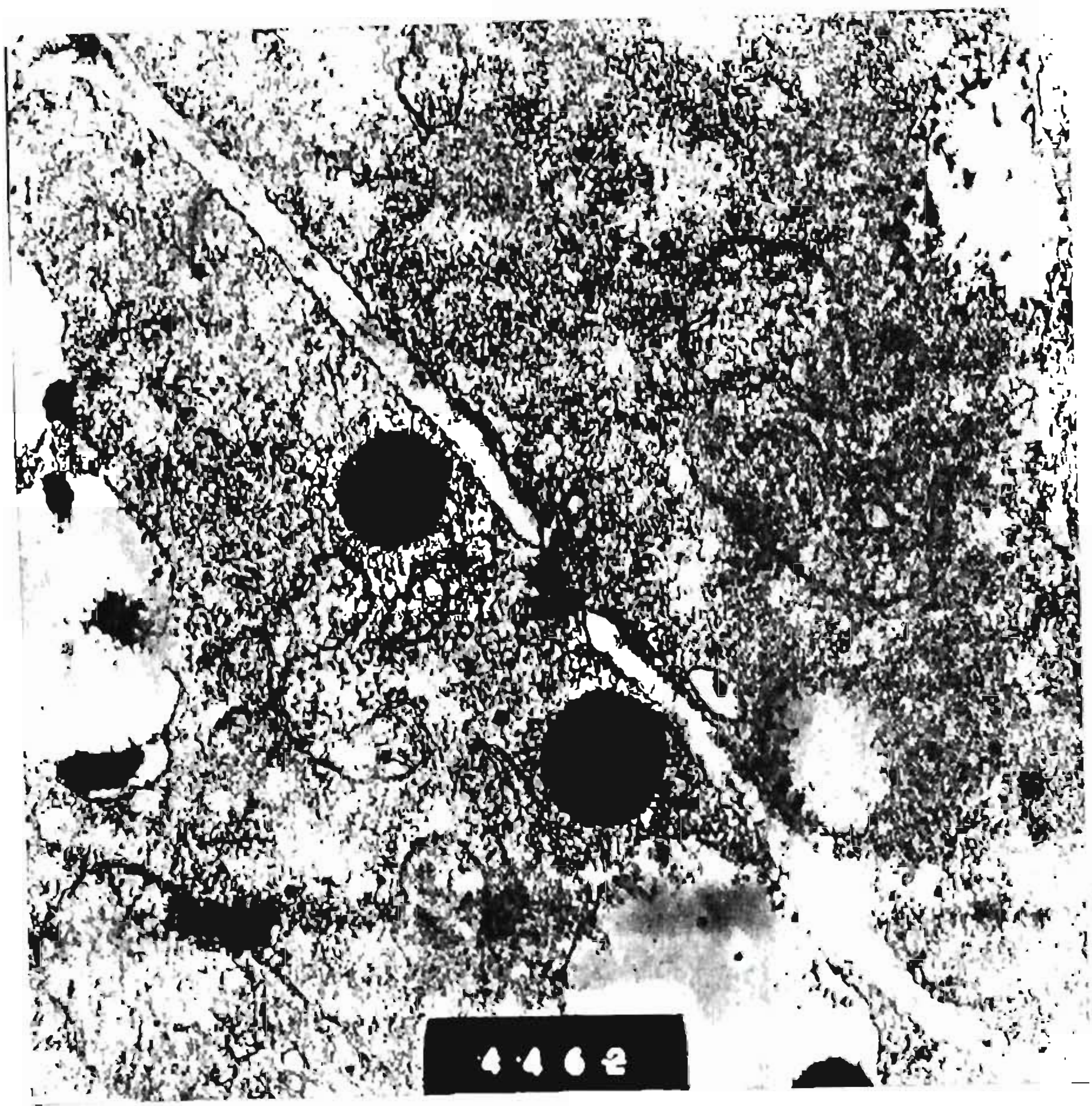

Figure 20. Electron micrograph of the septum area of a hyphal element in the mantle of an ectomycorrhiza formed on an 8-month-old containerized shortleaf pine seedling. ca. x 50,000.

study produced excellent quality shortleaf pine seedlings overall. The sandy loam soil/vermiculite potting-mix formed an easily-planted "plug" that released well when extracted from containers, yet the integrity of "bullets" of potting-mix was maintained without difficulty during handling (Figure 21).

Primarily as a result of fine design features of styroblock rooting cavities, root system development of containerized shortleaf pine seedlings was excellent. Root aberrations were minimized by channeling roots toward the central bottom hole -- emerging roots automatically dried, thus encouraging growth of numerous lateral roots into a tapered, relatively untangled root form (see Kinghorn, 1974; Sjoberg, 1974). Probably due to styroblock cavity ribs, no propensity toward circuitous growth and root binding was observed (Figure 22).

Growth parameters. Survival of 8-month-old containerized seedlings was exceptionally good, with a grand mean of 97.5 ± 0.43 percent; there were no statistical differences in survival percentages among treatment groups (Table 2).

Root collar diameters were small for 8-month-old seedlings, averaging overall 3.09 mm. There were no calculable statistical differences among treatments by Tukey's comparison, although analysis of variance (ANOVA) computations indicated that at least one treatment mean was

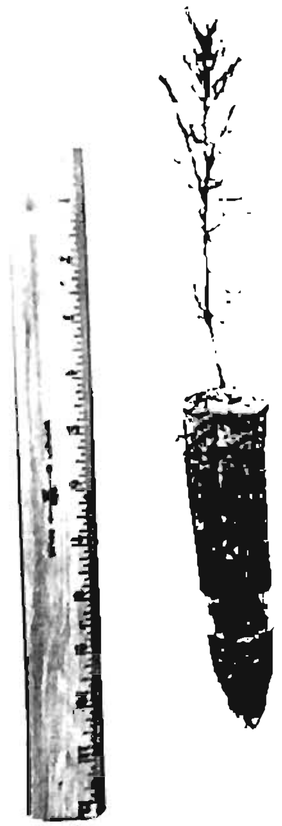

Figure 21. Eight-month-old shortleaf pine seedling grown in styroblock container using sandy loam soil/ vermiculite potting-mix -- note "ribs" in the plug.

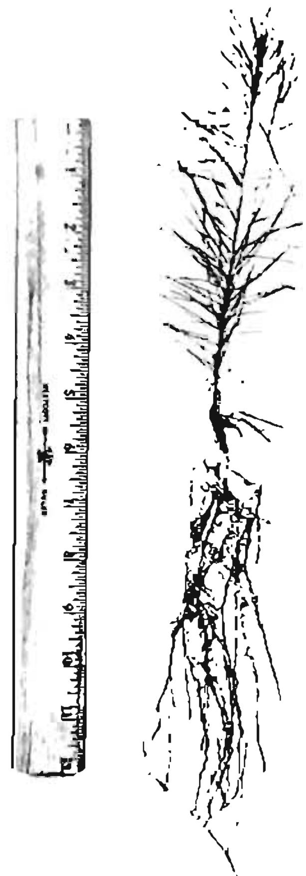

Figure 22. Eight-month-old containerized shortleaf pine seedling with potting-mix removed -- note excellent lateral root development and root/shoot ratio.

Table 2 . Survival among inoculation treatments for eight-month-old containerized shortleaf pine seedlings.

Treatment Group	Mean Survival ± Standard Error (%)
Cultured Mycelial Inoculation	97.00 ± 0.447
Basidiospore/Vermiculite Inoculation	97.25 ± 0.364
Seedcoat Basidiospore Inoculation	98.50 ± 0.364
Containerized Control	97.25 ± 0.538

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-ratio
Treatments	3	6.875	2.2917	0.59^{NS}
Residual	16	61.875	3.8672	
Total	19	68.750		

NS Not significant for at least the 0.05 level of probability.

different (Table 3.) Due to small average root collar diameters, some tendency for seedlings to "lodge" was noted during outplanting.

Total height of containerized seedlings was generally acceptable (grand mean 14.8 cm), but the range in total heights demonstrated excessive disparity; 6.0-27.0 cm. An analysis of variance (ANOVA) indicated a highly significant interaction between treatments and styroblock positioning, with statistical blocks (rows) also being highly significant. With regard to growth of seedlings, this translated to an "edge effect" with seedlings on the periphery of styroblocks suffering reduced height growth of highly significant proportions. This probably resulted from heat and moisture stress as insolation raised temperatures of exposed styroblock faces. Interaction of treatments with positioning prevented stastical demonstration of treatment effects (Table 4.).

Biomass accumulation parameters -- root, shoot, and total plant gram dry weights -- are given in Tables 5,6, and 7. Grand means for these parameters measured on containerized seedlings were as follows: shoot dry weight - 0.64 ± 0.018 g; root system dry weight - 0.55 ± 0.021 g; and total plant dry weight - 1.18 ± 0.033 g. No statistical differences among containerized treatment means were calculated for any of these parameters. However, total root

Table 3. Root collar diameter for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	TREATMENT MEAN (mm)	TUKEY'S COMPARISON (0.05)	ROW	MEAN DIAMETER per STYROBLOCK (mm)
Cultured Mycelial Inoculation	3.26	(1)	1	3.07
			2	3.39
			3	3.52
			4	3.17
			5	3.17
Basidiospore/ Vermiculite Inoculation	3.10	(1)	1	2.94
			2	3.21
			3	3.26
			4	3.16
			5	2.93
Seedcoat Basidiospore Inoculation	2.90	(1)	1	2.91
			2	2.98
			3	3.09
			4	2.78
			5	2.73
Containerized Control	3.02	(1)	1	3.01
			2	2.79
			3	2.89
			4	3.23
			5	3.18

(continued)

Table 3. Continued.

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-ratio
Treatments	3	7.035	2.345	7.24**
Row	4	2.216	.554	1.71^{NS}
R x T	12	7.013	.584	1.80^{NS}
Residual	380	123.115	.324	
Total	399	139.379		

** Significant at the 0.01 level of probability.
NS Not significant for at least the 0.05 level of probability.

Table 4. Total height for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	TREATMENT MEAN (cm)	ROW	MEAN HEIGHT per STYROBLOCK (cm)
Cultured Mycelial Inoculation	15.70	1	16.40
		2	16.50
		3	19.58
		4	14.13
		5	11.90
Basidiospore/Vermiculite Inoculation	16.88	1	13.75
		2	19.33
		3	17.95
		4	18.65
		5	14.75
Seedcoat Basidiospore Inoculation	12.03	1	12.40
		2	11.08
		3	13.52
		4	11.32
		5	11.82
Containerized Control	13.85	1	10.00
		2	13.30
		3	12.00
		4	19.98
		5	13.98

(continued)

Table 4. Continued.

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	1359.755	453.252	35.13**
Row	4	633.360	158.340	12.27**
RxT	12	1717.787	143.149	11.10**
Residual	380	4902.445	12.901	
Total	399	8613.348		

** Significant at the 0.01 level of probability.

Table 5. Shoot dry weight for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN DRY WEIGHT ± STANDARD ERROR (gm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	0.70 ± 0.026	(2)
Containerized Basidiospore/ Vermiculite Inoculation	0.62 ± 0.014	(2)
Containerized Seedcoat Basidiospore Inoculation	0.63 ± 0.020	(2)
Containerized Control	0.62 ± 0.013	(2)
Bare-root Nursery Stock	2.40 ± 0.087	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	62.0631	15.5158	70.66**
Residual	120	26.3499	0.2196	
Total	124	88.4131		

** Significant at the 0.01 level of probability.

Table 6. Total root system dry weight for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN DRY WEIGHT ± STANDARD ERROR (gm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	0.39 ± 0.025	(2)
Containerized Basidiospore/ Vermiculite Inoculation	0.60 ± 0.023	(2)
Containerized Seedcoat Basidiospore Inoculation	0.59 ± 0.019	(2)
Containerized Control	0.58 ± 0.016	(2)
Bare-root Nursery Stock	1.17 ± 0.047	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	8.5982	2.1496	21.66**
Residual	120	11.9102	0.0993	
Total	124	20.5084		

** Significant at the 0.01 level of probability.

Table 7. Total plant dry weight for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN DRY WEIGHT ± STANDARD ERROR (gm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	1.10 ± 0.041	(2)
Containerized Basidiospore/ Vermiculite Inoculation	1.22 ± 0.033	(2)
Containerized Seedcoat Basidiospore Inoculation	1.22 ± 0.036	(2)
Containerized Control	1.20 ± 0.021	(2)
Bare-root Nursery Stock	3.57 ± 0.115	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARES	F-ratio
Treatments	4	114.2031	28.5508	64.21**
Residual	120	53.3562	0.4446	
Total	124	167.5593		

** Significant at the 0.01 level of probability.

system mean dry weight for the cultured mycelial inoculation was notably small; again probably a result of potting-mix compaction mentioned above. But collectively, biomass statistics indicate that the containerized plants possessed a minimum of stored food reserves -- a fact which may be considered a detriment when planting on harsh sites such as minesoils. However, this apparent disadvantage was probably offset by reduced planting shock, which containerized seedlings enjoy.

Exclusive of the cultured mycelial inoculation treatment, the combined mean for root/shoot ratio was 0.97 ± 0.030, which is in the best range for seedling establishment (see Table 8). The possibility for severe winter dessication of evergreen species planted on young minesoils is quite high due to extended areas of landscape providing little windbreak, even near ground level. A high root/shoot ratio for newly-planted seedlings indicates a possibility for more rapid root extension and exploitation of available soil moisture. The poor root/shoot ratio recorded for the cultured mycelial inoculation, which was statistically smaller than other treatments, probably resulted from potting-mix compaction.

A measure of surface area on root systems of seedlings is the water-displacement volume. Containerized treatment grand mean for this parameter was 3.53 ± 0.156 ml, which

Table 8. Root/shoot ratio for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN DRY WEIGHT ± STANDARD ERROR (gm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	0.56 ± 0.033	(2)
Containerized Basidiospore/ Vermiculite Inoculation	0.96 ± 0.029	(1)
Containerized Seedcoat Basidiospore Inoculation	0.96 ± 0.026	(1)
Containerized Control	0.98 ± 0.033	(1)
Bare-root Nursery Stock	0.54 ± 0.024	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	5.1704	1.2926	12.03**
Residual	120	12.8970	0.1075	
Total	124	18.0673		

** Significant at the 0.01 level of probability.

indicated overall large available root system absorbing area for water and nutrients. The basidiospore/varmiculite inoculation treatment root system volume was significantly greater than both the cultured mycelial inoculation and containerized control treatments (Table 9).

Grown in styroblock containers, seedlings formed a strong main root with strong lateral root development (Figure 22). Grand mean for total combined length of all roots was 427.9 ± 190.73 mm, with no significant differences among treatments (Table 10). Formation of such an intensive root system is a marked survival advantage on East Texas minesoils, which tend to be massive and heavy.

Main root length, naturally, was a function of styroblock cavity depth (approx. 153 mm), and a grand mean of 208.6 ± 10.87 mm for all containerized treatments was recorded -- there were no significant differences in main root length among treatments (Table 11). On all plants examined, the main root had grown out the cavity bottom hole and self-pruned.

Marx and Barnett (1974) stated that any condition which regulates lateral root heirarchy development in containerized seedlings affects mycorrhizae formation. Although containerization imposed a small-rooting-volume constraint on root systems, seedlings exhibited intensive primary and secondary lateral root development. This

Table 9. Total root system volume for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN VOLUME ± STANDARD ERROR (ml)	TUKEY'S COMPARISON (0.05)
Cultured Mycelial Inoculation	3.05 ± 0.100	(2)
Basidiospore/Vermiculite Inoculation	4.34 ± 0.225	(1)
Seedcoat Basidiospore Inoculation	3.77 ± 0.106	(1,2)
Containerized Control	2.88 ± 0.198	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	13.6947	4.5649	4.11**
Residual	36	39.9753	1.1104	
Total	39	53.6701		

** Significant at the 0.01 level of probability.

Table 10. Total combined length of all roots for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN LENGTH ± STANDARD ERROR (mm)
Cultured Mycelial Inoculation	3459.9 ± 240.38
Basidiospore/Vermiculite Inoculation	4528.6 ± 200.20
Seedcoat Basidiospore Inoculation	4171.7 ± 103.74
Containerized Control	4928.5 ± 225.26

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	11664144.0	3888048.0	2.44^{NS}
Residual	36	57370144.0	1593615.0	
Total	39	69034288.0		

NS Not significant for at least the 0.05 level of probability.

Table 11. Main root length for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN LENGTH ± STANDARD ERROR (mm)
Cultured Mycelial Inoculation	199.8 ± 10.50
Basidiospore/Vermiculite Inoculation	252.6 ± 15.76
Seedcoat Basidiospore Inoculation	192.4 ± 9.77
Containerized Control	189.4 ± 7.32

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	26445.0938	8815.0313	1.74 NS
Residual	36	182706.5000	5075.1797	
Total	39	209151.5625		

NS Not significant for at least the 0.05 level of probability.

is mirrored in grand means for total number of primary roots (15.1 ± 0.59) and primary roots total combined length (2094.0 ± 96.14 mm). No significant differences in primary lateral root numbers or total combined lengths were found among treatments (Tables 12 and 13). Over 70.2% of primary laterals emerged within 50 mm of root collars, growing at a high angle (>80^0) until the sides of styroblock cavities were encountered; after which they grew nearly vertically along cavity walls before egressing through the bottom hole and self-pruning.

Secondary lateral roots were the principle sites of emergence of ectomycorrhizal short roots. The grand mean for total number of secondary laterals was 29.9 ± 1.79 with no significant differences in total count among treatments (Table 14). However, some treatment effects were significant for total combined length of secondary laterals, with the containerized control treatment measuring most and the cultured mycelial inoculation treatment least -- the grand mean was 1972.4 ± 130.01 mm (Table 15). Poor aeration, again, probably accounted for reduced secondary lateral root growth in the cultured mycelial inoculation treatment. Overall, excellent primary and secondary lateral root development on containerized seedlings was viewed as a principle positive influence on ectomycorrhizae evolution.

Table 12. Total number of primary lateral roots for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN COUNT ± STANDARD ERROR (#)
Cultured Mycelial Inoculation	13.3 ± 0.42
Basidiospore/Vermiculite Inoculation	15.1 ± 0.71
Seedcoat Basidiospore Inoculation	17.2 ± 0.56
Containerized Control	15.3 ± 0.48

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	76.2748	25.4249	2.07^{NS}
Residual	36	442.6995	12.2972	
Total	39	518.9741		

NS Not significant for at least the 0.05 level of probability.

Table 13. Total length of primary lateral roots for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN LENGTH ± STANDARD ERROR (mm)
Cultured Mycelial Inoculation	1942.9 ± 90.42
Basidiospore/Vermiculite Inoculation	2395.6 ± 130.44
Seedcoat Basidiospore Inoculation	1927.8 ± 76.12
Containerized Control	2104.9 ± 87.11

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	1415291.0	471763.6	1.22^{NS}
Residual	36	13886179.0	385727.2	
Total	39	15301470.0		

NS Not significant for at least the 0.05 level of probability.

Table 14. Total number of secondary lateral roots for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN COUNT ± STANDARD ERROR (#)
Cultured Mycelial Inoculation	23.8 ± 2.47
Basidiospore/Vermiculite Inoculation	27.1 ± 1.59
Seedcoat Basidiospore Inoculation	36.3 ± 1.36
Containerized Control	31.5 ± 1.96

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	883.6768	294.5588	2.05^{NS}
Residual	36	5167.0938	143.5304	
Total	39	6050.7695		

NS Not significant for at least the 0.05 level of probability.

Table 15. Total length of secondary lateral roots for eight-month-old containerized shortleaf pine seedlings.

TREATMENT GROUP	MEAN LENGTH ± STANDARD ERROR (mm)	TUKEY'S COMPARISON (0.05)
Cultured Mycelial Inoculation	1317.2 ± 157.96	(2)
Basidiospore/Vermiculite Inoculation	1880.4 ± 113.25	(1,2)
Seedcoat Basidiospore Inoculation	2057.0 ± 72.70	(1,2)
Containerized Control	2634.2 ± 160.94	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	3	8828864.0	2942954.0	4.27*
Residual	36	24827088.0	689641.3	
Total	39	33655952.0		

* Significant at the 0.05 level of probability.

Foliage chemical analyses. Several major factors probably affected foliar and lateral root concentrations of mineral nutrients accumulated in containerized seedlings: 1) the sandy loam soil used in potting-mix, 2) the vermiculite added to potting-mix, 3) flakes of peatmoss contained in the cultured mycelial inoculum, 4) fertilizer additions, 5) pesticide additions, and 6) inoculation treatments.

Analyses of sandy loam soil taken from the mining area at Martin Lake and used in styroblock potting-mix indicated that it possessed marginal fertility (see Appendix Table 1). Total nitrogen content was low, and the availability of phosphorus, potassium, calcium, and magnesium, were also somewhat deficient. Sodium availability was acceptable, as were availabilities of micronutrients, manganese, zinc, and copper. Although the soil contained an adequate level of organic matter, the CEC was low and base saturation indicated a rather infertile condition. Soil reaction was in a good range for growing pine.

Presumed chemically inert in potting-mixes, vermiculite does affect mineral nutrition, especially if fertilizers are used, by modifying the CEC; and much the same is true of peat. Vermiculite and peat have a high CEC based on dry weight compared to sandy loam soil (Klougart and Olsen, 1969; Buckman and Brady, 1969; Owston, 1972; Brix and van den Driessche, 1974). Owston (1972) reported the CEC in milliequivalents per 100g dry weight for 1:1 fine ground vermiculite-peatmoss to be 103. However, for purposes of this study, CEC should be compared on a volume basis -- if this is done, the CEC of sphagnum peat, and probably vermiculite, is not higher than soil (see Klougart and Olsen, 1969).

Ruehle and Marx (1977) found for loblolly pine seedlings grown in styroblocks, the level of fertilization used had little effect on myccrrhizae development. Excellent formation of mycorrhizae and biomass distribution (root/shoot ratio) of shortleaf pine seedlings in this study indicated that the fertilizer regime employed was beneficial. Presumably, accumulated concentrations of mineral nutrients in foliage and lateral roots of these seedlings was affected most by this high level of fertilization.

Apparently, repeated use of insecticides and one application of fungicide had little, if any, effect on mycorrhizae development. Modification of mineral absorption patterns by these applications could not be assessed, but could be significant.

The foliar total nitrogen concentration grand mean for all containerized treatments was 1.29 ± 0.023%. Although significant differences among means for treatments were demonstrated, nitrogen levels were not considered limiting to growth for any treatment (Table 16). Wells and Metz (1963) reported an average total nitrogen concentration for southern pines of 0.80%. Fowells and Krauss (1959) suggested that 2.32% nitrogen results in maximum growth; however, this level is probably too high for containerized seedlings, due to excessive stimulation of top growth and possible difficulties with winter hardening-off from succulency.

The phosphorus economy of soil is closely tied to mycorrhizae formation, with extractable phosphorus concentrations generally inversely related to mycorrhizae development in fertile soils. The overall mean of 178 ± 2.9 ppm for foliar phosphorus indicated that this element was supplied in less than adequate quantities (see Crutchfield and Bing, 1968; Crutchfield, 1969; Young, 1948). However, this deficiency may have stimulated ectomycorrhizae development on the containerized seedlings (see Kormanik et al., 1977). Significant differences among treatment foliar phosphorus concentrations were calculated with the containerized controls registering highest levels (Table 17).

Grand means for foliar concentrations of other macronutrients were as follows:

K	4569 ± 94.3 ppm
Ca	1974 ± 39.0 ppm
Mg	1027 ± 17.2 ppm
Na	437 ± 11.2 ppm.

Table 16. Foliage nitrogen (N) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN N CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	1.27 ± 0.014	(2)
Containerized Basidiospore/ Vermiculite Inoculation	1.06 ± 0.029	(3)
Containerized Seedcoat Basidiospore Inoculation	1.54 ± 0.025	(1)
Containerized Control	1.29 ± 0.023	(2)
Bare-root Nursery Stock	1.20 ± 0.018	(2,3)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	3.0554	0.7638	12.19**
Residual	120	7.5188	0.0627	
Total	124	10.5741		

** Significant at the 0.01 level of probability.

Table 17. Foliage phosphorus (P) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN P CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	144 ± 1.9	(3,4)
Containerized Basidiospore/ Vermiculite Inoculation	164 ± 1.7	(2,3)
Containerized Seedcoat Basidiospore Inoculation	185 ± 6.2	(2)
Containerized Control	223 ± 4.1	(1)
Bare-root Nursery Stock	124 ± 1.4	(4)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	148255.94	37063.98	22.99**
Residual	120	193425.56	1611.88	
Total	124	341681.50		

** Significant at the 0.01 level of probability.

No significant differences among treatment means for potassium were computed (Table 18); the level of this nutrient for all treatments was somewhat high (see Wells and Metz, 1963). The foliar calcium concentrations were below optimum levels, except for the containerized control which was significantly higher (Table 19). Significant differences in calcium concentrations also extended between the seedcoat basidiospore inoculation and the basidiospore/vermiculite and cultured mycelial inoculations -- suggesting that as quantity of P. tinctorius inoculum increased, the rate of calcium uptake was reduced. Although, significant differences among magnesium concentrations existed, all treatments registered ample measurements of this mineral nutrient (Table 20). Some variations in magnesium may have been due to influence of vermiculite $\{(Mg, Ca)_{0.7}(Mg,Fe,Al)_6(Al,Si)_8O_{20}(OH)_4 \cdot 8H_2O\}$. As might be expected in this heavily irrigated system, sodium levels were low, and no significant differences among containerized treatments were calculated (Table 21).

Overall treatment means for foliar concentrations of micro-nutrients are given below:

Mn	388 ± 13.2 ppm
Zn	81 ± 3.0 ppm
Cu	46 ± 5.1 ppm.

Concentrations of manganese were high, but were not

Table 18. Foliage potassium (K) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN K CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	4566 ± 56.0	(2)
Containerized Basidiospore/ Vermiculite Inoculation	4734 ± 121.0	(2)
Containerized Seedcoat Basidiospore Inoculation	4122 ± 76.4	(2)
Containerized Control	4862 ± 120.4	(2)
Bare-root Nursery Stock	7483 ± 116.3	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	177422128.0	44355520.0	34.37**
Residual	120	154852624.0	1290438.0	
Total	124	332274688.0		

** Significant at the 0.01 level of probability.

Table 19. Foliage calcium (Ca) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Ca CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	1238 ± 30.8	(3)
Containerized Basidiospore/ Vermiculite Inoculation	1482 ± 23.1	(3)
Containerized Seedcoat Basidiospore Inoculation	1974 ± 37.3	(2)
Containerized Control	3202 ± 66.4	(1)
Bare-root Nursery Stock	724 ± 23.6	(4)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	88543600.0	22135888.0	112.97**
Residual	120	23514400.0	195953.3	
Total	124	112058000.0		

** Significant at the 0.01 level of probability.

Table 20. Foliage magnesium (Mg) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Mg CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	1257 ± 23.1	(1)
Containerized Basidiospore/ Vermiculite Inoculation	682 ± 16.1	(3)
Containerized Seedcoat Basidiospore Inoculation	1069 ± 14.7	(2)
Containerized Control	1104 ± 13.8	(2)
Bare-root Nursery Stock	435 ± 7.3	(4)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	11516121.0	2879030.0	91.68**
Residual	120	3768492.0	31404.1	
Total	124	15284613.0		

** Significant at the 0.01 level of probability.

Table 21. Foliage sodium (Na) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Na CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	521 ± 15.5	(2)
Containerized Basidiospore/ Vermiculite Inoculation	483 ± 12.3	(2)
Containerized Seedcoat Basidiospore Inoculation	356 ± 7.2	(2)
Containerized Control	387 ± 9.9	(2)
Bare-root Nursery Stock	4220 ± 52.7	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	286689792.0	71672448.0	863.28**
Residual	120	9962780.0	83023.1	
Total	124	296652544.0		

** Significant at the 0.01 level of probability.

considered toxic for any treatment. The source of these high levels of manganese is not known, and variations among treatments were significant (Table 22). Some significant differences among treatment means for foliar zinc were calculated, but this micro-nutrient was accumulated in proper quantities for thrifty seedling development by all treatments (Table 23). Concentrations of copper varied non-significantly and were uniformly adequate (Table 24).

The foliar ash content grand mean for all containerized treatments was 2.4 ± 0.08%. Varying somewhat among treatments, it indicated that overall ion uptake was acceptable and silicon accumulation was minimal (Table 25).

Lateral roots chemical analyses. Stebbens (1950), in Chapter 3 of his book, Variation and Evolution in Plants, points out that vegetative characteristics are more subject to plastic variability than are reproductive ones. Growth habits of roots -- their continuous, open-ended development, and lack of nodes, internodes and determinate structures -- offer ample opportunity for external factors, including mineral nutrition, to exert influence on their development (Epstein, 1972).

Mineral nutrition relative to formation and growth of root systems and attendant mycorrhizae is an area virtually ignored in the literature. Consequently, no absolute references are available relating development of shortleaf

Table 22. Foliage manganese (Mn) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Mn CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	234 ± 13.4	(3)
Containerized Basidiospore/ Vermiculite Inoculation	502 ± 9.6	(1)
Containerized Seedcoat Basidiospore Inoculation	349 ± 12.5	(2)
Containerized Control	469 ± 17.1	(1)
Bare-Root Nursery Stock	412 ± 9.6	(1,2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	1135920.0	283980.0	14.02**
Residual	120	2430456.0	20253.8	
Total	124	3566376.0		

** Significant at the 0.01 level of probability.

Table 23. Foliage zinc (Zn) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Zn CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	98 ± 5.8	(1)
Containerized Basidiospore/ Vermiculite Inoculation	92 ± 1.4	(1,2)
Containerized Seedcoat Basidiospore Inoculation	68 ± 2.6	(2)
Containerized Control	67 ± 2.4	(2,3)
Bare-root Nursery Stock	37 ± 1.9	(3)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	55793.2	13948.3	10.63**
Residual	120	157419.1	1311.8	
Total	124	213212.3		

** Significant at the 0.01 level of probability.

Table 24. Foliage copper (Cu) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Cu CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	37 ± 4.7	(1)
Containerized Basidiospore/ Vermiculite Inoculation	44 ± 3.2	(1)
Containerized Seedcoat Basidiospore Inoculation	70 ± 6.2	(1)
Containerized Control	36 ± 4.0	(1)
Bare-root Nursery Stock	0	

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	62004.8	15501.2	7.16**
Residual	120	259775.4	2164.8	
Total	124	321780.2		

** Significant at the 0.01 level of probability.

Table 25. Foliage ash content for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN ASH CONTENT ± STANDARD ERROR (%)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	2.7 ± 0.05	(2)
Containerized Basidiospore/ Vermiculite Inoculation	1.4 ± 0.10	(3)
Containerized Seedcoat Basidiospore Inoculation	2.9 ± 0.07	(2)
Containerized Control	2.8 ± 0.09	(2)
Bare-root Nursery Stock	5.7 ± 0.11	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	249.7974	62.4493	64.00**
Residual	120	117.0989	0.9758	
Total	124	366.8962		

** Significant at the 0.01 level of probability.

pine seedling root systems with nutrient concentrations in lateral roots. For this reason, few conclusions may be drawn from statistical data presented -- much more research in this area is called for.

Grand means for root concentrations of mineral nutrients in containerized seedlings were as follows:

N	1.00 ± 0.026 %
P	174 ± 2.3 ppm
K	5101 ± 164.7 ppm
Ca	1382 ± 44.4 ppm
Mg	1093 ± 20.9 ppm
Na	777 ± 18.9 ppm
Mn	143 ± 6.8 ppm
Zn	55 ± 2.0 ppm
Cu	56 ± 3.6 ppm
Ash	11.2 ± 0.20%.

The total nitrogen in roots varied non-significantly among treatments (Table 26). Indications were that nitrogen was rapidly transported to foliage where it accumulated against a concentration gradient. Measurements of phosphorus concentrations were similar for roots and foliage, with significant disparity demonstrated among treatment means for roots (Table 27). These results also suggest that as quantities of *P. tinctorius* inoculum increased, root accumulation of phosphorus increased.

Table 26. Root nitrogen (N) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN N CONCENTRATION ± STANDARD ERROR (%)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	1.06 ± 0.029	(1)
Containerized Basidiospore/ Vermiculite Inoculation	0.97 ± 0.022	(1)
Containerized Seedcoat Basidiospore Inoculation	0.88 ± 0.014	(1)
Containerized Control	1.08 ± 0.037	(1)
Bare-root Nursery Stock	0.65 ± 0.022	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	3.0895	0.7724	9.19**
Residual	120	10.0823	0.0840	
Total	124	13.1718		

** Significant at the 0.01 level of probability.

Table 27. Root phosphorus (P) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN P CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	211 ± 3.2	(1)
Containerized Basidiospore/ Vermiculite Inoculation	188 ± 2.0	(2)
Containerized Seedcoat Basidiospore Inoculation	151 ± 2.4	(3)
Containerized Control	147 ± 2.0	(3)
Bare-root Nursery Stock	86 ± 1.0	(4)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	228849.2	57212.3	92.80**
Residual	120	73982.3	616.5	
Total	124	302831.5		

** Significant at the 0.01 level of probability.

Concentrations of potassium in roots were similar to foliage. The basidiospore/vermiculite inoculation inexplicably was 44% higher in potassium than the combined mean for other containerized treatments (Table 28). Root concentrations of calcium were consistent among treatments, with most levels being similar to foliage (Table 29). Significant differences among treatments for root concentrations of magnesium insinuated that it may be influenced by quantity of live _P. tinctorius_ inoculum in rooting media (Table 30).

Sodium apparently was absorbed into root systems faster than it was transported to foliage. Although not physiologically active, sodium in these high concentrations may have a marked effect on formation of mycorrhizae (Table 31).

Root concentrations of manganese indicated that it was rapidly transported to foliage (Table 32). The levels for zinc, like manganese, varied non-significantly and were similar to foliar concentrations (Table 33). Much the same was true of copper, although the mean for the seedcoat basidiospore inoculation was significantly higher (Table 34). High ash content in roots indicated that silicon was absorbed rapidly but not transported efficiently to foliage -- this peculiarity may have some influence on mycorrhizae development (Table 35).

Table 28. Root potassium (K) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN K CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	4781 ± 111.9	(2)
Containerized Basidiospore/ Vermiculite Inoculation	6630 ± 322.2	(1)
Containerized Seedcoat Basidiospore Inoculation	4038 ± 109.7	(2)
Containerized Control	4962 ± 67.4	(2)
Bare-root Nursery Stock	6691 ± 55.0	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	140225072.0	35056256.0	10.32**
Residual	120	407819520.0	3398496.0	
Total	124	548044544.0		

** Significant at the 0.01 level of probability.

Table 29. Root calcium (Ca) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Ca CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	1270 ± 29.1	(1)
Containerized Basidiospore/ Vermiculite Inoculation	1512 ± 56.5	(1)
Containerized Seedcoat Basidiospore Inoculation	1395 ± 62.4	(1)
Containerized Control	1348 ± 32.4	(1)
Bare-root Nursery Stock	388 ± 9.8	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	20500064.0	5125016.0	22.59**
Residual	120	27226432.0	226886.9	
Total	124	47726496.0		

** Significant at the 0.01 level of probability.

Table 30. Root magnesium (Mg) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Mg CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	1973 ± 36.6	(1)
Containerized Basidiospore/ Vermiculite Inoculation	1012 ± 13.2	(2)
Containerized Seedcoat Basidiospore Inoculation	733 ± 27.0	(3)
Containerized Control	654 ± 18.9	(3)
Bare-root Nursery Stock	311 ± 4.1	(4)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	39803440.0	9950860.0	152.07**
Residual	120	7852546.0	65437.9	
Total	124	47655984.0		

** Significant at the 0.01 level of probability.

Table 31. Root sodium (Na) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Na CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	771 ± 19.0	(2)
Containerized Basidiospore/ Vermiculite Inoculation	661 ± 21.1	(2)
Containerized Seedcoat Basidiospore Inoculation	903 ± 18.6	(2)
Containerized Control	772 ± 13.8	(2)
Bare-root Nursery Stock	3085 ± 68.0	(1)

ANALYSIS OF VARIANCE

SOURCE	DF DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	107312688.0	26828160.0	179.66**
Residual	120	17918848.0	149323.7	
Total	124	125231536.0		

** Significant at the 0.01 level of probability.

Table 32. Root manganese (Mn) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Mn CONCENTRATION ± STANDARD ERROR ppm	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	118 ± 4.5	(2)
Containerized Basidiospore/ Vermiculite Inoculation	141 ± 6.1	(2)
Containerized Seedcoat Basidiospore Inoculation	190 ± 10.3	(2)
Containerized Control	126 ± 5.4	(2)
Bare-root Nursery Stock	343 ± 12.5	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	874318.0	218579.5	25.05**
Residual	120	1047158.4	8726.3	
Total	124	1921476.4		

** Significant at the 0.01 level of probability.

Table 33. Root zinc (Zn) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Zn CONCENTRATION ± STANDARD ERROR ppm	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	58 ± 2.5	(1)
Containerized Basidiospore/ Vermiculite Inoculation	59 ± 1.4	(1)
Containerized Seedcoat Basidiospore Inoculation	44 ± 2.0	(1)
Containerized Control	57 ± 2.8	(1)
Bare-root Nursery Stock	16 ± 1.8	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	34378.8	8594.7	14.65**
Residual	120	70415.8	586.8	
Total	124	104794.6		

** Significant at the 0.01 level of probability.

Table 34. Root copper (Cu) concentration for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN Cu CONCENTRATION ± STANDARD ERROR ppm	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	50 ± 4.5	(2)
Containerized Basidiospore/ Vermiculite Inoculation	46 ± 2.8	(2)
Containerized Seedcoat Basidiospore Inoculation	86 ± 5.7	(1)
Containerized Control	37 ± 2.9	(2)
Bare-root Nursery Stock	0	

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	93690.8	23422.7	13.42**
Residual	120	209485.7	1745.7	
Total	124	303176.5		

** Significant at the 0.01 level of probability.

Table 35. Root ash content for eight-month-old containerized, and 1-0 nursery-grown shortleaf pine seedlings.

TREATMENT GROUP	MEAN ASH CONTENT ± STANDARD ERROR (%)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation	10.4 ± 0.26	(2)
Containerized Basidispore/ Vermiculite Inoculation	11.0 ± 0.20	(1,2)
Containerized Seedcoat Basidiospore Inoculation	10.8 ± 0.23	(2)
Containerized Control	12.8 ± 0.21	(1)
Bare-root Nursery Stock	7.7 ± 0.14	(3)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	4	343.8794	85.9698	15.05**
Residual	120	685.4971	5.7125	
Total	124	1029.3765		

** Significant at the 0.01 level of probability.

Nursery-grown Seedlings Evaluation

Ectomycorrhizae present on root systems of nursery-grown seedlings were typical in form to Thelephora terrestris, a mycobiont common to southeastern forest nurseries. Mean count of ectomycorrhizae was 388.6 ± 72.7 (Table 36)--far short of the grand mean of 2126.7 ± 92.3 on containerized seedlings.

Growth parameters. Nursery-grown seedlings had significantly higher values for biomass accumulation -- root, shoot, and total plant gram dry weight -- than had containerized seedlings (Tables 5-7). However, the root/shoot ratio was significantly poorer, with the exception of the containerized cultured mycelial inoculation treatment (Table 8).

A root system statistical summary for nursery-grown seedlings is given in Table 36. Generally, root systems of nursery-grown seedlings were more extensive than containerized systems and far less branched. Each seedling had a strongly-developed main root which had been pruned to 158.5 ± 14.36 mm during lifting from the nursery bed. Containerized seedlings had 39% more primary lateral roots, by means comparison, than nursery-grown seedlings, as well as 37% greater total root system combined length. However, total root system volume for nursery-grown seedlings was

Table 36. Root system statistical summary for 1-0 nursery-grown bare-root shortleaf pine seedlings.

ROOT SYSTEM DETAIL		MEAN ($\bar{x}$)	STANDARD ERROR
Mycorrhizal Short Roots:	Total number	388.6	± 72.66
Total Root System Volume (ml)		4.8	± 0.39
Main Root Length (mm)		158.5	± 14.36
Primary Lateral Roots:	Total number	10.9	± 1.00
	Total length (mm)	1733.7	±184.68
Secondary Lateral Roots:	Total number	23.3	± 3.01
	Total length (mm)	1226.2	±133.20
Total Root System Combined Length (mm)		3118.4	±203.68

36% greater than containerized seedlings, primarily due to larger main roots.

Foliage chemical analyses. Mean foliar concentrations of mineral nutrients for nursery-grown seedlings are given in Tables 16-25. Foliar concentrations of nitrogen, manganese, and zinc were comparable with levels recorded for containerized seedlings. However, phosphorus, calcium, magnesium, and copper were significantly lower. Potassium and sodium concentrations in nursery-grown seedlings were higher than normally encountered, which contributed to the high foliage ash content.

Lateral roots chemical analyses. Lateral roots of nursery-grown seedlings were significantly lower in concentrations of nitrogen, phosphorus, calcium, magnesium, zinc, and copper than roots of containerized seedlings (Tables 26, 27, 29, 30, 33, and 34). These lower mineral concentrations were reflected in a significantly lower root ash content (Table 35). Poor ectomycorrhizae development on nursery-grown seedlings may well have been a result of deficiencies of one or more of these nutrients.

Potassium and sodium concentrations in roots of nursery-grown seedlings were significantly higher than in containerized plants -- as they were in foliage (Tables 28 and 31). Inordinately high levels of sodium in roots may have acted to retard ectotrophic associations. Manganese levels were also significantly higher than in roots of containerized seedlings (Table 32).

Soil Analyses

Shortleaf pine has the widest range of any southeastern pine, and its ability to grow on a great variety of soils partly accounts for its distribution (Fowells, 1965). The best shortleaf sites are fine sandy loams or silt loams without distinct profile but with good internal drainage (Coile, 1952). It is usually more abundant than loblolly pine on drier, lower-nutrient soils, due to its larger root system, tolerance to poor soil aeration, and lower demand for mineral nutrients (Zak, 1961). But, generally, shortleaf pine does not grow well on soils with high calcium content or high pH, especially in the seedling stage (Chapman, 1941). Very little is known about how tailoring of ectomycorrhizae by inoculation with different mycobionts modifies tolerances of shortleaf pine to extreme edaphic conditions.

When recontoured lignite overburden materials are used as a medium for revegetation, certain chemical and physical properties influence its productivity: pH, exchangeable bases, texture, salinity, CEC, organic matter content, and absence of toxic concentrations of heavy metals, among others.

Mean pH for all plots on the mine at Martin Lake was 7.14 ± 0.018, significantly higher than unmined plots, which averaged 5.38 ± 0.032 (Table 37). Hossner, et al. (1980) have reported that pH of overburden stata can be related to contained quantities of total sulfur (primarily pyritic) -- low values to pH 2.2 were measured for several strata in the Wilcox formation in Texas. If these strata become mixed in spoil material near the surface, potential for growth-inhibiting acid formation may be realized. Minesoils at Martin Lake contained over 7 times the quantity of sulfates in unmined soils, by means comparison. With a grand mean of 5.15 ± 0.244 ppm sulfates in samples from mined plots, as compared with 0.70 ± 0.172 ppm for unmined plots -- a difference which was statistically significant -- acid formation was a real possibility.

However, high concentrations of calcium in fresh minesoil, which averaged 4599 ± 140 ppm, indicated that carbonates were present in sufficient quantities to buffer soil solutions, resulting in near-neutral reactions registered on the mine. Calcium levels were significantly higher on mined plots than on unmined, which averaged 338 ± 20.8 ppm (Table 39).

Speculating on the status of pH of these minesoils with passage of time, base saturation becomes an important

Table 37. Soil reaction (pH) for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN REACTION ± STANDARD ERROR (pH)	TUKEY'S COMPARISON (0.05)
Mined	#1	7.24 ± 0.015	(1)
	#2	7.05 ± 0.010	(1)
	#3	7.14 ± 0.029	(1)
Unmined	#1	5.60 ± 0.040	(2)
	#2	5.15 ± 0.023	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	23.260	5.815	297.20**
Residual	25	0.489	0.019	
Total	29	23.749		

** Significant at the 0.01 level of probability.

Table 38. Soil extractable sulfate (SO_4) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN SO_4 CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	4.54 ± 0.257	(2)
	#2	7.32 ± 0.302	(1)
	#3	3.60 ± 0.174	(2)
Unmined	#1	0.97 ± 0.274	(3)
	#2	0.42 ± 0.070	(3)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	188.705	47.176	29.41**
Residual	25	40.102	1.604	
Total	29	228.807		

** Significant at the 0.01 level of probability.

Table 39. Soil exchangeable calcium (Ca) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN Ca CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	5883 ± 304.9	(1)
	#2	4017 ± 32.0	(2)
	#3	3908 ± 80.9	(2)
Unmined	#1	378 ± 30.3	(3)
	#2	299 ± 11.3	(3)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	145757488.0	36439360.0	59.77**
Residual	25	15240364.0	609614.5	
Total	29	160997840.0		

** Significant at the 0.01 level of probability.

consideration. Base saturation of samples taken from mined plots at Martin Lake ranged 223-1005%, with a grand mean of 434 ± 40.3%; unmined plots averaged 53 ± 3.6%, and a significant difference among means for mined and unmined plots was calculated (Table 40). High base saturations above 100% indicate presence of large quantities of free salts, which are quite rapidly leached by slightly acid rain waters. In these minesoils, free salts may be predominately calcium carbonate ($CaCO_3$). This lime ($CaCO_3$) is the principle buffering agent against acid-producing hydrolyzing pyrites, which are not easily solubilized. Thus, with passage of a short period of time, pH should begin to drop as calcium carbonate is leached out and contained pyrites continue to produce sulfuric acid. Therefore, in considering revegetation of these minesoils with shortleaf pine seedlings, better soil conditions may exist 3-5 seasons after recontouring than in freshly-placed spoils.

Total nitrogen content of both mined and undisturbed soils was quite low and probably growth-limiting to most species. The grand mean for mined plots was 0.035 ± 0.003%, and 0.035 ± 0.002% for unmined. Some statistical differences among plots were demonstrable, but at these low levels of nitrogen content, differences probably had little effect on relative growth rates (Table 41). Under low nutrient

Table 40. Soil base saturation (BS) for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN BS ± STANDARD ERROR (%)	TUKEY'S COMPARISON (0.05)
Mined	#1	573 ± 55.5	(1)
	#2	362 ± 37.8	(1,2)
	#3	367 ± 25.3	(1)
Unmined	#1	69 ± 4.2	(2,3)
	#2	37 ± 2.9	(3)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	1222113.0	305528.2	9.84**
Residual	25	776124.1	31045.0	
Total	29	1998237.1		

** Significant at the 0.01 level of probability.

Table 41. Soil nitrogen (N) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN N CONCENTRATION ± STANDARD ERROR (%)	TUKEY'S COMPARISON (0.05)
Mined	#1	0.037 ± 0.005	(1,2)
	#2	0.031 ± 0.005	(2)
	#3	0.038 ± 0.001	(1,2)
Unmined	#1	0.048 ± 0.003	(1,2)
	#2	0.065 ± 0.001	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	0.0043	0.0011	3.20*
Residual	25	0.0084	0.0003	
Total	29	0.0127		

* Significant at the 0.05 level of probability.

conditions such as this, tailored mycorrhizae have produced most beneficial results.

Minesoils proved to have significantly higher concentrations of phosphorus, potassium, and magnesium than undisturbed soils (Tables 42, 43, and 44). Grand means are given below:

	Mined	Unmined
P	23 ± 1.1 ppm	2 ± 0.2 ppm
K	136 ± 2.5 ppm	42 ± 1.4 ppm
Mg	1317 ± 17.2 ppm	42 ± 2.0 ppm.

Sources of high levels of magnesium in minesoils are not known, but are probably associated with clay mineralogy.

When base saturation exceeds 80%, a possibility of high salinity conditions is indicated. The grand mean concentration of sodium in minesoils was 117 ± 7.2 ppm; although significantly higher than in undisturbed soil, this level is insufficient to cause a salinity problem (Table 45). Low sodium concentrations in the face of a highly elevated base saturation is further indication that soil solutions were probably dominated by calcium compounds. The grand mean for sodium in undisturbed plots was 9 ± 0.3 ppm.

Availability of exchangeable micronutrient heavy metals is closely tied to pH, with toxicity levels developing below pH 3.0. At time of measurement, the exchangeable

Table 42. Soil extractable phosphorus (P) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN P CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	23 ± 0.7	(1)
	#2	23 ± 1.7	(1)
	#3	22 ± 0.8	(1)
Unmined	#1	3 ± 0.2	(2)
	#2	2 ± 0.1	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	2895.524	723.881	28.12**
Residual	25	643.666	25.747	
Total	29	3539.190		

** Significant at the 0.01 level of probability.

Table 43. Soil exchangeable potassium (K) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN K CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	138 ± 1.5	(1)
	#2	130 ± 1.6	(1)
	#3	141 ± 5.0	(1)
Unmined	#1	40 ± 2.0	(2)
	#2	43 ± 0.7	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	64818.0	16204.5	78.40**
Residual	25	5167.5	206.7	
Total	29	69985.5		

** Significant at the 0.01 level of probability.

Table 44. Soil exchangeable magnesium (Mg) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN Mg CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	1294 ± 16.1	(1)
	#2	1286 ± 19.1	(1)
	#3	1372 ± 16.4	(1)
Unmined	#1	33 ± 2.8	(2)
	#2	52 ± 1.3	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	11728602.0	2932150.0	540.86**
Residual	25	135532.6	5421.3	
Total	29	11864134.6		

** Significant at the 0.01 level of probability.

Table 45. Soil exchangeable sodium (Na) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN Na CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	109 ± 10.8	(1)
	#2	131 ± 4.1	(1)
	#3	110 ± 6.7	(1)
Unmined	#1	10 ± 0.5	(2)
	#2	9 ± 0.2	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	84659.9	21165.0	19.75**
Residual	25	26788.0	1071.5	
Total	29	111447.9		

** Significant at the 0.01 level of probability.

cations, manganese, zinc, and copper were available in mined and undisturbed soils at Martin Lake in optimum concentrations. Grand means are given below:

	Mined	Unmined
Mn	21 ± 1.2 ppm	92 ± 5.9 ppm
Zn	14 ± 0.2 ppm	14 ± 0.5 ppm
Cu	4 ± 0.7 ppm	3 ± 0.4 ppm.

Significantly lower concentrations of manganese were recorded in minesoils, but no differences were found for zinc and copper between undisturbed and mined sites (Tables 46, 47, and 48).

Significantly higher levels of combustible organics recorded in minesoils were due in major portion to included coal partings (Table 49). It is unclear how these partings may add to the CEC of soil, but without humic acid chains present in normal soil organic matter, benefits are probably minimal. Due to complement of oxidizable sulfur, any humus advantages gained by their presence are probably offset by acid-producing potential.

Hossner et al. (1980) have found the primary clays present in Wilcox formation overburden to be kaolinite and chlorite. The CEC of minesoils at Martin Lake were similar to those normally experienced in soils containing these clays. The average CEC was 9.74 ± 0.727 meq/100g on mined, and 4.86 ± 0.310 meq/100g on undisturbed sites, with

Table 46 . Soil exchangeable manganese (Mn) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN Mn CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	22 ± 0.9	(2)
	#2	20 ± 1.1	(2)
	#3	22 ± 1.4	(2)
Unmined	#1	106 ± 9.1	(1)
	#2	78 ± 2.6	(1)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	38656.1	9664.0	17.01**
Residual	25	14200.7	568.0	
Total	29	52856.8		

** Significant at the 0.01 level of probability.

Table 47. Soil exchangeable zinc (Zn) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN Zn CONCENTRATION ± STANDARD ERROR (ppm)	TUKEY'S COMPARISON (0.05)
Mined	#1	14 ± 0.2	(1,2)
	#2	12 ± 0.3	(1,2)
	#3	15 ± 0.1	(1,2)
Unmined	#1	16 ± 0.4	(1)
	#2	12 ± 0.7	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	73.867	18.467	3.86*
Residual	25	119.500	4.780	
Total	29	193.367		

Table 48. Soil exchangeable copper (Cu) concentration for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN Cu CONCENTRATION ± STANDARD ERROR (ppm)
Mined	#1	3 ± 0.8
	#2	4 ± 0.6
	#3	4 ± 0.8
Unmined	#1	1 ± 0.3
	#2	4 ± 0.5

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	38.533	9.633	0.77^{NS}
Residual	25	310.833	12.433	
Total	29	349.366		

NS - Not significant for at least the 0.05 level of probability.

Table 49. Soil organic matter (OM) content for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN OM CONTENT ± STANDARD ERROR (%)	TUKEY'S COMPARISON (0.05)
Mined	#1	7.21 ± 0.118	(1)
	#2	6.61 ± 0.131	(1)
	#3	6.60 ± 0.145	(1)
Unmined	#1	1.74 ± 0.097	(2)
	#2	2.00 ± 0.064	(2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	177.183	44.296	112.29**
Residual	25	9.862	0.394	
Total	29	187.045		

** Significant at the 0.01 level of probability.

the minesoil being significantly higher (Table 50).

All samples of minesoil were clay loams with nearly equal proportions of sand, silt, and clay (Appendix Table 2). This texture produces a heavy, plastic soil that is easily eroded by running water. A characteristic feature of these minesoils is the tendency to form a deep, hard crust when an exposed surface dries (Figure 23). The undisturbed soils were typical sandy loams, loamy sands, or sandy clay loams.

Evaluation of Field Tests on Minesoils

One factor which had marked influence on establishment of shortleaf pine seedlings at Martin Lake during the 1979 season was precipitation pattern, both in quantity and seasonal distribution. Records of monthly precipitation from two reporting stations near Martin Lake are presented below (National Climatic Center, 1979):

	Longview, TX	Carthage, TX
Mar.	15.5 cm	17.2 cm
Apr.	15.9	10.3
May	16.7	21.6
Jun.	7.9	12.3
Jul.	20.8	12.8
Aug.	2.1	2.4
Sep.	21.2	22.3
Oct.	11.6	7.2
Nov.	6.8	12.7
Totals	118.4 cm	118.8 cm.

Note that over 48 cm (18.9 in.) of precipitation fell in

Table 50. Soil cation exchange capacity (CEC) for plots on mined and undisturbed sites at Martin Lake.

PLOT		MEAN CEC ± STANDARD ERROR (meq/100g)	TUKEY'S COMPARISON (0.05)
Mined	#1	8.86 ± 0.745	(1,2)
	#2	10.79 ± 0.842	(1)
	#3	9.58 ± 0.594	(1)
Unmined	#1	3.44 ± 0.189	(2)
	#2	6.28 ± 0.429	(1,2)

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Plots	4	207.713	51.928	4.71**
Residual	25	275.568	11.023	
Total	29	483.281		

** Significant at the 0.01 level of probability.

Figure 23. Minesoil at Martin Lake -- note deep, hard crust that forms as surface dries.

the early spring season, and as much as 30.8 cm (12.1 in.) of rainfall was received in mid-summer.

Heavy precipitation contributed to another condition which had severe detrimental effects on survival and growth of shortleaf pine seedlings at Martin Lake. This condition was the encroachment and subsequent bloom of growth by coastal bermudagrass and crimson clover (*Trifolium incarnatum* L.) on study plots. Although at the time plots were installed most areas were essentially void of vegetation, coastal bermudagrass had been sprigged over the area the previous season, but had not become established due to droughty conditions during spring and summer, 1978. Apparently, past sprigging of coastal bermudagrass and natural seeding of crimson clover caused invasion of study plots by their species, which in some areas produced a mat of vegetation approximately 25-50 cm deep around tree seedlings.

Limstrom (1960) recognized two classes of ground cover on coal spoils: 1) *heavy*, which completely shades or over-tops 50 percent or more of planted seedlings during the first growing season, and 2) *light*, which completely shades or overtops less than 50 percent. Light vegetation protects seedlings from dessication by drying winds, improves soil conditions, and reduces soil losses from erosion. On the other hand, heavy vegetation competes excessively for moisture, nutrients and light -- dense cover also encourages high rodent populations, particularly rabbit and gopher, which can be extremely damaging to young seedlings (Walker and Perkins, 1958).

Ground cover which developed on the three mined plots was heavy, while cover on both undisturbed plots was light. However, a population of pocket gophers (Geomys spp.) was evident on unmined plot #1, contributing substantially to seedling mortality. Most seedling mortality on mined and unmined sites was directly attributable to competition with dense ground cover vegetation or its attendant rodent population; and growth and development of surviving plants was impeded by competition, especially on mined plots.

Growth parameters. At the time of planting, containerized seedlings had 447% more ectomycorrhizal short roots -- which had been produced by P. tinctorius -- than 1-0 nursery-grown bare-root seedlings, by means comparison. Overall, containerized seedlings experienced 54% better survival, again by means comparison, than bare-root seedlings on all plots. The grand mean for survival of containerized seedlings, with better developed mycorrhizae, was 62.32%, while bare-root seedlings had 40.45%. All treatments of containerized seedlings, except the cultured mycelial inoculation, produced significantly superior survival than all treatments of bare-root seedlings (Table 51). On mined plots only, containerized seedlings had 101% better survival than bare-root seedlings, by means comparison -- containerized seedlings registered 55.25% overall survival on mined plots, and bare-root seedlings had 27.42%. On unmined plots overall survival for containerized seedlings was 72.92%, and 60.00% for bare-root seedlings -- which were far more attractive to pocket gophers. Inoculation treatments of nursery-grown seedlings had no significant effect on survival, height growth, or root collar diameter growth.

Generally, survival for all seedlings was much better on unmined than mined plots. Grand mean for survival on the mine was 43.33%, and 67.38% on unmined sites. Statistically, the two poorest plots for survival were on the mine, and the best plot was on an undisturbed area.

There was little difference in height growth between containerized and bare-root seedlings, although the containerized basidiospore/vermiculite inoculation had best growth, and the bare-root nursery-stock control had worst (Table 52). Generally, all treatments responded with good height growth with an overall mean of 17.62 cm for containerized seedlings and 13.45 cm for bare-root. All seedlings produced significantly better height growth on undisturbed sites than on the mine. The grand mean for unmined plots was 25.69 cm, with 9.26 cm for mined areas (See Figures

Table 51. First season survival for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP		MEAN SURVIVAL (%)	TUKEY'S COMPARISON (0.05)
Containerized Cultured Mycelial Inoculation		56.66	(1,2)
Containerized Basidiospore/ Vermiculite Inoculation		66.00	(1)
Containerized Seedcoat Basidiospore Inoculation		64.66	(1)
Containerized Control		61.98	(1)
Bare-root Basidiospore/ Vermiculite Inoculation		34.00	(2)
Bare-root Cultured Mycelial Inoculation		40.68	(2)
Bare-root Nursery Stock Control		46.68	(2)
Mined plot	#1	30.00	(3)
	#2	62.84	(1,2)
	#3	37.14	(3)
Unmined plot	#1	55.71	(2)
	#2	79.06	(1)

(continued)

Table 51. Continued.

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	4758.499	793.083	2.81*
Plots	4	10945.626	2736.406	9.70**
Residual	24	6771.395	282.141	
Total	34	22475.520		

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.

Table 52. First season height growth for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (cm) W/TUKEY'S COMPARISON (0.05)	PLOT		MEAN HEIGHT (cm)
Containerized Cultured Mycelial Inoculation	16.94 (1,2)	Mined	#1	8.52
			#2	7.82
			#3	13.30
		Unmined	#1	30.04
			#2	25.00
Containerized Basidiospore/ Vermiculite Inoculation	18.64 (1)	Mined	#1	11.76
			#2	10.34
			#3	17.34
		Unmined	#1	30.30
			#2	23.46
Containerized Seedcoat Basidiospore Inoculation	17.10 (1,2)	Mined	#1	8.06
			#2	8.60
			#3	10.56
		Unmined	#1	30.68
			#2	27.60
Containerized Control	17.79 (1,2)	Mined	#1	6.54
			#2	7.22
			#3	14.24
		Unmined	#1	31.34
			#2	29.60
Bare-root Basidiospore/ Vermiculite Inoculation	13.34 (1,2)	Mined	#1	8.30
			#2	7.48
			#3	8.34
		Unmined	#1	23.42
			#2	19.16
Bare-root Cultured Mycelial Inoculation	14.32 (1,2)	Mined	#1	6.52
			#2	7.34
			#3	14.10
		Unmined	#1	26.96
			#2	16.70

(continued)

Table 52. Continued.

TREATMENT GROUP	TREATMENT MEAN (cm) W/TUKEY'S COMPARISON (0.05)	PLOT		MEAN HEIGHT (cm)
Bare-root Nursery Stock Control	12.69 (2)	Mined	#1	2.00
			#2	5.10
			#3	10.98
		Unmined	#1	29.42
			#2	15.96
Plot mean W/Tukey's Comparison (0.05)	(4)	Mined	#1	7.39
	(4)		#2	7.70
	(3)		#3	12.69
	(1)	Unmined	#1	28.88
	(2)		#2	22.50

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	822.028	137.005	3.63**
Plots	4	12669.590	3167.397	83.90**
T x P	24	865.539	36.064	0.96^{NS}
Residual	140	5285.297	37.752	
Total	174	19642.453		

** Significant at the 0.01 level of probability.
NS Not significant for at least the 0.05 level of probability.

24 and 25.

Root collar diameter growth for all seedlings was poor. The grand mean for containerized seedlings was 1.79 mm, and 2.67 mm for bare-root seedlings. Treatment and plot effects were both highly significant, but a highly significant treatment/plot interaction prevented any meaningful statistical breakdown of these effects (Table 53). Although not statistically demonstrable, root collar diameter growth for unmined plots, with an overall mean of 2.61 mm, was better than mined plots, with 1.87 mm.

Foliar analyses. First season foliage total nitrogen concentrations for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake were low, and may have been growth-limiting. There were no significant differences among treatment means, but nitrogen contents for all seedlings planted on unmined sites were significantly higher than for mined sites (Table 54). The grand mean for total nitrogen content was 0.99% -- plants on the mine averaged 0.75%, and those on undisturbed sites 1.38%.

Highly significant interaction between treatments and plots was found for phosphorus concentrations in foliage of all seedlings after the first season (Table 55). This precluded a statistical breakdown of treatment and plot effects, which were themselves highly significant. The

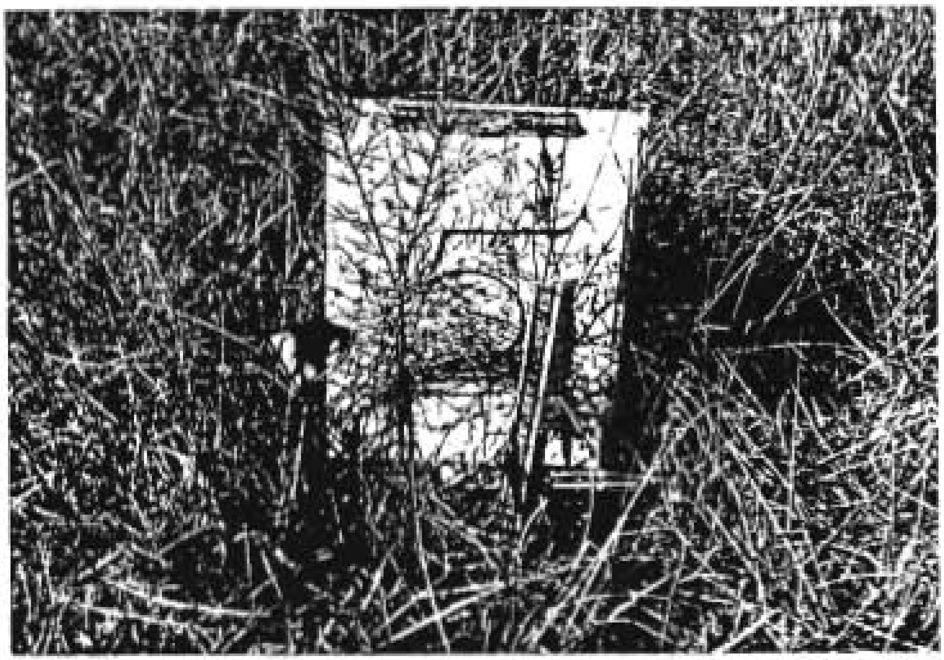

Figure 24a. Shortleaf pine seedling from the containerized basidiospore/vermiculite treatment, after the first growing season on mined plot #3 at Martin Lake.

Figure 24b. Shortleaf pine seedling from the containerized control treatment, after the first growing season on mined plot #1.

Figure 25a. Shortleaf pine seedling from the containerized cultured mycelia treatment, after first growing season on unmined plot #1 at Martin Lake.

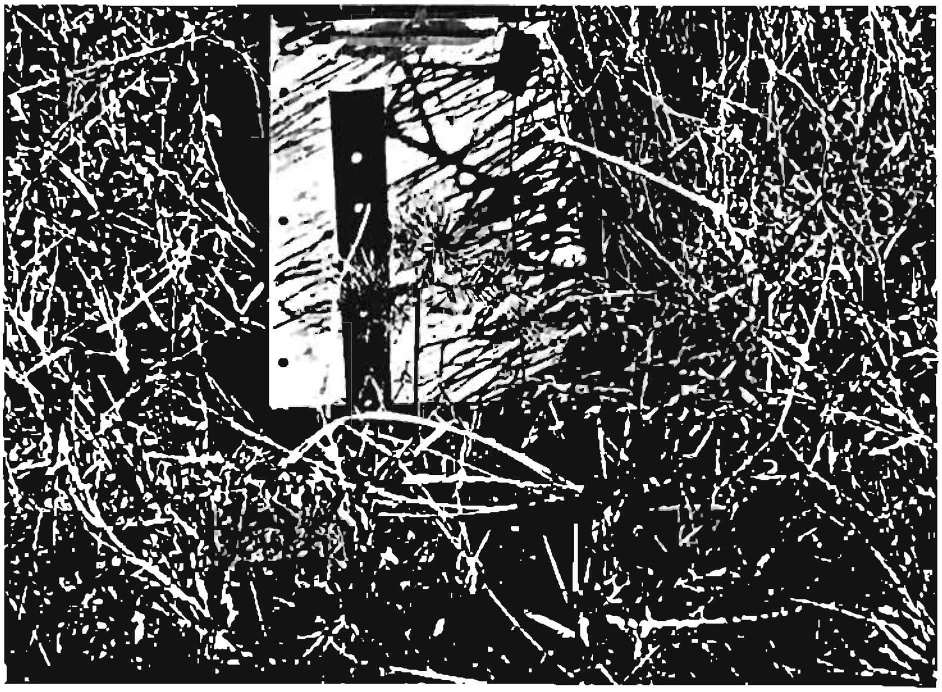

Figure 25b. Shortleaf pine seedling from the bare-root cultured mycelia inoculation, after first growing season on unmined plot #2.

Table 53. First season root collar diameter growth for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT	TREATMENT MEAN (mm)	PLOT		MEAN DIAMETER (mm)
Containerized Cultured Mycelial Inoculation	1.57	Mined	#1	1.12
			#2	1.68
			#3	1.95
		Unmined	#1	1.81
			#2	1.31
Containerized Basidiospore Vermiculite Inoculation	1.90	Mined	#1	2.12
			#2	1.88
			#3	2.06
		Unmined	#1	2.07
			#2	1.38
Containerized Seedcoat Basidiospore Inoculation	2.04	Mined	#1	2.07
			#2	1.26
			#3	1.92
		Unmined	#1	2.32
			#2	1.96
Containerized Control	1.64	Mined	#1	1.52
			#2	1.80
			#3	1.06
		Unmined	#1	1.80
			#2	2.04
Bare-root Basidiospore/ Vermiculite Inoculation	2.89	Mined	#1	2.12
			#2	2.24
			#3	1.96
		Unmined	#1	3.56
			#2	4.57
Bare-root Cultured Mycelial Inoculation	2.46	Mined	#1	2.30
			#2	2.04
			#3	1.56
		Unmined	#1	2.85
			#2	3.53

(continued)

Table 53. Continued.

TREATMENT	TREATMENT MEAN (mm)	PLOT	MEAN DIAMETER (mm)
Bare-root Nursery Stock Control	2.65	Mined #1	1.81
		#2	1.78
		#3	2.38
		Unmined #1	3.99
		#2	3.30
Plot mean		Mined #1	1.96
		#2	1.81
		#3	1.84
		Unmined #1	2.63
		#2	2.59

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	38.867	6.479	7.38**
Plots	4	23.214	5.804	6.61**
T x P	24	45.627	1.901	2.17**
Residual	140	122.917	0.878	
Total	174	230.626		

** Significant at the 0.01 level of probability.

Table 54. First season foliage nitrogen (N) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (%)	PLOT	MEAN N CONCENTRATION (%)
Containerized Cultured Mycelial Inoculation	1.04	Mined #1	0.62
		#2	0.76
		#3	0.74
		Unmined #1	1.26
		#2	1.87
Containerized Basidiospore/ Vermiculite Inoculation	1.00	Mined #1	0.88
		#2	0.82
		#3	0.72
		Unmined #1	1.22
		#2	1.38
Containerized Seedcoat Basidiospore Inoculation	0.97	Mined #1	0.66
		#2	0.70
		#3	0.80
		Unmined #1	1.32
		#2	1.38
Containerized Control	0.92	Mined #1	0.64
		#2	0.60
		#3	0.71
		Unmined #1	1.30
		#2	1.31
Bare-root Basidiospore/ Vermiculite Inoculation	1.13	Mined #1	0.89
		#2	0.88
		#3	0.93
		Unmined #1	1.53
		#2	1.44
Bare-root Cultured Mycelial Inoculation	0.99	Mined #1	0.80
		#2	0.80
		#3	0.75
		Unmined #1	1.29
		#2	1.31

(continued)

Table 54. Continued.

TREATMENT GROUP	TREATMENT MEAN (%)	PLOT		MEAN N CONCENTRATION (%)
Bare-root Nursery Stock Control	0.94	Mined	#1	0.70
			#2	0.73
			#3	0.69
		Unmined	#1	1.30
			#2	1.30
Plot mean W/Tukey's Comparison (0.05)	(2)	Mined	#1	0.74
	(2)		#2	0.76
	(2)		#3	0.76
	(1)	Unmined	#1	1.32
	(1)		#2	1.43

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	0.317	0.053	2.14[NS]
Plots	4	6.512	1.628	65.91**
T x P	24	0.622	0.026	1.05[NS]
Residual	35	0.864	0.025	
Total	69	8.316		

[NS] Not significant for at least the 0.05 level of probability.

** Significant at the 0.01 level of probability.

Table 55. First season foliage phosphorus (P) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT		MEAN P CONCENTRATION (ppm)
Containerized Cultured Mycelial Inoculation	174	Mined	#1	205
		M	#2	192
			#3	215
		Unmined	#1	149
			#2	109
Containerized Basidiospore/ Vermiculite Inoculation	189	Mined	#1	231
			#2	232
			#3	233
		Unmined	#1	121
			#2	130
Containerized Seedcoat Basidiospore Inoculation	168	Mined	#1	206
			#2	214
			#3	208
		Unmined	#1	99
			#2	114
Containerized Control	200	Mined	#1	235
			#2	231
			#3	225
		Unmined	#1	147
			#2	161
Bare-root Basidiospore/ Vermiculite Inoculation	175	Mined	#1	187
			#2	203
			#3	197
		Unmined	#1	172
			#2	117
Bare-root Cultured Mycelial Inoculation	192	Mined	#1	266
			#2	217
			#3	233
		Unmined	#1	117
			#2	131

(continued)

Table 55. Continued.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT	MEAN P CONCENTRATION (ppm)
Bare-root Nursery Stock Control	200	Mined #1	237
		#2	234
		#3	250
		Unmined #1	146
		#2	134
Plot mean		Mined #1	224
		#2	218
		#3	223
		Unmined #1	136
		#2	128

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	10265.371	1710.895	7.17**
Plots	4	135472.759	33868.191	141.86**
T x P	24	15833.688	659.737	2.76**
Residual	35	8356.000	238.743	
Total	69	169927.812		

** Significant at the 0.01 level of probability.

grand mean for foliar phosphorus concentration was 185 ppm; somewhat higher than the average concentration at time of planting, but still probably growth-limiting, both on mined and undisturbed sites. For plants on the mine, the average foliar concentration of phosphorus was 222 ppm, and on undisturbed sites 132 ppm. These higher levels on the mine reflect nearly 10 times greater concentration of extractable soil phosphorus found in minesoils as compared with unmined soils.

Potassium concentrations were significantly higher in seedlings grown on unmined than on mined plots (Table 56). The grand mean for foliar concentrations of potassium was 5919 ppm, with an average of 6943 ppm for plants on undisturbed sites and 5236 ppm for mined areas. Since exchangeable potassium concentrations were higher in mined than in undisturbed soils, no explanation for higher levels in foliage from plants grown on reclaimed spoils is obvious. However, potassium levels in all plants were high, and probably not limiting to growth on either area.

Minesoil concentrations of exchangeable calcium were more than 10 times concentrations in undisturbed soils, but foliar levels of calcium in shortleaf pine seedlings after one season of growth did not reflect this difference to the degree expected. Some significant differences among plots on and off the mine were found, but not in every case

Table 56. First season foliage potassium (K) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (ppm) W/TUKEY'S COMPARISON (0.05)	PLOT	MEAN K CONCENTRATION (ppm)
Containerized Cultured Mycelial Inoculation	5884 (1,2)	Mined #1	4085
		#2	5615
		#3	4045
		Unmined #1	7895
		#2	7780
Containerized Basidiospore/ Vermiculite Inoculation	6512 (1,2)	Mined #1	6635
		#2	5960
		#3	6900
		Unmined #1	6520
		#2	6545
Containerized Seedcoat Basidiospore Inoculation	7087 (1)	Mined #1	7700
		#2	6575
		#3	5690
		Unmined #1	7730
		#2	7740
Containerized Control	5398 (2)	Mined #1	5130
		#2	5130
		#3	5380
		Unmined #1	5080
		#2	6270
Bare-root Basidiospore/ Vermiculite Inoculation	5601 (1,2)	Mined #1	4160
		#2	4685
		#3	4640
		Unmined #1	7460
		#2	7060
Bare-root Cultured Mycelial Inoculation	5258 (2)	Mined #1	4590
		#2	3810
		#3	4210
		Unmined #1	6660
		#2	7020

(continued)

Table 56. Continued.

TREATMENT GROUP	TREATMENT MEAN (ppm) W/TUKEY'S COMPARISON (0.05)	PLOT		MEAN K CONCENTRATION (ppm)
Bare-root Nursery Stock Control	5694 (1,2)	Mined	#1	4310
			#2	4310
			#3	6400
		Unmined	#1	7500
			#2	5950
Plot mean W/Tukey's comparison (0.05)	(2)	Mined	#1	5230
	(2)		#2	5155
	(2)		#3	5324
	(1)	Unmined	#1	6978
	(1)		#2	6909

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	25772088.6	4295348.0	3.16*
Plots	4	49207148.6	12301787.0	9.05**
T x P	24	40848192.0	1702008.0	1.25 NS
Residual	35	47551360.0	1358610.0	
Total	69	163378800.0		

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.
NS Not significant for at least the 0.05 level of probability.

(Table 57). The grand mean for foliar concentrations of calcium was 2071 ppm -- no significant differences were calculated among treatment means.

Magnesium and sodium concentrations were significantly higher in seedlings grown on mined than on unmined sites (Tables 58 and 59). These results compare with soil exchange levels. The grand mean for magnesium was 1828 ppm, and 851 ppm for sodium -- both being in normal ranges for thrifty pine growth.

No significant differences among treatment means or plot means were found for foliar concentrations of manganese or zinc (Tables 60 and 61). Only trace amounts of copper were detectable in all seedlings after the first growing season (see Appendix Table 13). The grand mean for manganese was 473 ppm, and zinc averaged overall 23 ppm. Manganese and zinc were found in optimum concentrations; low levels of copper may have been growth-limiting.

Ash contents for all seedlings were normal. Although significant differences among treatment and plot means were computed, they were not diagnostic (Table 62).

Table 57. First season foliage calcium (Ca) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT	MEAN Ca CONCENTRATION (ppm)
Containerized Cultured Mycelial Inoculation	2295	Mined #1	2888
		#2	3050
		#3	1788
		Unmined #1	2000
		#2	1750
Containerized Basidiospore/ Vermiculite Inoculation	2020	Mined #1	2800
		#2	2050
		#3	1600
		Unmined #1	2200
		#2	1450
Containerized Seedcoat Basidiospore Inoculation	2155	Mined #1	2525
		#2	2350
		#3	2500
		Unmined #1	1750
		#2	1650
Containerized Control	2070	Mined #1	2650
		#2	2000
		#3	2650
		Unmined #1	1500
		#2	1550
Bare-root Basidiospore/ Vermiculite Inoculation	1900	Mined #1	1950
		#2	2000
		#3	2050
		Unmined #1	1850
		#2	1650
Bare-root Cultured Mycelial Inoculation	1980	Mined #1	2525
		#2	1800
		#3	1800
		Unmined #1	180C
		#2	1975

(continued)

Table 57. Continued.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT		MEAN Ca CONCENTRATION (ppm)
Bare-root Nursery Stock Control	2077	Mined	#1	2750
			#2	2437
			#3	2450
		Unmined	#1	1650
			#2	1100
Plot mean W/Tukey's comparison (0.05)	(1)	Mined	#1	2584
	(1,2)		#2	2241
	(2)		#3	2120
	(2,3)	Unmined	#1	1821
	(3)		#2	1589

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	973982.1	162330.4	0.92^{NS}
Plots	4	8242089.3	2060522.0	11.69**
T x P	24	5847526.0	243646.9	1.38^{NS}
Residual	35	6167187.0	176205.3	
Total	69	21230784.0		

NS Not significant for at least the 0.05 level of probability

** Significant at the 0.01 level of probability.

Table 58. First season foliage magnesium (Mg) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (ppm) W/TUKEY'S COMPARISON (0,05)	PLOT		MEAN Mg CONCENTRATION (ppm)
Containerized Cultured Mycelial Inoculation	2132 (1)	Mined	#1	3100
			#2	3312
			#3	2750
		Unmined	#1	762
			#2	738
Containerized Basidiospore/ Vermiculite Inoculation	1550 (2)	Mined	#1	1750
			#2	2150
			#3	2150
		Unmined	#1	825
			#2	875
Containerized Seedcoat Basidiospore Inoculation	1987 (1,2)	Mined	#1	2688
			#2	2775
			#3	2700
		Unmined	#1	850
			#2	925
Containerized Control	1652 (1,2)	Mined	#1	2325
			#2	2250
			#3	1962
		Unmined	#1	825
			#2	900
Bare-root Basidiospore/ Vermiculite Inoculation	1727 (1,2)	Mined	#1	2012
			#2	2400
			#3	2500
		Unmined	#1	895
			#2	830
Bare-root Cultured Mycelial Inoculation	1785 (1,2)	Mined	#1	2450
			#2	2225
			#3	2300
		Unmined	#1	975
			#2	975

(continued)

Table 58. Continued.

TREATMENT GROUP	TREATMENT MEAN (ppm) W/TUKEY'S COMPARISON (0.05)	PLOT	MEAN Mg CONCENTRATION (ppm)
Bare-root Nursery Stock Control	1960 (1,2)	Mined #1	2350
		#2	2900
		#3	2825
		Unmined #1	795
		#2	930
Plot Mean W/Tukey's Comparison (0.05)	(1)	Mined #1	2382
	(1)	#2	2573
	(1)	#3	2455
	(2)	Unmined #1	847
	(2)	#2	882

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	2556178.6	426029.8	3.02*
Plots	4	43597326.5	10899332.0	77.27**
T x P	24	3432752.0	143031.3	1.01^{NS}
Residual	35	4937073.0	141059.2	
Total	69	54523344.0		

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.
NS Not significant for at least the 0.05 level or probability.

Table 59. First season foliage sodium (Na) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT		MEAN Na CONCENTRATION (ppm)
Containerized Cultured Mycelial Inoculation	882	Mined	#1	1545
			#2	1015
			#3	1390
		Unmined	#1	75
			#2	85
Containerized Badisiospore/ Vermiculite Inoculation	408	Mined	#1	875
			#2	750
			#3	220
		Unmined	#1	100
			#2	95
Containerized Seedcoat Basidiospore Inoculation	1160	Mined	#1	2625
			#2	1885
			#3	985
		Unmined	#1	265
			#2	40
Containerized Control	899	Mined	#1	2035
			#2	1240
			#3	975
		Unmined	#1	90
			#2	155
Bare-root Basidiospore/ Vermiculite Inoculation	530	Mined	#1	1165
			#2	785
			#3	525
		Unmined	#1	80
			#2	95
Bare-root Cultured Mycelial Inoculation	1044	Mined	#1	1885
			#2	1855
			#3	1285
		Unmined	#1	92
			#2	102

(continued)

Table 59. Continued.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT	MEAN Na CONCENTRATION (ppm)
Bare-root Nursery Stock Control	1031	Mined #1	1445
		#2	2230
		#3	1335
		Unmined #1	55
		#2	90
Plot mean W/Tukey's Comparison (0.05)	(1)	Mined #1	1654
	(1,2)	#2	1394
	(2)	#3	959
	(3)	Unmined #1	108
	(3)	#2	95

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	4669980.0	778330.0	2.21 NS
Plots	4	29041709.3	7260427.0	20.62**
T x P	24	6037824.0	251576.0	0.71 NS
Residual	35	12322574.0	352073.5	
Total	69	52072096.0		

NS Not significant for at least the 0.05 level of probability.
** Significant at the 0.01 level of probability.

Table 60. First season foliage manganese (Mn) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT		MEAN Mn CONCENTRATION (ppm)
Containerized Cultured Mycelial Inoculation	376	Mined	#1	405
			#2	330
			#3	395
		Unmined	#1	365
			#2	385
Containerized Basidiospore/ Vermiculite Inoculation	449	Mined	#1	445
			#2	465
			#3	510
		Unmined	#1	440
			#2	385
Containerized Seedcoat Basidiospore Inoculation	450	Mined	#1	430
			#2	520
			#3	560
		Unmined	#1	330
			#2	410
Containerized Control	536	Mined	#1	510
			#2	410
			#3	370
		Unmined	#1	670
			#2	720
Bare-root Basidiospore/ Vermiculite Inoculation	434	Mined	#1	560
			#2	200
			#3	460
		Unmined	#1	500
			#2	450
Bare-root Cultured Mycelial Inoculation	537	Mined	#1	590
			#2	600
			#3	330
		Unmined	#1	775
			#2	390

(continued)

Table 60. Continued.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT	MEAN Mn CONCENTRATION (ppm)
Bare-root Nursery Stock Control	532	Mined #1	510
		#2	520
		#3	500
		Unmined #1	560
		#2	570
Plot mean		Mined #1	493
		#2	435
		#3	446
		Unmined #1	520
		#2	473

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	235797.1	39299.5	1.74^{NS}
Plots	4	66534.3	16633.6	0.74^{NS}
T x P	24	630843.6	26285.1	1.16^{NS}
Residual	35	791400.0	22611.4	
Total	69	1724575.0		

NS Not significant for at least the 0.05 level of probability.

Table 61. First season foliage zinc (Zn) concentration for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT	MEAN Zn CONCENTRATION (ppm)
Containerized Cultured Mycelial Inoculation	22	Mined #1	10
		#2	18
		#3	22
		Unmined #1	30
		#2	30
Containerized Basidiospore/ Vermiculite Inoculation	25	Mined #1	22
		#2	22
		#3	20
		Unmined #1	32
		#2	28
Containerized Seedcoat Basidiospore Inoculation	22	Mined #1	18
		#2	18
		#3	12
		Unmined #1	30
		#2	32
Containerized Control	25	Mined #1	35
		#2	18
		#3	18
		Unmined #1	28
		#2	28
Bare-root Basidiospore/ Vermiculite Inoculation	22	Mined #1	20
		#2	28
		#3	25
		Unmined #1	18
		#2	20
Bare-root Cultured Mycelial Inoculation	21	Mined #1	18
		#2	20
		#3	20
		Unmined #1	20
		#2	28

(continued)

Table 61. Continued.

TREATMENT GROUP	TREATMENT MEAN (ppm)	PLOT	MEAN Zn CONCENTRATION (ppm)
Bare-root Nursery Stock Stock Control	26	Mined #1	25
		#2	30
		#3	28
		Unmined #1	22
		#2	22
Plot mean		Mined #1	21
		#2	22
		#3	21
		Unmined #1	26
		#2	27

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	209.286	34.881	0.67^{NS}
Plots	4	446.429	111.607	2.16^{NS}
T x P	24	1733.563	72.232	1.39^{NS}
Residual	35	1812.500	51.786	
Total	69	4201.777		

NS Not significant for at least the 0.05 level of probability.

Table 62. First season foliage ash content for containerized and bare-root shortleaf pine seedlings planted on mined and undisturbed sites at Martin Lake.

TREATMENT GROUP	TREATMENT MEAN (%) W/TUKEY'S COMPARISON (0.05)	PLOT		MEAN ASH CONTENT (%)
Containerized Cultured Mycelial Inoculation	2.6 (1,2)	Mined	#1	2.8
			#2	3.0
			#3	2.0
		Unmined	#1	2.4
			#2	2.6
Containerized Basidiospore/ Vermiculite Inoculation	2.5 (1,2)	Mined	#1	2.5
			#2	2.8
			#3	2.4
		Unmined	#1	2.6
			#2	2.3
Containerized Seedcoat Basidiospore Inoculation	2.8 (1)	Mined	#1	2.8
			#2	3.2
			#3	3.0
		Unmined	#1	2.4
			#2	2.6
Containerized Control	2.4 (2,3)	Mined	#1	2.4
		Mined	#2	2.6
			#3	2.3
		Unmined	#1	2.4
			#2	2.2
Bare-root Basidiospore/ Vermiculite Inoculation	2.1 (3)	Mined	#1	1.8
			#2	2.3
			#3	1.6
		Unmined	#1	2.3
			#2	2.5
Bare-root Cultured Mycelial Inoculation	2.4 (1,2,3)	Mined	#1	2.4
			#2	2.5
			#3	2.4
		Unmined	#1	2.5
			#2	2.4

(continued)

Table 62. Continued.

TREATMENT GROUP	TREATMENT MEAN (%) W/TUKEY'S COMPARISON (0.05)	PLOT		MEAN ASH CONTENT (%)
Bare-root Nursery Stock Control	2.6 (1,2)	Mined	#1	2.5
			#2	2.8
			#3	2.8
		Unmined	#1	2.4
			#2	2.2
Plot mean W/Tukey's Comparison (0.05)	(1,2)	Mined	#1	2.4
	(1)		#2	2.7
	(2)		#3	2.4
	(1,2)	Unmined	#1	2.4
	(2)		#2	2.4

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-ratio
Treatments	6	2.538	0.423	5.90**
Plots	4	1.157	0.289	4.03**
T x P	24	2.549	0.106	1.48^{NS}
Residual	35	2.510	0.072	
Total	69	8.754		

** Significant at the 0.01 level of probability.
NS Not significant for at least the 0.05 level of probability.

SUMMARY AND CONCLUSIONS

This study demonstrated that artificial inoculation of containerized shortleaf pine seedlings with P. tinctorius propagules will produce abundant ectomycorrhizae on root systems. Basidiospores of P. tinctorius were found to be as effective a source of inoculum for containerized shortleaf pine seedlings as mass-cultured vegetative mycelia. Use of basidiospores proved far less consumptive of time and materials than cultured mycelia. Spores were easily applied to growing media and may be stored for long periods at low temperatures.

The Styroblock-8® containerization system used in this study, in conjunction with sandy loam soil/vermiculite (2:1 v/v) potting-mix produced excellent quality shortleaf pine seedlings. The "root plugs" were easily handled and planted. The container cavities produced root systems with strong primary and secondary lateral root development, offering luxuriant sites for mycorrhizae formation. No deleterious root aberrations were produced by the styro-blocks. Although the containerized shortleaf pine seedlings had low biomass, the root/shoot ratio was significantly better, in most cases, than 1-0 nursery-grown bare-root seedlings, and the quantity of ectomycorrhizae functioning on root systems was far greater.

There were no indications that foliar concentrations of N, P, K, Ca, Mg, Na, Mn, Zn, or Cu accumulated in containerized seedlings were influenced by degree of mycorrhizae development. Calcium accumulation in needles may have been affected by the quantity of _P. tinctorius_ inoculum present in the rooting medium.

Concentrations of N, P, K, Ca, Mg, Na, Mn, Zn, and Cu in lateral roots were determined, and some indications were found that high levels of sodium and silicon accumulated in lateral roots may retard ectomycorrhizae formation. Magnesium concentrations in lateral roots also may have been influenced by the quantity of _P. tinctorius_ inoculum present in the rooting medium.

The fixation procedures employed for ultrastructural examination of ectomycorrhizal short roots from shortleaf pine seedlings were quite effective -- the common problems caused by section disruption due to tannin crystallization were overcome. Transmission electron photomicrographs revealed that a Basidiomycete and another fungus were mycotrophic, full Hartig-net and mantle development were common, and apparent host and mycobiont physiological activity was positively influenced by intimate symbiotic relationship. Evolution of mycorrhizae progressed from an obvious infection process at the host epidermis and outer cortical cells, to a balanced symbiosis in the Hartig-net region of the deep cortex. No hyphae were found invading the host pith.

Total nitrogen concentrations in mined and undisturbed soils at the Martin Lake lignite stripmine were extremely low, with non-significant differences among sites. Minesoil concentrations of P, K, Ca, Mg, Na, and SO_4 were significantly higher than adjacent undisturbed soils. Significantly larger quantities of combustible carbons also found were probably due to included coal partings. Soil reaction (pH) was significantly higher in minesoils but was expected to fall as soluble salts were leached. Texturally, minesoils were clay loams that formed deep, hard crusts when exposed surfaces dried. The cation exchange capacities (CEC) on the mine were typical of soils containing kaolinite and chlorite clays, which have been found to be common in Wilcox formation lignite overburden.

Containerized shortleaf pine seedlings with their far better initial ectomycorrhizae development survived significantly better than bare-root seedlings after the first growing season on minesoils at Martin Lake. Inoculation treatments of bare-root seedlings with P. tinctorius basidiospores and vegetative mycelia had no significant effect on survival or growth. The best height growth was obtained by a spore-inoculated containerized treatment, and the poorest growth was registered by nursery-stock controls. All treatments survived and grew significantly better on unmined soils. After the first growing season, foliar concentrations of N, P, K, Ca, Mg, Na, Mn, Zn, and Cu were more significantly affected by site -- mined or unmined -- than by treatment. Inoculation treatments with P. tinctorius did not significantly improve low foliar concentrations of nitrogen or phosphorus in containerized or bare-root shortleaf pine seedlings grown on minesoils at Martin Lake.

The results of this study point out the need for more research to be conducted on artificial infestation of containerized tree seedlings with mycorrhizae fungal symbionts, which could contribute to far better reclamation of deeply-disturbed sites in East Texas. Other mycobiont/host combinations should be evaluated, and some particular emphases directed at the effects of root accumulation of various mineral nutrients on mycorrhizae formation are warranted.

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APPENDIX

† - Used in statistical computer program.

Table 1. Soil analyses -- reaction (pH), and nitrogen, phosphorus, exchangeable cations and sulfate concentrations.

Row No.	Reaction (pH)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu	SO_4
			- - - - - - - - - -	-	-	Parts Per Million	-	-	- - - - - - - - - - - -	-	-
Mined Plot #1											
1	7.30	0.056	17	126	8300	1290	93	30	14	10	2.75
2	7.25	0.050	26	144	6100	1163	86	23	15	t	5.50
3	7.10	0.048	19	137	4600	1275	123	15	16	2	4.25
4	7.20	0.008	25	150	4400	1425	210	20	12	t	6.50
5	7.30	t	22	132	7400	1260	114	20	14	t	3.25
6	7.30	0.059	27	138	4500	1350	30	25	15	8	5.00
Mined Plot #2											
1	7.00	0.045	38	144	3950	1245	134	10	11	8	8.25
2	7.10	0.039	16	120	3800	1110	115	25	10	4	6.75
3	7.00	0.042	28	126	4200	1305	174	18	12	t	7.75
4	7.10	t	15	126	4000	1290	129	25	12	7	7.50
5	7.10	t	15	126	3900	1350	125	20	13	6	4.40
6	7.00	0.059	28	138	4250	1418	111	25	14	2	9.25
Mined Plot #3											
1	7.05	0.025	22	168	3500	1440	60	12	15	4	2.25
2	6.90	0.045	20	162	4400	1238	75	30	16	2	3.25
3	7.30	0.036	28	93	3800	1365	109	30	15	10	3.50
4	7.30	0.042	19	150	4400	1500	137	15	15	t	3.60
5	7.20	0.039	26	144	4000	1340	156	25	15	t	5.20
6	7.10	0.042	16	129	3350	1350	123	17	14	10	3.80

(continued)

Table 1. Continued.

Row No.	Reaction (pH)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu	SO_4
			- - - - - - - -	- - Parts Per Million	- - - - - - - - - - - -						
Unmined Plot #1											
1	5.55	0.031	2	30	225	20	12	63	15	2	t
2	5.55	0.042	3	39	300	27	8	80	15	t	3.00
3	5.35	0.034	2	30	300	23	8	60	15	t	t
4	5.50	0.045	2	42	300	25	15	100	15	3	t
5	5.65	0.064	3	60	465	44	11	180	20	t	t
6	6.00	0.073	5	42	675	60	8	155	14	3	2.80
Unmined Plot #2											
1	5.05	0.062	2	39	308	43	10	78	19	6	1.10
2	5.00	0.070	2	48	210	49	8	63	10	4	t
3	5.10	0.067	2	42	330	59	8	65	13	2	0.25
4	5.15	0.076	2	42	300	59	10	100	11	2	0.20
5	5.30	0.062	4	48	390	57	10	90	10	t	0.50
6	5.30	0.053	2	39	255	46	8	75	8	8	0.50
Styroblock Soil											
	6.00	0.031	2	30	315	16	10	75	8	4	t

t trace amount

Table 2. Soil analyses -- percent organic matter, cation exchange capacity, base saturation, and texture.

Row No.	O.M. (%)	CEC (meq/100g)	Sum of Meq.*	Base Saturation (%)	- Soil Fraction - Sand (%)	Silt (%)	Clay (%)	Soil Textural Class
Mined Plot #1								
1	8.37	11.89	52.80	444	31.6	34.4	34.0	cl-clay loam
2	7.09	6.79	40.78	601	29.6	34.4	34.0	cl
3	6.78	11.77	34.34	292	31.6	32.4	36.0	cl
4	6.49	3.48	34.98	1005	29.6	32.8	37.6	cl
5	7.16	5.68	48.16	848	23.6	38.8	37.6	cl
6	7.37	13.58	34.05	251	29.6	32.8	37.6	cl
Mined Plot #2								
1	6.41	5.90	30.91	524	29.6	36.8	33.6	cl
2	6.28	10.56	28.91	274	31.6	38.8	29.6	cl
3	5.66	4.62	32.78	709	29.6	36.8	33.6	cl
4	6.58	15.07	31.46	209	29.6	36.8	33.6	cl
5	6.90	13.50	31.43	233	29.6	34.4	36.0	cl
6	7.81	15.11	33.71	223	27.6	34.8	37.6	cl
Mined Plot #3								
1	7.63	11.36	30.00	264	29.6	32.8	37.6	cl
2	6.10	14.37	32.89	229	31.6	32.4	36.0	cl
3	7.37	7.84	30.90	394	31.6	34.4	34.0	cl
4	6.09	6.58	35.28	536	29.6	34.8	35.6	cl

continued)

Table 2. Continued.

Row No.	O.M. (%)	CEC (meq/ 100g)	Sum of Meq.*	Base Saturation (%)	- Soil Sand (%)	Fraction Silt (%)	- Clay (%)	Soil Textural Class
Mined Plot #3								
5	6.79	6.11	32.03	524	25.6	38.4	36.0	cl
6	5.62	11.24	28.68	255	31.6	32.4	36.0	cl
Unmined Plot #1								
1	1.07	3.44	1.42	41	77.6	18.0	4.4	ls-loamy sand
2	1.88	2.34	1.86	79	80.0	16.0	4.0	ls
3	1.12	4.33	1.80	42	78.0	18.0	4.0	ls
4	1.86	2.03	1.88	93	78.4	18.0	3.6	ls
5	2.12	4.05	2.89	71	78.0	18.0	4.0	ls
6	2.38	4.44	4.01	90	80.0	18.0	2.0	ls
Unmined Plot #2								
1	1.99	3.48	2.04	59	67.6	26.0	6.4	sl-sandy loam
2	1.64	5.26	1.61	31	69.6	24.0	6.4	scl-sandy clay loam
3	2.01	8.98	2.28	25	59.6	34.0	6.4	sl
4	2.64	9.24	2.13	23	65.6	28.0	6.4	sl
5	1.98	4.65	2.58	56	63.6	32.0	4.4	sl
6	1.73	6.05	1.79	30	73.6	22.0	4.4	sl

(continued)

Table 2. Continued.

Row No.	O.M. (%)	CEC (meq/ 100g)	Sum of Meq.*	Base Saturation (%)	- Soil Fraction - Sand (%)	Silt (%)	Clay (%)	Soil Textural Class
Styroblock Soil								
	1.10	4.90	1.83	37	80.0	16.0	4.0	ls

* Sum of milliequivalents for K, Ca, Mg, and Na.

Table 3. Total height and root collar diameter for eight-month-old containerized shortleaf pine seedlings.*

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CULTURED MYCELIAL INOCULATION								
1	8.0	2.49†	12.0	3.69†	15.5	3.84†	18.5	3.22†
(100.0%)	8.0	2.21	15.5	4.94	18.0	2.66	17.5	3.06
	9.0	2.81	16.5	4.47	20.0	3.88	17.0	3.95
	10.0	2.27	16.0	4.21	20.0	3.66	20.5	3.46
	9.5	3.96†	17.5	4.53†	15.5	2.11†	20.5	3.16†
	8.0	3.74	18.0	3.16	21.0	2.60	21.0	2.09
	11.5	2.44	17.0	3.82	21.5	3.18	22.0	2.22
	9.5	3.44	14.0	4.64	16.0	3.98	20.0	2.61
	8.5	3.59	15.0	4.19	16.0	2.27	20.0	3.26
	13.0	3.91†	16.5	2.20†	20.0	3.83†	19.0	2.52†
	12.5	3.45	16.0	3.41	23.0	3.60	21.5	3.94
	10.0	2.66	20.0	3.79	20.0	2.82	21.5	2.23
	12.5	3.76	19.0	3.77	21.5	2.76	24.0	2.17
	10.0	3.40	25.0	4.06	20.0	3.72	20.5	3.17
	15.0	3.03†	18.0	3.28†	18.0	2.23†	18.0	2.14†
	15.5	3.55	14.0	2.67	19.5	3.27	20.5	2.21
	16.5	3.97	18.0	3.32	22.0	3.02	22.5	3.26
	17.0	3.19	17.0	3.00	20.5	3.43	23.0	2.16
	15.0	3.08	17.0	3.92	20.0	3.13	23.0	2.47
	16.5	3.38†	16.5	2.64†	20.5	3.05†	20.0	2.20†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CULTURED MYCELIAL INOCULATION								
2	18.0	3.86†	17.0	3.92†	16.0	3.20†	21.0	3.37†
(97.5%)	20.0	3.04	19.0	3.22	16.5	3.81	18.0	3.73
	17.0	2.27	16.0	3.08	17.5	3.48	20.0	3.49
	13.0	3.86	15.0	3.81	18.5	3.07	16.5	4.21
	17.0	3.36†	15.0	3.80†	20.5	3.49†	15.0	2.28†
	14.0	2.20	13.0	3.26	15.0	3.33	15.0	2.95
	16.0	3.97	17.5	3.11	15.0	3.49	14.0	3.40
	17.0	3.15	16.0	3.88	18.5	3.25	17.0	2.33
	14.0	3.20	18.5	3.95	16.5	3.76	17.0	2.67
	17.0	3.26†	19.5	3.66†	13.0	3.34†	16.5	2.46†
	13.0	3.35	16.0	3.45	15.0	3.89	14.0	3.34
	15.0	3.87	14.0	3.97	12.0	3.36	14.0	2.93
	14.0	3.16	15.0	3.84	14.0	3.98		
			16.0	3.71	20.0	3.69	18.0	3.56
	15.0	4.76†	14.5	3.64†	19.0	3.93†	18.5	3.83†
	19.0	3.30	19.0	3.45	16.5	3.33	17.0	3.66
	17.0	3.70	18.0	3.40	17.5	3.22	18.5	3.21
	16.0	3.10	14.5	3.98	15.5	3.27	17.0	3.17
	12.0	3.39	14.5	3.93	15.0	3.08	17.0	3.50
	16.0	2.52†	16.0	3.03†	11.5	3.01†	15.0	3.03†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CULTURED MYCELIAL INOCULATION								
3	19.0	3.43†	21.5	3.66†	18.0	3.28†	18.5	3.03†
(97.50%)	19.0	3.28	24.5	4.57	15.0	3.15	19.0	3.02
	22.0	4.29	21.0	3.16	20.0	3.73	20.0	3.16
	21.0	3.44	20.0	3.29			20.0	3.69
	22.5	3.72†	19.0	3.08†	19.0	3.48†	16.0	3.64†
	23.0	3.45	19.0	3.92	17.0	3.96	20.0	2.18
	21.0	3.02	19.0	3.17	16.0	2.71	23.5	2.93
	22.0	3.16	16.0	3.25	19.0	3.45	23.5	3.24
	21.0	3.94	17.5	3.10	20.0	3.70	18.0	3.75
	19.0	3.54†	20.0	3.71†	17.5	3.96†	18.5	3.06†
	22.5	2.53			18.0	3.13	16.0	2.13
	21.0	2.04	19.5	3.23	16.5	3.33	20.5	3.48
	22.0	3.02	20.0	3.24	13.5	2.50	20.0	3.63
	21.0	3.18	19.5	2.26	19.0	3.12	18.0	3.65
	19.0	3.03†	22.0	3.62†	18.0	3.47†	20.0	3.50†
	19.0	3.29	21.0	3.26	13.0	2.08	15.0	2.58
	20.0	3.53	22.0	3.96	18.0	2.66	17.5	3.46
	25.0	3.50	21.0	3.84	16.5	2.70	17.5	3.50
	22.0	3.74	17.0	3.59	15.0	3.91	19.0	3.02
	22.0	3.84†	24.0	3.88†	16.5	3.96†	21.5	3.50†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CULTURED MYCELIAL INOCULATION								
4			9.5	2.98†	11.0	2.26†		
(95.00%)	12.0	2.87†	11.0	3.20	10.5	3.52	12.5	3.58†
	11.0	3.83	12.0	2.63	18.0	3.83	14.0	3.60
	11.5	3.04	12.0	3.23	15.0	2.93	16.0	3.05
	13.0	2.85†	14.0	3.70†	16.0	2.31†	18.0	3.44†
	13.5	2.10	20.0	3.55	18.5	3.61	18.0	3.19
	17.0	3.20	20.5	3.25	20.5	3.03	15.0	3.32
	16.0	2.05	11.0	2.48			10.0	2.75
	11.0	2.18	13.0	3.06	12.0	3.25	14.0	4.38
	13.5	3.57†	17.0	3.47†	12.0	2.65†	17.0	3.47†
	14.0	2.41	12.5	3.62	17.0	3.39	15.0	3.49
	12.0	3.87	18.0	3.51	18.0	3.97	19.0	3.26
	13.5	3.17	21.0	3.29	17.0	3.12	18.0	3.41
	17.0	2.79	14.5	2.00	13.0	3.54	11.0	3.60
	10.0	3.70†	14.0	3.80†	7.0	2.07†	12.5	3.01†
	14.5	3.68			16.5	3.65	14.0	3.07
	15.0	3.89	14.0	3.17	20.0	3.12	15.5	3.02
	13.0	3.24	15.0	3.71	19.0	3.74	15.5	3.57
	14.0	2.98	17.0	3.64	19.0	3.23	17.0	3.90
	16.0	3.66†	21.0	3.96†	16.5	3.06†	20.0	2.91†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CULTURED MYCELIAL INOCULATION								
5 (95.00%)	16.5	3.36†			12.0	3.89†	12.0	3.96†
	16.0	3.28	13.5	3.46†	14.0	3.15		
	15.5	3.39	12.5	3.78	14.5	3.64	11.0	3.10
	17.0	3.13	11.5	3.10	14.5	2.79	12.5	3.04
	13.0	3.29†	12.5	3.36†	14.0	3.52†	10.5	3.92†
	11.0	3.58	9.5	3.48	9.0	2.92	11.0	3.22
	9.5	3.32	10.5	3.82	11.5	2.52	10.0	2.95
	14.0	2.92	16.0	3.37	14.0	3.52	9.0	2.13
	15.0	2.10	14.5	3.62	14.0	3.59	11.0	2.94
	16.0	2.08†	13.0	3.04†	10.0	3.60†	10.5	2.19†
	13.0	3.72	14.0	3.58	8.0	2.25	10.0	2.43
	12.5	3.20	13.0	3.28	10.0	2.17	10.0	3.37
	8.5	2.15	10.5	2.22	7.0	2.33	7.0	2.14
	12.0	3.95	13.0	3.50†	13.0	2.73†	8.0	2.45†
	15.5	3.97†			11.5	2.29	8.0	2.67
	14.0	3.91			13.0	3.22	8.0	3.83
	9.0	2.26	11.0	2.35	12.5	3.94	11.0	2.07
	11.0	3.98	14.5	3.68	9.0	2.71	8.5	2.01
	14.0	3.66	9.0	2.76	9.0	2.53	7.5	2.86
	7.0	2.91†	12.0	2.10†	9.0	3.89†	7.0	2.17†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
<u>BASIDIOSPORE/VERMICULITE INOCULATION</u>								
1	10.5	2.56†	13.5	2.71†	12.0	2.13†	19.5	3.37†
(98.75%)	8.5	2.19	19.0	3.31	16.0	2.28	15.5	2.50
	11.0	2.40	15.5	3.81	16.0	2.78	14.5	2.03
	11.0	2.78	13.0	4.50	19.5	3.35	16.0	3.46
	7.0	3.40†	13.5	3.21†	16.0	3.89†	14.5	2.72†
	9.0	2.08	12.5	4.18	17.0	3.17	14.5	3.53
	9.0	2.42	9.0	2.81	12.5	3.80	15.0	3.45
	12.0	2.81	20.0	3.68	15.0	3.45	12.0	2.77
	11.5	2.60	17.5	3.14	17.0	3.71	16.0	3.30
	10.0	2.61†	15.0	2.96†			17.0	2.29†
	12.0	3.99	14.0	2.71	18.5	3.16†	15.0	2.45
	11.0	2.67	15.0	2.66	10.0	2.61	16.5	3.15
	9.0	2.81	11.5	2.45	13.0	2.53	13.0	2.94
	15.0	4.41	16.0	3.34	20.5	2.10	16.0	2.82
	14.0	2.85†	15.5	3.57†	15.5	2.55†	15.5	3.75†
	13.5	3.75	14.0	3.14	16.0	3.20	14.5	2.71
	12.0	2.62	20.0	3.64	17.5	3.63	17.5	2.80
	11.5	2.94	14.0	2.87	15.0	3.95	15.5	2.66
	10.0	2.96	14.0	2.69	14.5	2.29	13.0	2.22
	11.0	2.55†	12.0	2.90†	13.5	2.55†	11.0	2.99†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
BASIDIOSPORE/VERMICULITE INOCULATION								
2	18.0	3.16†	17.0	2.04†	21.0	3.66†	18.5	2.54†
(96.25%)	17.0	2.72	18.0	3.75	19.5	3.55		
	19.0	3.64	18.0	3.27	24.0	3.45	23.0	3.49
	22.5	3.08	20.0	3.47	18.5	3.47		
	17.0	2.79†	19.5	3.53†	20.0	2.28†	18.5	3.20†
	22.0	3.38	20.0	2.87	23.0	3.11	27.0	3.24
	21.0	2.82	22.0	2.56	14.0	1.18	23.5	3.30
	16.5	2.72	18.0	2.55	18.5	3.89	18.0	3.92
	19.0	2.71	18.0	3.51	17.5	3.62	17.5	3.85
	21.5	3.44†	18.0	3.94†	17.0	3.16†	17.5	3.27†
	18.0	2.67	17.0	3.45	26.0	3.81	21.5	3.98
	19.0	3.12	18.0	2.82	25.0	3.28	22.0	3.80
	22.0	2.49	21.0	3.35	25.5	3.41	25.5	3.97
	21.5	3.43	18.5	3.08	19.0	3.71	18.0	2.32
	19.0	3.57†	20.0	3.41†	22.0	3.52†	15.5	3.88†
	21.0	3.66	16.0	4.09	24.5	3.32	21.5	2.16
	20.5	3.67	18.0	2.28	23.0	3.65	21.0	3.86
	21.5	3.70	18.5	3.79	26.0	3.65		
	21.0	2.11	23.0	3.07	24.0	3.84	22.5	3.53
	18.0	2.59†	21.5	3.56†	23.5	3.52†	23.5	3.14†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
BASIDIOSPORE/VERMICULITE INOCULATION								
3	16.0	3.30†	17.0	3.95†	21.5	2.15†	20.0	3.86†
(98.75)	17.5	3.39	20.0	3.07	20.0	3.05	20.0	3.17
	18.5	3.74	18.0	3.09	14.0	3.18	19.0	3.31
			18.5	3.65	22.5	3.57	21.0	3.73
	12.0	3.54†	14.0	3.17†	18.0	3.58†	20.0	3.66†
	15.0	3.84	16.0	3.29	19.0	3.12	20.0	3.77
	15.0	3.42	16.0	3.97	21.0	3.46	15.0	3.09
	19.0	3.70	21.0	3.49	16.5	3.69	21.0	3.28
	19.0	3.77	19.0	3.86	20.5	3.13	20.0	3.10
	19.0	3.25†	19.0	3.53†	20.0	3.26†	21.0	3.18†
	16.5	3.45	18.0	3.30	15.0	3.32	17.0	2.91
	12.0	3.22	16.0	3.47	18.0	3.03	19.5	3.18
	17.0	3.56	15.0	3.15	19.0	3.38	12.0	2.29
	19.0	3.19	16.5	3.35	22.0	2.92	23.5	3.17
	20.0	3.09†	18.0	3.23†	21.5	3.29†	17.5	3.96†
	20.5	3.11	18.0	3.34	21.0	3.39	24.0	3.00
	15.0	3.07	19.0	3.66	14.0	2.02	20.0	3.43
	20.0	3.35	17.0	2.88	18.0	3.77	19.5	3.99
	20.5	3.22	21.0	3.12	14.0	2.61	14.0	2.61
	19.0	3.10†	13.0	1.97†	15.0	2.71†	17.5	3.37†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
<u>BASIDIOSPORE/VERMICULITE INOCULATION</u>								
4	24.0	4.32†	21.0	3.36†	20.0	3.28†	22.0	3.60†
(95.00%)	20.0	3.50	23.0	3.87	20.0	3.67	12.5	2.15
			21.5	3.87	16.0	3.95	16.0	3.01
	24.0	3.41	22.0	3.03	20.0	3.91	17.0	2.65
	23.5	3.17†	20.0	3.00†	18.5	3.31†	14.5	3.72†
	21.5	3.67	16.5	3.73	15.5	3.30	17.5	2.56
	18.0	3.86	18.5	3.77	18.0	3.98	21.0	3.09
	16.5	2.11	19.0	2.71	21.0	3.39	18.5	2.72
	22.0	3.59	17.0	2.32	13.0	1.43	11.5	2.40
	26.0	3.01†	18.0	2.98†	17.5	2.29†	14.5	2.94†
	21.0	2.53	18.0	3.32	21.5	3.73	15.5	3.47
	16.0	2.94	20.0	3.26	21.5	3.24	17.0	2.54
	15.0	2.62	15.0	3.63	16.5	2.31	14.0	3.93
	16.0	3.52	20.0	3.90	21.5	2.39	22.0	3.72
	22.5	3.29†	16.0	3.14†	17.0	3.05†	22.5	3.15†
	20.0	3.14	19.0	3.36	20.5	3.08	17.0	3.38
	21.5	3.06	21.0	3.32	22.0	3.27	14.0	2.48
	19.5	3.87	20.0	3.44				
	19.0	3.33	16.0	3.26	15.5	2.94†	16.0	3.70
	11.0	2.84†	13.5	2.62†			15.5	3.20†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
BASIDIOSPORE/VERMICULITE INOCULATION								
5	16.0	3.26†			16.5	3.09†	12.0	3.81†
(97.50%)	21.0	3.48	16.0	2.79†	15.0	2.32	11.0	2.86
	20.5	3.77	16.5	3.35	17.5	3.81	14.0	3.50
	19.5	3.62	16.5	3.80	16.0	3.07	12.0	2.94
	20.0	2.82†	16.5	3.03†	17.0	3.30†	14.5	3.31†
	18.5	3.96	16.5	3.14	15.0	3.83	13.5	2.21
	21.5	3.90	12.5	2.21	18.0	3.80	13.0	3.26
	19.5	3.51	21.5	3.16	13.0	2.81	9.0	2.65
	14.5	2.52	13.5	2.29	14.0	3.75	7.0	1.01
	17.5	2.98†	15.5	3.02†	13.0	2.28†	8.0	1.54†
	17.5	3.63	15.5	3.86	13.0	2.80	9.0	2.86
	17.5	3.55	16.0	3.37	12.0	2.85	9.0	2.40
			14.5	2.32	15.0	3.43	12.0	2.43
	15.0	2.81	20.5	3.61	22.0	2.95	8.0	3.79
	13.0	1.44†	16.0	3.61†	12.5	3.82†	8.0	2.58†
	20.0	3.46	15.0	2.86	14.0	2.21	9.0	2.56
	16.5	3.80	15.5	3.03	16.0	3.50	9.0	2.41
	16.0	3.06	14.0	2.87	17.5	3.26	10.0	2.60
	18.5	3.05	19.5	3.80	13.0	2.40	14.0	2.30
	19.0	3.66†	19.0	3.25†	11.0	2.24†	14.0	2.67†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
SEEDCOAT BASIDIOSPORE INOCULATION								
1	7.0	2.85†	7.0	2.66†	6.0	2.74†	7.5	2.14†
(96.25%)	7.5	2.81	8.0	2.04	11.0	2.70	10.0	3.75
	9.5	2.97	10.0	2.72	9.0	2.84	12.0	3.49
	6.0	2.87	11.0	2.49	13.0	3.33	17.0	3.81
	7.0	2.97†	9.0	2.12†	11.0	3.29†	11.0	2.66†
	6.0	2.80	11.0	3.72	14.5	2.35	17.0	2.80
	11.0	3.94			19.0	3.90	23.0	3.06
	6.0	2.24	7.5	2.49	8.0	2.57	11.0	2.43
	9.0	2.35	15.0	2.30	14.0	2.86	11.0	2.30
	8.0	2.57†	13.0	2.57†	16.5	2.75†	16.5	2.33†
	8.0	2.62	12.0	2.97	14.0	2.82	13.0	3.77
	10.0	2.61	11.5	2.85	14.0	2.85	15.5	2.23
	10.0	3.63			13.5	3.58	17.5	3.11
	6.5	2.85	9.0	3.43	9.0	2.89	10.0	2.28
	10.0	3.32†	11.0	3.59†	15.0	3.17†	9.0	2.37†
	11.0	3.15	11.0	2.43	17.0	3.82	8.0	2.61
	11.0	2.03	16.0	3.33	18.0	3.52	17.0	3.71
			15.0	2.89	16.5	3.46	14.5	2.98
	9.0	3.07	17.0	2.60	13.5	3.39	17.5	3.82
	24.0	4.29†	16.0	3.03†	19.0	3.40†	24.5	3.39†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
SEEDCOAT BASIDIOSPORE INOCULATION								
2	23.0	3.34†	16.0	3.87†	11.0	3.14†	16.0	2.76†
(100.0%)	13.5	3.64	10.5	3.57	10.0	3.38	11.0	3.69
	11.0	3.85	6.0	2.77	7.0	2.04	11.0	3.89
	13.0	2.72	9.5	3.56	8.0	2.82	9.0	3.29
	11.5	2.88†	8.0	2.63†	7.0	2.86†	10.0	2.85†
	9.0	3.10	9.0	2.65	9.0	2.08	7.0	3.64
	12.0	2.18	9.0	2.41	8.0	2.42	7.0	2.40
	11.0	2.59	9.0	2.19	12.0	3.27	12.0	3.23
	11.5	2.86	11.0	2.19	10.0	2.70	10.0	3.65
	11.0	3.52†	9.0	2.78†	11.0	3.73†	13.0	2.58†
	8.0	2.45	9.0	2.32	9.0	3.26	10.0	2.08
	7.0	3.10	8.5	2.75	9.0	3.53	9.5	2.53
	5.0	2.42	5.0	2.45	8.5	2.04	7.5	2.33
	12.0	2.00	8.5	2.42	16.0	3.43	13.5	3.20
	11.0	2.66†	14.5	3.76†	7.5	2.63†	13.0	3.54†
	13.0	2.74	13.0	3.75	8.0	2.23	11.0	2.29
	8.0	2.06	12.0	3.00	12.0	3.18	9.5	2.61
	9.0	2.52	11.5	3.14	8.0	2.73	10.0	2.16
	8.0	2.22	10.0	2.74	7.0	2.90	6.5	2.40
	7.0	2.56†	8.0	2.03†	7.0	2.71†	7.0	2.78†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
SEEDCOAT BASIDIOSPORE INOCULATION								
3	12.0	2.46†	7.0	2.73†	10.0	2.50†	7.0	2.87†
(100.0%)	12.0	2.85	14.0	3.19	17.0	3.25	9.0	2.95
	10.5	3.19	11.0	2.30	11.0	2.28	14.0	2.27
	11.5	2.43	14.0	3.48	12.0	3.13	13.5	3.31
	11.0	3.38†	15.0	3.97†	14.0	3.89†	11.0	3.29†
	17.5	2.84	14.0	3.96	17.5	3.57	13.0	3.01
	19.5	2.69	18.0	3.12	18.5	3.78	23.0	3.95
	12.0	2.25	10.0	2.83	8.0	2.48	8.0	2.12
	11.5	2.36	13.0	2.02	13.0	2.52	12.0	2.66
	12.5	2.58†	13.0	2.02†	12.0	2.86†	11.0	2.96†
	15.0	2.93	16.0	3.01	13.0	2.08	10.5	3.63
	13.0	3.37	16.0	3.54	15.0	3.10	17.5	3.72
	17.5	2.21	16.0	2.78	18.0	3.03	14.5	2.34
	11.0	2.97	12.0	3.19	9.0	2.31	9.5	3.76
	18.5	2.53†	12.0	3.53†	13.5	3.75†	8.5	3.56†
	10.0	3.40	11.0	2.23	12.0	2.97	10.5	2.36
	15.0	3.19	13.5	2.05	14.0	3.95	11.0	2.10
	15.0	2.29	15.0	2.12	9.0	2.78	15.0	3.58
	15.0	3.74	17.0	3.78	16.5	3.14	15.0	3.69
	19.0	2.88†	17.5	3.61†	22.0	3.34†	24.0	3.13†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
SEEDCOAT BASIDIOSPORE INOCULATION								
4	21.0	3.26†	8.0	2.58†	14.5	3.08†	17.5	3.35†
(98.75%)	12.5	2.63	15.0	3.80	12.5	3.17	13.0	3.28
	13.5	3.04	12.0	2.19	14.5	3.30	12.0	3.32
	13.5	2.37	16.0	3.40	12.0	3.88	10.0	3.55
	8.5	2.03†	11.0	2.40†	13.0	3.17†	11.0	3.95†
	8.0	2.10	8.0	2.56	10.0	2.53	8.5	2.06
	9.0	2.88	7.0	2.71			7.5	2.95
	11.0	3.61	12.0	2.38	15.5	3.12	9.5	2.57
	10.0	2.51	10.5	2.30	13.5	3.94	13.0	3.19
	10.5	2.17†	10.0	3.48†	11.5	2.32†	12.0	3.69†
	7.5	2.69	10.0	3.74	12.5	3.70	8.0	3.97
	8.0	2.83	11.0	3.76	10.0	2.01	10.0	3.06
	7.5	2.90	7.0	2.85	7.0	2.30	7.0	3.17
	14.0	3.78	15.0	3.12	16.0	3.95	20.0	3.36
	11.0	2.79†	11.5	2.89†	10.0	2.44†	21.0	3.34†
	8.0	2.11	12.0	2.82	11.0	2.58	16.5	3.56
	15.0	3.68	12.0	2.31	10.0	2.16	16.5	2.77
	9.0	2.97	11.0	2.15	9.0	3.81	12.0	2.72
	6.5	1.10	8.5	2.28	7.0	2.25	9.0	2.01
	5.0	1.27†	6.5	2.38†	7.0	2.89†	6.0	2.03†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
SEEDCOAT BASIDIOSPORE INOCULATION								
5	11.0	2.66†	8.5	2.46†	8.5	2.53†	7.5	2.25†
(97.50%)	14.0	2.13	12.0	2.34	10.0	2.80	8.0	2.60
	15.0	3.90	9.0	2.40	14.0	2.88	7.0	2.23
	16.0	3.88	13.0	2.20	12.0	3.13	11.5	3.10
			13.0	2.37†	15.0	2.80†	10.0	2.31†
	12.5	2.22†	15.5	2.78	20.5	3.48	9.0	2.29
			18.5	2.42	16.0	3.60	9.0	2.71
	13.0	2.81	9.5	2.80	8.5	2.00	8.0	2.72
	11.5	2.12	8.0	2.52	9.0	2.44	7.0	2.77
	12.0	2.46†	14.5	2.67†	10.5	2.55†	7.0	2.27†
	15.0	2.55	14.0	2.22	12.0	2.24	12.5	2.46
	14.0	2.49	14.5	2.42	8.5	2.51	14.0	2.36
	22.5	3.69	17.0	3.78	14.0	3.43	9.0	2.10
	9.0	2.76	12.5	3.27	8.0	3.67	7.0	3.75
	10.0	2.43†	13.5	3.20†	9.5	3.27†	7.0	2.57†
	10.0	2.33	14.0	2.27	15.0	3.18	8.0	2.09
	11.5	3.21	17.0	3.49	10.5	2.53	7.5	2.19
	11.0	2.41	18.5	3.68	15.5	3.37	5.0	2.07
	19.5	3.26	15.5	3.59	12.0	2.22	9.0	3.11
	22.0	3.07†	20.0	3.98†	14.5	3.19†	10.0	3.24†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CONTAINERIZED CONTROL								
1	12.5	3.32†	10.5	3.54†	15.0	3.48†	18.0	3.69†
(100.0%)	11.5	3.41	11.5	3.66	12.0	3.08	13.0	3.03
	9.5	3.05	9.0	3.23	12.0	3.04	16.0	3.09
	7.0	2.29	12.0	3.15	13.0	3.23	8.0	2.54
	9.5	3.70†	9.0	3.53†	12.0	3.92†	8.0	4.46†
	9.0	3.76	8.0	3.31	10.0	3.54	7.0	2.45
	7.5	2.55	5.0	2.95	9.5	3.16	11.0	3.78
	10.0	3.71	10.0	3.31	14.5	2.62	10.0	2.28
	11.0	2.05	13.0	2.78	12.0	2.87	12.0	2.13
	8.0	2.30†	10.0	2.01†	12.0	2.12†	10.0	2.42†
	10.0	3.13	11.0	2.59	9.5	3.42	8.5	2.46
	7.0	2.79	9.0	2.45	10.5	3.60	12.0	2.03
	7.0	2.45	9.0	3.38	6.0	2.54	7.0	2.57
	11.0	2.29	13.5	3.44	13.0	2.88	13.0	3.88
	11.0	2.10†	6.5	2.30†	11.5	3.32†	11.0	2.15†
	9.0	3.23	9.0	2.83	11.0	2.57	7.5	2.07
	10.5	2.66	10.0	2.20	8.0	2.87	13.0	3.82
	8.0	2.82	10.5	2.59	10.0	3.85	9.0	2.27
	8.0	2.71	8.0	2.03	8.0	3.04	7.0	2.53
	7.0	2.23†	7.0	2.79†	4.5	3.89†	7.0	2.96†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CONTAINERIZED CONTROL								
2	7.5	2.36†	6.5	2.36†	6.5	2.67†	8.5	2.38†
(98.75%)	7.5	2.46	12.0	2.73	9.5	2.74		
	11.5	2.98	12.0	2.40	14.0	2.01	13.0	2.72
	12.5	3.12	17.5	3.53	12.0	2.65	16.0	2.93
	16.5	3.64†	15.5	2.17†	15.0	2.20†	16.0	2.07†
	13.5	2.58	15.5	2.45	16.0	2.56	20.0	3.14
	20.0	3.66	20.0	3.85	20.0	3.80	20.0	4.46
	7.0	2.66	8.0	2.69	9.0	2.11	9.0	2.08
	11.0	2.33	12.0	3.87	14.0	2.96	12.0	3.20
	11.0	2.18†	13.0	2.59†	12.0	2.36†	13.0	3.63†
	14.5	3.72	16.0	3.81	13.0	3.49	18.0	3.69
	13.0	2.42	15.0	2.67	15.5	3.16	18.0	3.17
	18.0	3.46	18.0	2.44	20.5	3.44	17.5	3.50
	11.0	2.85	8.0	2.40	7.5	2.20	9.5	2.97
	11.5	2.70†	8.5	2.55†	11.5	2.91†	12.0	3.50†
	10.0	2.38	11.0	2.77	12.0	2.88	10.0	3.02
	15.5	3.62	13.5	3.28	14.5	3.50	15.0	3.63
	21.0	4.06	17.0	3.43	13.5	3.97	18.5	3.89
	18.0	3.04	21.0	3.68	18.5	3.76	21.0	3.32
	17.0	2.90†	19.5	3.74†	23.0	3.37†	22.0	3.52†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CONTAINERIZED CONTROL								
3	12.0	3.72†	16.0	3.31†	15.0	3.17†	20.0	2.55†
(97.50%)	13.0	3.85	17.0	3.50	14.5	3.46	11.5	2.69
	11.0	2.83	13.5	2.28	10.5	2.87	14.0	3.70
	11.0	2.54	11.5	2.95	10.0	2.33	12.0	2.24
	12.0	3.32†	10.0	3.85†	12.0	3.24†	11.5	3.38†
	10.0	3.49	11.0	3.02	10.0	2.74	9.0	2.47
	8.0	3.53	6.0	3.39	7.0	2.17	15.0	3.00
	11.0	2.20	16.5	3.39	10.0	2.87	9.5	2.53
	8.0	1.76	14.0	3.12	10.0	2.30	12.0	3.60
	8.0	1.29†	9.0	2.12†			12.0	3.06†
	8.0	2.31	11.0	2.24	12.0	2.04†	12.0	2.55
	8.5	3.60	9.0	2.13	9.0	1.84	9.0	2.94
	7.5	2.79	7.5	2.73	10.5	2.69	9.0	2.83
	12.0	2.36	16.0	2.60	16.0	3.58	11.0	3.83
	12.5	2.89†	13.0	2.05†	11.0	3.06†	18.5	3.09†
	9.0	2.34	20.0	3.61	12.5	3.26	13.0	3.75
	10.0	2.09	11.0	2.09	9.5	2.34	10.0	3.16
	9.0	2.89			12.5	3.46	10.0	3.15
	8.0	3.75	6.0	2.55	11.0	3.80	9.5	2.18
	8.0	2.38†	9.5	2.90†	10.0	3.86†	8.0	2.52†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CONTAINERIZED CONTROL								
4	19.5	3.91†	20.5	2.08†	17.5	3.11†	18.5	3.67†
(96.25%)	17.0	2.95	24.5	3.44	19.5	3.12	17.5	3.36
	19.0	3.27	18.0	3.14	17.0	3.08	18.5	3.71
	18.0	3.06	21.0	3.12	22.5	3.61	22.0	3.27
	20.5	3.13†	22.5	3.46†	19.0	2.43†	21.0	3.69†
	25.0	3.71	23.0	3.34	22.5	2.52	20.5	3.87
	24.0	3.30			20.0	2.02	21.0	3.47
	15.0	2.23	16.5	2.50	17.5	2.71	17.0	2.15
	20.0	3.43	18.5	2.80	18.5	3.48	15.0	2.91
	18.0	3.34†	21.0	3.90†	19.0	3.65†	18.0	2.22†
	20.0	3.80	19.5	3.50	18.0	3.04	17.5	3.00
	24.0	3.49	21.5	3.84	23.0	3.03	20.5	3.59
	22.5	3.59	25.5	3.15	20.0	3.75	19.0	3.90
	21.0	3.21	13.5	2.92	16.5	2.53	20.0	3.75
	21.5	3.46†	18.5	2.23†	20.0	2.79†	18.0	2.98†
	20.5	3.50	19.0	3.49	19.0	3.86	17.5	2.49
	18.0	2.83			18.0	3.88	18.5	2.22
	20.0	3.21	22.5	3.04	19.5	3.00	20.0	3.87
	21.5	2.92	23.5	3.86†	22.0	3.60	21.5	3.54
	27.5	3.97†			19.5	2.83†	16.0	3.87†

(continued)

Table 3. Continued.

Styroblock No. (% Survival)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)	HT. (cm)	DIA. (mm)
CONTAINERIZED CONTROL								
5	19.0	3.55†	20.0	3.69†			16.0	3.60†
(93.75%)	18.5	3.03			10.5	2.56†	15.0	3.10
	17.5	3.32	14.0	3.38	15.0	3.05	15.0	3.96
	14.0	3.23	19.0	3.78	14.0	3.75	9.5	2.77
	18.0	3.07†	13.5	2.81†	14.0	3.65†	10.0	3.17†
	14.0	3.13	14.5	3.17	14.5	3.37	11.0	3.69
	14.5	3.72	12.5	2.66	11.0	3.79	11.0	2.01
			13.0	3.29	16.5	3.51	14.5	3.41
	18.5	3.70	15.5	3.71	12.5	3.22	10.0	2.07
	14.5	3.18†	13.0	3.40†	14.0	2.76†	9.0	2.34†
	17.0	3.55	16.0	2.17	12.0	2.96	8.0	3.16
	17.0	2.17	10.0	2.13	11.0	3.25	10.0	3.47
	12.5	2.79	11.0	2.39			10.0	3.44
	21.5	3.78	12.5	2.75	16.5	3.07	12.0	3.56
	16.0	3.40†	15.0	3.33†	17.0	3.72†	12.0	3.44†
	18.5	3.24	18.5	3.10	11.0	3.50		
	15.0	3.78	15.5	3.04	12.0	2.20	8.0	2.02
	15.0	3.98	14.0	3.31	10.0	2.78	8.0	2.36
	14.5	2.61	13.5	3.97	11.0	3.59	9.0	3.84
	15.5	2.54†	14.5	3.46†	13.0	3.33†	5.0	2.69†

* Blanks indicate dead or moribund plants.

Table 4. Root measurements -- eight-month-old containerized shortleaf pine seedlings.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
CULTURED MYCELIAL INOCULATION						
1	2.33	245	Total Top Height** : 86 mm			
			4	52	17	40
			4	173	28	75
					67	
					27	
			10	211	152	133
			14	222	69	120
					36	
					34	
					26	
					17	
					22	
			15	115	37	95
					21	
			16	357	52	98
					40	
					35	
					28	
					30	
			20	179	24	45
					25	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)			39	229	16	30
			44	181	74	63
					34	
			91	58		15
			92	90		10
			119	71		10
						286
		TOTAL		1939	911	1020
TOTAL ROOT SYSTEM LENGTH:			3095 mm			
TOTAL NO. PRIMARY ROOTS:			12			
TOTAL NO. SECONDARY ROOTS:			23			
CULTURED MYCELIAL INOCULATION						
2	4.03	295	Total Top Height**: 193 mm			
			4	178	208	138
					31	
			4	291	37	379
					27	
					185	
					140	
					62	
					103	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)					80	
					60	
					31	
					66	
					31	
					32	
					34	
					50	
			9	172	227	275
					78	
					31	
					30	
					32	
			9	160	36	203
					43	
			12	170	22	185
					34	
					19	
					42	
					21	
					18	
			30	139	71	284
					30	
					25	
					158	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)					39	
			30	240	52	189
					30	
					69	
					27	
					32	
					60	
					28	
			34	137	97	249
					76	
					47	
					28	
					35	
			55	300	25	50
			55	218	168	100
					32	
					74	
					37	
					106	
					145	
					242	
					30	
			59	249	96	76
					20	
			68	59		25

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)			75	93	25	91
					34	
					35	
					25	
					19	
			98	81	22	145
					50	
					35	
					26	
			114	130		40
			125	234		45
						395
		TOTAL		2851	3960	2869

TOTAL ROOT SYSTEM LENGTH: 7106 mm
TOTAL NO. PRIMARY ROOTS: 16
TOTAL NO. SECONDARY ROOTS: 66

CULTURED MYCELIAL INOCULATION

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3	3.20	265	Total Top Height** : 168 mm			
			5	115	23	98
					30	
					23	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)			5	110	26	89
			5	97	40	150
			8	156	134	190
					35	
					117	
					40	
					34	
			12	165	31	278
					23	
					25	
			12	79	53	110
					34	
			15	138		56
			17	100	26	105
			20	188	31	146
			27	103	48	70
			29	68	25	55
			39	84		40
			47	61		30
			49	84		41
						310
		TOTAL		1548	798	1768

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)						
TOTAL ROOT SYSTEM LENGTH: 2611 mm						
TOTAL NO. PRIMARY ROOTS: 14						
TOTAL NO. SECONDARY ROOTS: 19						
CULTURED MYCELIAL INOCULATION						
4	3.51	240	Total Top Height** : 214 mm			
			7	212	48	208
			8	202	216	221
			9	275	98	104
					205	
					55	
					40	
					28	
			9	202	146	379
					84	
					73	
					41	
					57	
					79	
					30	
			12	162	31	111
					20	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)			16	237	68	203
					44	
					53	
					46	
			29	136		40
			31	138	62	94
			32	195	31	131
					20	
					50	
					19	
			36	105	115	107
			50	166		29
			81	108		21
			93	87		30
			115	80		5
			132	50		9
						86
		TOTAL		2355	1759	1778

TOTAL ROOT SYSTEM LENGTH: 4354 mm
TOTAL NO. PRIMARY ROOTS: 15
TOTAL NO. SECONDARY ROOTS: 26

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
CULTURED MYCELIAL INOCULATION						
5	3.29	150	Total Top Height** : 182 mm			
			2	103	35	220
					32	
					25	
			4	99	31	101
					32	
					28	
			5	90		78
			12	219	59	295
					104	
					31	
			13	135		67
			18	170		89
			19	156		279
			21	148	46	283
					31	
					90	
			25	152	40	215
			30	160		73
			34	121	63	125
					20	
			38	151		148

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5 (cont.)			58	100		54
			58	119	47	102
					31	
			75	77		40
						378
		TOTAL		2000	745	2547
TOTAL ROOT SYSTEM LENGTH:			2895 mm			
TOTAL NO. PRIMARY ROOTS:			15			
TOTAL NO. SECONDARY ROOTS			17			
CULTURED MYCELIAL INOCULATION						
6	2.64	178	Total Top Height** : 180 mm			
			7	170	65	329
					34	
					32	
			7	64		87
			9	201	48	273
					62	
					44	
					33	
					61	
			23	150	130	388

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
6 (cont.)					42	
					40	
					53	
					101	
					51	
			35	130		55
			47	131		61
			48	61		40
			67	54		48
			69	112		57
			87	88		25
			91	98		44
			105	71		31
			130	45		25
						54
		TOTAL		1375	796	1517

TOTAL ROOT SYSTEM LENGTH: 2349 mm
TOTAL NO. PRIMARY ROOTS: 13
TOTAL NO. SECONDARY ROOTS: 14

CULTURED MYCELIAL INOCULATION

Plant No.	Total Volume* (ml)	Main Root Length (mm)	
7	2.45	150	Total Top Height** : 244 mm

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)			8	185	86	443
					46	
					78	
					49	
			11	305	134	326
					72	
					36	
					61	
					50	
					60	
					37	
					28	
			16	142		115
			24	178		57
			25	183	51	91
					40	
					29	
			47	163	28	93
					26	
			47	55		35
						86
		TOTAL		1211	911	1246

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)						
TOTAL ROOT SYSTEM LENGTH:			2272 mm			
TOTAL NO. PRIMARY ROOTS:			7			
TOTAL NO. SECONDARY ROOTS:			17			
CULTURED MYCELIAL INOCULATION						
8	3.46	85	Total Top Height** : 82 mm			
			5	153	52	300
					80	
					134	
					80	
					101	
					39	
					40	
			6	149	28	198
					35	
					27	
					28	
			8	255	142	134
					69	
					40	
					30	
			12	229		79

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)						
			14	98	48	61
			22	140		30
			24	157		28
			25	176	77	93
			28	98		33
			34	111		27
			40	60	32	25
			44	100		15
						63
		TOTAL		1726	1082	1086
TOTAL ROOT SYSTEM LENGTH:			2893 mm			
TOTAL NO. PRIMARY ROOTS:			12			
TOTAL NO. SECONDARY ROOTS:			18			
CULTURED MYCELIAL INOCULATION						
9	2.08	150	Total Top Height** : 218 mm			
			3	113	93	96
					16	
			6	164	36	142
					137	
			7	137	25	207
			10	164		115

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)			20	123		58
			32	209		72
			44	89	24	87
			75	299	53	149
					28	
					30	
					22	
					45	
					24	
			102	52		15
			115	43		22
			120	44	36	25
			135	70		20
			144	97	30	40
					27	
						303
		TOTAL		1604	626	1352

TOTAL ROOT SYSTEM LENGTH: 2380 mm
TOTAL NO. PRIMARY ROOTS: 13
TOTAL NO. SECONDARY ROOTS: 15

CULTURED MYCELIAL INOCULATION

10	3.53	240	Total Top Height** : 216 mm

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
10 (cont.)						
			4	147		67
			5	237	199	
					41	
					27	
					26	
					32	
			7	157	97	221
			11	190	20	75
			15	304	40	343
					232	
					68	
					32	
					26	
					22	
			22	198	162	488
					28	
			31	208	92	294
					46	
			32	258		71
			38	197		54
			40	170	24	69
			53	210	55	57
					51	
					66	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
10 (cont.)					38	
			65	224	22	40
					21	
			77	114	38	63
					27	
					52	
			85	92		25
			117	69		44
			126	45		30
						121
		TOTAL		2820	1584	2062
TOTAL ROOT SYSTEM LENGTH:			4644 mm			
TOTAL NO. PRIMARY ROOTS:			16			
TOTAL NO. SECONDARY ROOTS:			22			
BASIDIOSPORE/VERMICULITE INOCULATION						
1	4.40	162	Total Top Height** : 162 mm			
			11	172	100	158
					28	
			12	146	374	594
					151	
					72	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)					54	
			12	228	117	497
					85	
					31	
					57	
					42	
			17	206	75	147
					31	
			17	161	115	277
					31	
			19	220	45	79
			28	211		113
			29	180	130	138
					37	
					62	
			30	97		63
			32	149		41
			42	138		37
			53	162	25	144
					18	
			66	55		48
			68	74		57
			135	125	86	10
					51	
			135	330	25	21

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)					41	
					46	
						456
		TOTAL		2654	1929	2880
TOTAL ROOT SYSTEM LENGTH:			4745 mm			
TOTAL NO. PRIMARY ROOTS:			16			
TOTAL NO. SECONDARY ROOTS:			26			
BASIDIOSPORE/VERMICULITE INOCULATION						
2	2.11	148	Total Top Height** : 94 mm			
			14	130		117
			15	143	192	489
					54	
					84	
					69	
					61	
			15	117	46	188
					53	
					40	
			18	131	53	338
					144	
					71	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)					99	
					95	
					54	
			18	114	55	215
					181	
					40	
					51	
			31	193	76	400
					228	
					201	
					91	
			33	102	123	125
					50	
			35	112	72	83
					51	
			41	188	189	121
					81	
			46	62		56
			49	104		35
			55	105		65
			58	81		30
			61	98		25
			69	49		10
			101	47		12
			104	102		15

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)			131	72		8
			131	70		5
						50
		TOTAL		2020	2604	2387
TOTAL ROOT SYSTEM LENGTH:			4772 mm			
TOTAL NO. PRIMARY ROOTS:			19			
TOTAL NO. SECONDARY ROOTS:			28			
BASIDIOSPORE/VERMICULITE INOCULATION						
3	5.12	206	Total Top Height** : 154 mm			
			5	215	83	178
					42	
					52	
					30	
					25	
			6	141	55	186
					102	
					58	
					22	
			8	106	178	223
					77	
			10	165	164	161

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)					151	
					46	
					29	
			12	251	69	123
					27	
					37	
			15	262		97
			15	394	36	204
					60	
			16	376	24	253
					109	
					47	
					23	
			19	302	28	237
					52	
					30	
			20	67	48	89
			20	191	194	216
			29	124		117
			31	108	59	125
					35	
					21	
					20	
			34	302	75	64
					47	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)					30	
			42	185	35	79
					32	
			45	133		158
			46	93		45
			51	152	59	52
			62	319	56	395
			62	80	81	65
			64	79		31
			70	142		21
			79	96	31	37
					20	
			90	115		23
			120	89		10
						179
		TOTAL		4487	2499	3368

TOTAL ROOT SYSTEM LENGTH: 7192 mm
TOTAL NO. PRIMARY ROOTS: 25
TOTAL NO. SECONDARY ROOTS: 43

BASIDIOSPORE/VERMICULITE INOCULATION

4	5.40	129	Total Top Height** : 130 mm

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)			9	134	39	289
					25	
					37	
					20	
					15	
					14	
			9	156	45	549
					26	
					67	
			14	171	72	310
					68	
					53	
					49	
					15	
			22	155	103	343
					43	
					19	
					57	
			29	156	91	748
					24	
					229	
					261	
			35	190	89	347
					103	
					32	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)					31	
			40	364	208	654
					51	
					47	
			45	105	47	187
					66	
			59	77		83
			69	88	32	36
			96	44	46	49
						303
		TOTAL		1640	2124	3898

TOTAL ROOT SYSTEM LENGTH: 3893 mm
TOTAL NO. PRIMARY ROOTS: 11
TOTAL NO. SECONDARY ROOTS: 33

BASIDIOSPORE/VERMICULITE INOCULATION

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5	4.81	426	Total Top Height** : 205 mm			
			9	102	46	209
					34	
			9	175	122	359
					50	
					44	
			10	179	79	257

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5 (cont.)					169	
			19	173	17	165
					36	
			23	416	180	443
			32	166	90	332
					31	
					56	
					26	
			39	172	148	90
			54	397	28	66
					90	
					49	
			70	122	58	92
					21	
			78	154	57	106
					53	
						346
		TOTAL		2056	1484	2464

TOTAL ROOT SYSTEM LENGTH: 3966 mm
TOTAL NO. PRIMARY ROOTS: 10
TOTAL NO. SECONDARY ROOTS: 21

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
BASIDIOSPORE/VERMICULITE INOCULATION						
6	2.07	210	Total Top Height** : 172 mm			
			5	50		40
			8	147	110	481
					27	
					124	
					25	
					22	
					137	
					33	
			12	125		74
			22	77		35
			22	304	47	98
					90	
			25	109	49	88
			25	92		71
			33	164	25	69
					37	
					40	
					153	
			41	168		30
			45	144		40
			62	46		27

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
6 (cont.)			81	87		33
			108	90		76
			140	165		47
						289
		TOTAL		1768	919	1498

TOTAL ROOT SYSTEM LENGTH: 2897 mm
TOTAL NO. PRIMARY ROOTS: 14
TOTAL NO. SECONDARY ROOTS: 14

BASIDIOSPORE/VERMICULITE INOCULATION

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7	4.15	292	Total Top Height** : 163 mm			
			5	261	68	398
					65	
					32	
			6	28	50	35
			8	165	122	431
			9	430	99	567
					47	
					70	
					50	
					49	
					32	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)			12	27		30
			12	77	30	141
			17	88		64
			24	58		51
			36	131		40
			41	396	97	173
			50	100	35	79
			56	317		67
			93	57		38
			100	37		25
			112	50		20
						185
		TOTAL		2222	846	2344
TOTAL ROOT SYSTEM LENGTH:			3360 mm			
TOTAL NO. PRIMARY ROOTS:			15			
TOTAL NO. SECONDARY ROOTS:			14			
BASIDIOSPORE/VERMICULITE INOCULATION						
8	6.77	300	Total Top Height** : 180 mm			
			3	144	60	257
					93	
					97	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)					27	
					44	
					48	
					60	
					49	
					52	
					29	
					24	
					24	
					31	
			4	176	42	122
					41	
					33	
			4	86	70	98
					36	
			20	216	55	169
					68	
					74	
					41	
			25	202	80	134
					96	
					39	
			26	132		52
			27	274	131	173
					43	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)			33	131	231	143
					30	
					25	
			35	121		77
			40	205		41
			44	422	52	68
					35	
					96	
					111	
			51	137	24	59
			51	85		25
			60	153		61
			84	106		33
			101	49		43
			104	217	55	20
					52	
						178
		TOTAL		2856	2203	1753

TOTAL ROOT SYSTEM LENGTH: 5359 mm
TOTAL NO. PRIMARY ROOTS: 17
TOTAL NO. SECONDARY ROOTS: 37

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
BASIDIOSPORE/VERMICULITE INOCULATION						
9	4.55	271	Total Top Height** : 220 mm			
			6	419	314	484
					221	
					226	
					43	
					43	
					34	
					54	
			14	188	31	357
					121	
					72	
					33	
					27	
					53	
					64	
			16	247	142	563
					180	
					147	
					79	
			23	182	36	279
					29	
					47	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)					28	
					188	
					87	
					30	
			33	309	74	296
					70	
					60	
					34	
					39	
					47	
			52	148	29	85
					27	
					26	
			53	219		69
			64	109	105	83
			83	101	64	115
			88	202		33
			96	85		56
			116	58		27
			127	55		20
						331
		TOTAL		2322	2904	2798

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)						
TOTAL ROOT SYSTEM LENGTH:			5497 mm			
TOTAL NO. PRIMARY ROOTS:			13			
TOTAL NO. SECONDARY ROOTS:			36			
BASIDIOSPORE/VERMICULITE INOCULATION						
10	4.04	382	Total Top Height** : 212 mm			
			12	200	41	397
					61	
			14	192	68	401
					94	
			23	241	40	289
					23	
					59	
					25	
					31	
					29	
			24	78		73
			25	265	87	284
					159	
					160	
					83	
					53	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
10 (cont.)			29	140		65
			35	85		36
			43	152		78
			45	44		89
			48	172	43	98
					41	
			78	362	102	78
					93	
						285
		TOTAL		1931	1292	2173

TOTAL ROOT SYSTEM LENGTH: 3605 mm
TOTAL NO. PRIMARY ROOTS: 11
TOTAL NO. SECONDARY ROOTS: 19

SEEDCOAT BASIDIOSPORE INOCULATION

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1	2.13	142	Total Top Height** : 78 mm			
			2	75	117	65
					20	
					22	
			3	144	64	240
					40	
					24	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)					18	
					79	
					49	
					102	
					61	
					60	
					33	
					31	
			5	158	20	78
					46	
			8	74	30	110
					28	
			8	70	20	91
					18	
					54	
					17	
					92	
					48	
					27	
			15	31	28	64
					52	
					18	
					16	
					15	
			18	145	29	35

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)			20	95	25	98
					65	
					26	
					22	
			25	106		27
			26	104		25
			30	148		30
			37	152	36	35
			40	79	43	56
			40	106	41	47
					28	
			54	69		30
			60	80		27
			61	60		15
						389
		TOTAL		1696	1564	1462
TOTAL ROOT SYSTEM LENGTH:			3402 mm			
TOTAL NO. PRIMARY ROOTS:			17			
TOTAL NO. SECONDARY ROOTS:			39			
SEEDCOAT BASIDIOSPORE INOCULATION						
2	4.59	216	TOTAL TOP HEIGHT** :	111 mm		

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)			4	41	35	86
					24	
			5	244	41	209
					48	
					27	
					56	
					52	
					108	
					26	
					47	
					84	
					137	
					54	
					100	
					68	
					25	
					141	
					40	
					39	
					44	
			6	67	82	244
					26	
					30	
					22	
			8	235	169	115

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)					24	
					23	
			15	66	21	48
					37	
			15	65		30
			20	68	184	98
			28	35	36	40
			30	152		35
			33	90		53
			41	26	69	41
					50	
			43	120	24	20
					34	
			51	171	32	33
					88	
					32	
					28	
			53	54	27	45
			58	115		21
			60	93		36
			60	89	26	58
					33	
			66	107		20
			79	78		15
			104	47		12

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)			148	110		10
						374
		TOTAL		2073	2293	1643

TOTAL ROOT SYSTEM LENGTH: 4582 mm
TOTAL NO. PRIMARY ROOTS: 21
TOTAL NO. SECONDARY ROOTS: 42

SEEDCOAT BASIDIOSPORE INOCULATION

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3	3.93	235	TOTAL TOP HEIGHT** : 95 mm			
			2	252	33	40
			2	149	111	53
			5	122	54	168
					27	
					23	
			10	50	43	71
					21	
					38	
			13	140	221	97
					144	
					112	
					56	
					51	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)					49	
					31	
					20	
					28	
			16	138		54
			17	139		65
			20	78	154	143
					33	
					35	
			25	153	110	115
					136	
					41	
			30	101	172	45
			32	136	45	84
			40	234	36	79
			41	118		41
			48	115	21	36
			52	101		33
			68	93	23	40
			68	100		14
			79	141		10
			85	152		11
			86	77		18
			98	93		8
						296

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)						
		TOTAL		2682	1868	1521
TOTAL ROOT SYSTEM LENGTH:			4785 mm			
TOTAL NO. PRIMARY ROOTS:			21			
TOTAL NO. SECONDARY ROOTS:			28			
SEEDCOAT BASIDIOSPORE INOCULATION						
4	3.85	135	TOTAL TOP HEIGHT** : 98 mm			
			4	174	75	197
					51	
					64	
					86	
					36	
					45	
					35	
					47	
					38	
					28	
			4	196	105	170
					25	
					25	
					20	
			6	132	181	205

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)					185	
					30	
					43	
			7	139	110	294
					101	
					103	
					41	
					31	
					45	
					37	
			11	57	30	103
					92	
					122	
					21	
					26	
			16	169	36	81
					21	
					35	
					25	
			21	84	60	78
					41	
			23	124	125	215
					70	
					46	
					68	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)					30	
			24	98	32	73
					31	
			37	159	43	65
					72	
			40	58	84	98
					38	
			50	87	68	46
			57	104		35
			57	113	50	59
			70	65	21	42
			78	67	40	50
					31	
			83	24		10
			86	87		32
			100	28		12
			103	34		18
			112	53		10
			115	20		11
			117	46		10
			119	27		15
						384
		TOTAL		2145	2944	2313

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)						
TOTAL ROOT SYSTEM LENGTH:		5224 mm				
TOTAL NO. PRIMARY ROOTS:		24				
TOTAL NO. SECONDARY ROOTS:		52				
SEEDCOAT BASIDIOSPORE INOCULATION						
5	3.80	232	TOTAL TOP HEIGHT** : 85 mm			
			3	24	34	51
					12	
			6	55	46	140
					21	
					24	
					16	
			8	140	27	89
					18	
			17	220	186	225
					151	
					94	
					41	
					22	
					25	
			19	154	20	231

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5 (cont.)					25	
					39	
					29	
					43	
					23	
					52	
					24	
			24	102	124	115
					37	
					25	
			37	84	51	108
					46	
					35	
					81	
					30	
					22	
					35	
					46	
					16	
			42	54	40	61
					115	
					20	
			50	60	16	25
			51	23	39	24
					28	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5 (cont.)			72	137		29
			94	62	49	45
					28	
					15	
			105	61		10
			122	53		7
			135	45		3
						398
		TOTAL		1274	1870	1561
TOTAL ROOT SYSTEM LENGTH:			3376 mm			
TOTAL NO. PRIMARY ROOTS:			15			
TOTAL NO. SECONDARY ROOTS:			43			
SEEDCOAT BASIDIOSPORE INOCULATION						
6	3.98	148	TOTAL TOP HEIGHT** : 81			
			7	100	114	123
					43	
					34	
					40	
			7	86	67	430
					104	
					121	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
6 (cont.)					62	
					33	
					48	
					30	
					42	
					34	
			8	227	251	369
					30	
					62	
					73	
			15	124	36	152
					23	
			22	319	54	146
					60	
					30	
					38	
					32	
					34	
					27	
					31	
					28	
			31	196	81	111
					43	
					67	
			40	177	67	115

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
6 (cont.)					36	
					22	
			46	91	32	83
					27	
			61	60		48
			66	101		13
			74	135		24
			85	73		21
			103	177		12
			111	45		25
						631
		TOTAL		1911	1956	2303
TOTAL ROOT SYSTEM LENGTH:			4015 mm			
TOTAL NO. PRIMARY ROOTS:			14			
TOTAL NO. SECONDARY ROOTS:			36			
SEEDCOAT BASIDIOSPORE INOCULATION						
7	4.00	328	TOTAL TOP HEIGHT** :	171 mm		
			5	210	28	221
					32	
					57	
					129	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)					22	
			5	188	158	302
					162	
					29	
					24	
					39	
			6	161	79	218
			6	198	42	258
					34	
					38	
			12	107		101
			17	228	24	163
			24	240	18	249
					80	
			45	172	23	154
			51	125	53	98
					22	
			56	158		83
			62	115	63	75
					95	
			89	207	25	51
			89	161	99	64
			108	138		40
			130	72		23
			130	95		27

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)						135
		TOTAL		2575	1375	2262
TOTAL ROOT SYSTEM LENGTH:			4278 mm			
TOTAL NO. PRIMARY ROOTS:			16			
TOTAL NO. SECONDARY ROOTS:			24			
SEEDCOAT BASIDIOSPORE INOCULATION						
8	4.18	188	TOTAL TOP HEIGHT** :	148 mm		
			5	107	113	178
					92	
					66	
					39	
					125	
					52	
			5	177	72	111
					53	
					59	
					102	
					37	
					26	
			9	118	22	98
					34	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)					50	
					27	
			13	114	125	71
			13	108	45	58
					36	
					30	
			14	191	107	186
			17	168	97	220
					47	
					34	
					81	
					35	
					39	
					22	
					25	
			25	101	56	67
					27	
			34	186	236	93
					40	
					32	
			38	142	62	55
					33	
					40	
					32	
					34	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)			42	68		48
			45	41		30
			56	57		29
			97	55		21
						237
		TOTAL		1688	2284	1552

TOTAL ROOT SYSTEM LENGTH: 4105 mm
TOTAL NO. PRIMARY ROOTS: 14
TOTAL NO. SECONDARY ROOTS: 39

SEEDCOAT BASISIOSPORE INOCULATION

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9	4.00	168	TOTAL TOP HEIGHT** : 104 mm			
			3	202	106	277
					42	
					34	
			5	71	269	533
					203	
					88	
					62	
					50	
			6	143	58	148
					40	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)			8	53	22	50
			11	29	219	165
					37	
					21	
			14	203		96
			18	31	47	61
			24	112	26	117
					44	
					35	
					43	
					39	
					27	
			31	68	43	53
			32	31	64	34
			39	82	225	136
			43	24	37	70
					32	
			75	51		25
			103	43		18
			105	37		11
			120	51		14
						410
		TOTAL		1231	1913	2218
TOTAL ROOT SYSTEM LENGTH:			3312 mm			

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)						
TOTAL NO. PRIMARY ROOTS:			16			
TOTAL NO. SECONDARY ROOTS:			26			
SEEDCOAT BASISIOSPORE INOCULATION						
10	3.20	132	TOTAL TOP HEIGHT** :	102 mm		
			4	154	43	81
					39	
					26	
					31	
			5	143	133	201
					120	
					60	
			6	211	275	246
					145	
					95	
					51	
					46	
					43	
			8	200	184	329
					140	
					166	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
10 (cont.)					55	
					84	
					46	
			15	212	70	85
					27	
					65	
					122	
			19	142	62	79
					26	
			31	107	166	81
					41	
					45	
			35	125		64
			37	200		70
			50	175	97	67
			53	67		10
			71	180		33
			95	49		5
			110	38		15
						395
		TOTAL		2003	2503	1761

TOTAL ROOT SYSTEM LENGTH: 4638 mm
TOTAL NO. PRIMARY ROOTS: 14
TOTAL NO. SECONDARY ROOTS: 29

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
CONTAINERIZED CONTROL						
1	3.28	226	TOTAL TOP HEIGHT** : 91 mm			
			9	214	151	277
					116	
					123	
			10	215	335	234
			10	144	56	165
					37	
					48	
			11	148	228	248
					46	
					90	
					37	
			16	155	91	159
					42	
			21	366	48	289
					57	
					139	
					32	
					44	
					141	
					314	
					91	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)					58	
					35	
			22	102	194	178
					414	
			24	159	57	123
					91	
					41	
			29	164	88	133
					90	
					24	
			30	259	72	98
					36	
			31	99	109	77
					46	
			35	117		35
			40	109		46
			43	101		29
			49	176		51
			50	105		20
			52	108		15
			64	133	137	35
			65	179	62	75
			71	85		30
						345

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)						
		TOTAL		3138	3820	2662
TOTAL ROOT SYSTEM LENGTH:			7184 mm			
TOTAL NO. PRIMARY ROOTS:			20			
TOTAL NO. SECONDARY ROOTS:			37			
CONTAINERIZED CONTROL						
2	1.10	194	TOTAL TOP HEIGHT** : 109 mm			
			5	231	127	157
					82	
					71	
					126	
			6	183	74	59
			8	175	51	237
					57	
					52	
					77	
			16	189	133	167
					68	
					25	
			19	191	66	341
					55	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)					81	
					56	
					65	
					51	
			21	199	204	98
			23	249		54
			27	206		64
			32	108	35	61
			42	216	116	356
					141	
					69	
					88	
					151	
					49	
					85	
					66	
					51	
			44	144		97
			49	97		50
			69	159		41
			81	55		15
			94	176		25
			97	117		16
			98	91		12
						35

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)						
		TOTAL		2786	2372	1885
TOTAL ROOT SYSTEM LENGTH:			5352 mm			
TOTAL NO. PRIMARY ROOTS:			17			
TOTAL NO. SECONDARY ROOTS:			29			
CONTAINERIZED CONTROL						
3	3.16	186	TOTAL TOP HEIGHT** : 67 mm			
			7	129	93	707
					151	
					92	
					141	
					222	
					113	
					43	
					47	
					30	
					27	
					35	
					36	
					65	
					78	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)					32	
					27	
			19	126	119	407
					34	
					52	
					44	
					29	
					64	
					33	
					58	
					41	
					43	
					38	
			21	176	104	
					64	
					108	
					77	
					58	
					62	
					170	
					60	
					101	
					34	
					41	
					83	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)					37	
					42	
			23	42		47
			25	169	49	230
					41	
					47	
					81	
			28	138	29	155
					70	
					121	
					34	
			30	169		53
			32	79		127
			35	65		22
			35	34		11
			44	101	126	120
					129	
			51	80		28
			53	57		20
			57	89		36
			64	164	68	73
					35	
			64	71		20
			76	68		29
			91	89	46	19

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)			99	86		15
			117	69		4
						115
		TOTAL		2001	3704	2783
TOTAL ROOT SYSTEM LENGTH:			5891 mm			
TOTAL NO. PRIMARY ROOTS:			20			
TOTAL NO. SECONDARY ROOTS:			54			
CONTAINERIZED CONTROL						
4	2.11	230	TOTAL TOP HEIGHT** : 91 mm			
			8	134	35	182
			11	215	91	344
					37	
					21	
					20	
					62	
					61	
			15	257	77	358
					28	
					37	
					66	
					102	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)			15	254		151
			22	96	168	387
					26	
					105	
					78	
					77	
					31	
					28	
			27	129		93
			30	158	79	237
					22	
					32	
			32	127		79
			36	122	103	373
					128	
					51	
					93	
					52	
					74	
					80	
			41	191		67
			62	111		54
						581
		TOTAL		1794	1864	2906

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)						
TOTAL ROOT SYSTEM LENGTH:		3888 mm				
TOTAL NO. PRIMARY ROOTS:		11				
TOTAL NO. SECONDARY ROOTS:		29				
CONTAINERIZED CONTROL						
5	2.30	185	TOTAL TOP HEIGHT** : 79 mm			
			5	220	142	253
					81	
					64	
					59	
			8	284	144	287
					56	
			8	185		178
			10	151		67
			14	134	31	373
					152	
					227	
					37	
					43	
					100	
					69	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5 (cont.)					41	
					39	
					28	
					103	
			17	130	279	198
					111	
			19	171		30
			21	132	305	151
					30	
					27	
					221	
					94	
			31	118	121	148
					76	
					49	
					122	
			41	246		27
			45	101	44	60
			48	87		25
			110	72		10
						187
		TOTAL		2031	2895	1994
TOTAL ROOT SYSTEM LENGTH:			5111 mm			
TOTAL NO. PRIMARY ROOTS:			13			

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5 (cont.)						
TOTAL NO. SECONDARY ROOTS:			28			
CONTAINERIZED CONTROL						
6	3.61	141	TOTAL TOP HEIGHT** : 91 mm			
			11	121	183	289
			12	116		178
			12	142	44	301
					92	
			20	79	42	137
			26	334	53	132
					48	
			32	103		56
			39	128	48	334
					106	
					86	
					33	
					43	
					46	
			41	86	71	78
					104	
					47	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
6 (cont.)			57	68		47
			63	103		30
			66	72		38
			69	77		30
			73	51		35
			92	46		23
			97	43		15
						165
		TOTAL		1569	1046	1888
TOTAL ROOT SYSTEM LENGTH:			2756 mm			
TOTAL NO. PRIMARY ROOTS:			15			
TOTAL NO. SECONDARY ROOTS:			15			
CONTAINERIZED CONTROL						
7	1.64	170	TOTAL TOP HEIGHT** : 138 mm			
			5	190		25
			7	132	103	132
					86	
			12	138	98	230
					79	
					43	
					47	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)			13	41		40
			18	93		35
			22	99	145	192
					161	
					56	
			23	109		43
			25	94	112	85
					89	
			26	101		41
			28	84		23
			30	65		31
			33	47		30
			37	66		24
			37	50		
			49	71	67	75
					33	
					28	
						250
		TOTAL		1380	1147	1256

TOTAL ROOT SYSTEM LENGTH: 2697 mm
TOTAL NO. PRIMARY ROOTS: 15
TOTAL NO. SECONDARY ROOTS: 14

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
CONTAINERIZED CONTROL						
8	5.48	145	TOTAL TOP HEIGHT** : 84 mm			
			12	293	203	786
					265	
					85	
					207	
			13	209		310
			17	372	131	400
			24	181	64	280
					63	
					298	
					218	
					83	
					179	
					64	
					199	
			25	260	238	230
					34	
					36	
			28	117	74	262
					150	
					55	
			30	169	52	170

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)					31	
					45	
			31	138	32	
					40	
					31	
			39	129	168	245
					74	
					175	
					37	
			43	176		95
			51	246		126
			54	89		20
			87	81		55
						297
		TOTAL		2460	3331	3276
TOTAL ROOT SYSTEM LENGTH:			5936 mm			
TOTAL NO. PRIMARY ROOTS:			13			
TOTAL NO. SECONDARY ROOTS:			29			
CONTAINERIZED CONTROL						
9	3.72	135	TOTAL TOP HEIGHT** : 83 mm			
			4	128	94	780

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)					58	
					94	
					77	
					73	
					62	
					55	
					55	
					37	
					50	
			4	103	243	337
					78	
					31	
			6	109	46	128
			12	116	34	97
					22	
					118	
			19	114	119	571
					197	
					32	
					57	
					30	
					32	
					114	
					87	
					33	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)			20	124	111	168
					55	
					39	
			22	91		59
			23	97		68
			24	119	111	334
					163	
					158	
					82	
					114	
					101	
					120	
			34	105		47
			38	163	93	109
					61	
					89	
			45	79		38
			50	154		68
			64	111	54	57
			69	57	106	93
					99	
					58	
			71	54		20
						123

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)						
		TOTAL		1724	3542	3097
TOTAL ROOT SYSTEM LENGTH:			5401 mm			
TOTAL NO. PRIMARY ROOTS:			16			
TOTAL NO. SECONDARY ROOTS:			33			
CONTAINERIZED CONTROL						
10	2.36	282	TOTAL TOP HEIGHT** :	112 mm		
			9	218	25	181
					22	
					16	
					34	
					26	
					70	
					64	
			13	356	100	287
					166	
			15		30	
					91	
					113	
					42	
					28	

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
10 (cont.)					38	
					39	
					35	
					40	
					15	
					46	
					72	
					39	
					51	
					14	
					22	
					19	
			15	219	309	144
			20	285	126	396
					31	
					21	
					65	
					30	
					28	
					6	
					83	
					40	
					145	
					61	
			21	217	19	87

(continued)

Table 4. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
10 (cont.)					22	
			21	269	20	185
					77	
					83	
					72	
			23	114	54	65
					14	
			30	63		39
			45	115	58	73
			54	93		29
			54	20		14
			56	144		35
			71	53		30
			83			15
			84			27
						31
		TOTAL		2166	2621	1955
TOTAL ROOT SYSTEM LENGTH:			5069			
TOTAL NO. PRIMARY ROOTS:			13			
TOTAL NO. SECONDARY ROOTS:			47			

* Total root system volume determined by water displacement.
** Measured relative to root collar.

Table 5. Root and shoot dry weights of eight-month-old containerized shortleaf pine seedlings.*

PLANT NO.	GRAM DRY WEIGHTS ROOT	SHOOT	TOTAL	ROOT/SHOOT RATIO
CULTURED MYCELIAL INOCULATION				
1†	0.51	1.01	1.52	0.50
2†	0.31	0.35	0.66	0.89
3†	0.81	0.57	1.38	1.42
4†	0.22	0.72	0.94	0.31
5†	0.45	0.55	1.00	0.82
6†	0.04	0.42	0.46	0.10
7†	1.20	1.27	2.47	0.94
8†	0.65	0.52	1.17	1.25
9†	0.28	0.92	1.20	0.30
10†	0.24	0.72	0.96	0.33
11†	0.32	0.71	1.03	0.45
12†	0.27	0.89	1.16	0.30
13†	0.36	0.67	1.03	0.54
14†	0.32	0.54	0.86	0.59
15†	0.10	0.77	0.87	0.13
16†	0.39	0.86	1.25	0.45
17†	0.67	0.68	1.35	0.99
18†	0.34	0.80	1.14	0.43
19†	0.81	1.24	2.05	0.65
20†	0.25	0.78	1.03	0.32
21†	0.65	0.55	1.20	1.18
22†	0.42	0.65	1.07	0.65
23†	0.05	0.40	0.45	0.13
24†	0.10	0.33	0.43	0.30
25†	0.10	0.65	0.75	0.15
26	1.09	0.86	1.95	1.27
27	0.31	0.34	0.65	0.91
28	0.71	0.79	1.50	0.90
29	1.19	0.66	1.85	1.80
30	1.00	0.57	1.57	1.75
31	0.35	0.50	0.85	0.70
32	1.02	0.85	1.87	1.20
33	0.52	0.59	1.11	0.88
34	0.48	0.34	0.82	1.41
35	0.60	0.54	1.14	1.11
36	1.14	0.35	1.49	3.26
37	0.61	0.73	1.34	0.84
38	0.49	0.72	1.21	0.68

(continued)

Table 5. Continued.

PLANT NO.	GRAM DRY WEIGHTS ROOT	SHOOT	TOTAL	ROOT/SHOOT RATIO
39	0.66	0.91	1.57	0.73
40	0.70	0.82	1.52	0.85
41	0.56	0.40	0.96	1.40
42	0.53	0.49	1.02	1.08
43	0.69	0.68	1.37	1.01
44	0.49	0.58	1.07	0.84
45	0.55	0.62	1.17	0.89
46	0.60	0.74	1.34	0.81
47	0.32	0.65	0.97	0.49
48	1.00	0.55	1.55	1.82
49	0.74	0.89	1.63	0.83
50	0.61	0.47	1.08	1.30
BASIDIOSPORE/VERMICULITE INOCULATION				
1 †	0.39	0.84	1.23	0.46
2 †	0.40	0.50	0.90	0.80
3 †	0.41	0.50	0.91	0.82
4 †	0.61	0.49	1.10	1.24
5 †	0.59	0.63	1.22	0.94
6 †	0.10	0.35	0.45	0.29
7 †	0.62	0.60	1.22	1.03
8 †	0.52	0.51	1.03	1.02
9 †	0.99	0.69	1.68	1.43
10 †	0.48	0.65	1.13	0.74
11 †	0.62	0.54	1.16	1.15
12 †	0.59	0.77	1.36	0.77
13 †	0.45	0.53	0.98	0.85
14 †	0.92	0.63	1.55	1.46
15 †	0.42	0.61	1.03	0.69
16 †	0.80	0.65	1.45	1.23
17 †	0.50	0.46	0.96	1.09
18 †	0.69	0.75	1.44	0.92
19 †	0.92	0.69	1.61	1.33
20 †	0.88	0.99	1.87	0.89
21 †	0.10	0.36	0.46	0.28
22 †	0.55	0.68	1.23	0.81
23 †	0.51	0.51	1.02	1.00

(continued)

Table 5. Continued.

PLANT NO.	GRAM DRY WEIGHTS ROOT	SHOOT	TOTAL	ROOT/SHOOT RATIO
24†	0.96	0.64	1.60	1.50
25†	1.05	0.88	1.93	1.19
26	0.60	0.41	1.01	1.46
27	0.79	0.58	1.37	1.36
28	0.29	0.41	0.70	0.71
29	0.38	0.61	0.99	0.62
30	0.60	0.66	1.26	0.91
31	0.98	0.84	1.82	1.17
32	1.16	0.58	1.74	2.00
33	0.61	0.53	1.14	1.15
34	0.55	0.86	1.41	0.64
35	0.48	0.60	1.08	0.80
36	0.60	0.70	1.30	0.86
37	0.72	0.87	1.59	0.83
38	0.58	0.82	1.40	0.71
39	0.55	0.47	1.02	1.17
40	0.60	0.29	0.89	2.07
41	0.64	0.31	0.95	2.06
42	0.65	0.52	1.17	1.25
43	0.49	0.72	1.21	0.68
44	0.91	0.71	1.62	1.28
45	0.12	0.40	0.52	0.30
46	0.39	0.63	1.02	0.62
47	0.53	0.56	1.09	0.95
48	0.75	0.62	1.37	1.21
49	0.59	0.44	1.03	1.34
50	0.61	0.51	1.12	1.20
SEEDCOAT BASIDIOSPORE INOCULATION				
1†	0.72	0.58	1.30	1.24
2†	0.69	0.40	1.09	1.73
3†	0.57	0.62	1.19	0.92
4†	0.68	0.71	1.39	0.96
5†	0.49	0.52	1.01	0.94
6†	0.58	0.66	1.24	0.88
7†	0.75	0.63	1.38	1.19
8†	0.92	1.09	2.01	0.84
9†	0.21	0.42	0.63	0.50
10†	0.55	0.40	0.95	1.38

(continued)

Table 5. Continued.

PLANT NO	GRAM DRY WEIGHTS ROOT	SHOOT	TOTAL	ROOT/SHOOT RATIO
11†	0.25	0.39	0.64	0.64
12†	0.77	0.81	1.58	0.95
13†	0.60	0.59	1.19	1.02
14†	0.62	0.72	1.34	0.86
15†	0.79	0.67	1.46	1.18
16†	0.68	0.45	1.13	1.51
17†	0.55	0.78	1.33	0.71
18†	0.67	0.89	1.56	0.75
19†	0.73	0.68	1.41	1.07
20†	0.45	0.60	1.05	0.75
21†	0.15	0.20	0.35	0.75
22†	0.36	0.59	0.95	0.61
23†	0.74	1.04	1.78	0.71
24†	0.95	0.97	1.92	0.98
25†	0.29	0.29	0.58	1.00
26	0.59	0.52	1.11	1.13
27	0.60	0.59	1.19	1.02
28	0.89	1.66	2.55	0.54
29	0.40	0.43	0.83	0.93
30	0.41	0.65	1.06	0.63
31	0.30	0.23	0.53	1.30
32	0.46	0.34	0.80	1.35
33	0.23	0.36	0.59	0.64
34	0.86	0.62	1.48	1.39
35	0.61	0.88	1.49	0.69
36	0.51	0.54	1.05	0.94
37	1.33	1.42	2.75	0.94
38	0.70	0.43	1.13	1.63
39	0.41	0.38	0.79	1.08
40	0.50	0.48	0.98	1.04
41	0.58	0.41	0.99	1.41
42	0.62	0.53	1.15	1.17
43	0.59	0.28	0.87	2.11
44	0.44	0.31	0.74	1.42
45	0.50	0.45	0.95	1.11
46	0.68	0.37	1.05	1.84
47	1.11	0.79	1.90	1.41
48	0.63	0.44	1.07	1.43
49	0.61	0.36	0.97	1.69
50	0.85	0.63	1.48	1.35

(continued)

Table 5. Continued.

PLANT NO	GRAM DRY WEIGHTS ROOT	SHOOT	TOTAL	ROOT/SHOOT RATIO
CONTAINERIZED CONTROL				
1†	0.62	1.00	1.62	0.62
2†	0.65	0.62	1.27	1.05
3†	0.58	0.54	1.12	1.07
4†	0.59	0.58	1.17	1.02
5†	0.51	0.53	1.04	0.96
6†	1.05	0.47	1.52	2.23
7†	0.54	0.50	1.04	1.08
8†	0.55	0.47	1.02	1.17
9†	0.56	0.59	1.15	0.95
10†	0.52	0.48	1.00	1.08
11†	0.51	0.71	1.22	0.72
12†	0.49	0.40	0.89	1.23
13†	0.38	0.47	0.85	0.81
14†	0.72	0.77	1.49	0.94
15†	0.86	0.69	1.55	1.25
16†	0.35	0.67	1.02	0.52
17†	0.59	0.53	1.12	1.11
18†	0.62	0.60	1.22	1.03
19†	0.47	0.61	1.08	0.77
20†	0.49	0.82	1.31	0.60
21†	0.64	0.68	1.32	0.94
22†	0.99	0.61	1.60	1.62
23†	0.46	0.69	1.15	0.67
24†	0.28	0.54	0.82	0.52
25†	0.50	0.89	1.39	0.56
26	0.60	0.59	1.19	1.02
27	0.72	0.51	1.23	1.41
28	0.42	0.21	0.63	2.00
29	0.70	0.29	0.99	2.41
30	0.67	0.38	1.05	1.76
31	0.44	0.28	0.72	1.57
32	0.53	0.29	0.82	1.83
33	0.63	0.60	1.23	1.05
34	1.08	0.69	1.77	1.57
35	0.27	0.32	0.59	0.84
36	0.88	0.55	1.43	1.60
37	0.61	0.46	1.07	1.33
38	0.75	0.73	1.48	1.03

(continued)

Table 5. Continued.

PLANT NO.	GRAM DRY WEIGHTS ROOT	SHOOT	TOTAL	ROOT/SHOOT RATIO
39	0.69	0.59	1.28	1.17
40	0.90	0.30	1.20	3.00
41	0.69	0.34	1.03	2.03
42	0.65	0.48	1.13	1.35
43	0.61	0.49	1.10	1.24
44	1.17	0.58	1.75	2.02
45	0.81	0.48	1.29	1.69
46	0.42	0.35	0.77	1.20
47	0.25	0.17	0.42	1.47
48	0.65	0.67	1.32	0.97
49	1.19	0.65	1.84	1.83
50	0.70	0.40	1.10	1.75

* Plants disected at the root collar.

Table 6. Foliage chemical analysis -- eight-month-old containerized shortleaf pine seedlings.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - - Parts Per Million							
Cultured Mycelial Inoculation										
1†	4.8	1.19	160	4380	900	1100	780	240	200	60
2†	2.8	1.24	120	4200	1000	1550	640	200	240	80
3†	2.8	1.13	200	4260	950	1200	400	560	220	40
4†	2.4	1.19	128	4560	1100	1200	500	160	180	t
5†	2.4	1.36	128	5360	900	1300	720	320	80	30
6†	2.4	1.13	144	4800	1200	1400	280	160	90	t
7†	2.0	1.24	144	4240	800	1250	420	60	125	t
8†	3.2	1.81	148	4560	1450	1625	650	200	60	120
9†	3.2	1.07	136	6400	1000	1150	270	100	40	40
10†	2.8	1.58	164	4840	1900	1500	460	80	130	80
11†	2.4	1.41	132	5200	1600	1300	360	400	50	t
12†	3.2	1.13	204	4720	1600	1450	800	400	60	t
13†	2.8	1.24	148	5360	1400	1175	420	80	100	80
14†	3.0	1.24	144	4560	1200	1350	540	160	230	80
15†	3.2	1.02	116	5080	1000	1050	340	240	60	t
16†	2.4	1.19	132	4240	1500	1350	620	220	40	t
17†	2.8	1.24	124	3600	1900	1700	780	160	30	t
18†	2.4	1.19	128	4480	1500	1200	560	40	50	t
19†	2.8	1.30	164	4560	1100	1250	520	320	90	t
20†	2.4	1.19	140	4880	800	1100	300	160	50	t
21†	2.4	1.24	132	4080	1600	1500	560	160	60	t
22†	3.2	1.24	140	4400	950	1325	550	660	80	t
23†	2.4	1.30	132	4320	1700	1200	360	160	30	t
24†	2.4	1.30	132	3600	1000	600	840	280	100	200
25†	2.0	1.36	152	3480	900	600	360	320	60	120
26	4.1	1.13	128	4200	1800	1100	480	100	140	160

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
27	3.4	1.76	182	4000	1700	800	800	280	40	140
28	4.5	1.55	126	4040	1500	1575	650	460	70	t
29	2.9	1.14	140	3700	1000	1150	770	360	70	40
30	4.7	1.43	124	5300	1600	1075	310	460	90	20
31	4.0	1.42	182	4060	1000	700	800	140	140	60
32	4.3	1.38	146	4600	1400	600	400	60	120	t
33	2.3	1.67	178	3860	1400	1125	740	340	180	t
34	2.2	1.63	170	4780	1250	650	750	540	110	180
35	3.4	1.19	196	4900	1100	1000	310	120	135	120
36	2.1	1.53	198	4600	1200	800	580	460	100	t
37	3.4	1.70	142	4980	1200	1175	520	400	110	t
38	3.7	1.57	142	4460	900	1300	550	280	160	t
39	3.6	1.13	140	4740	1500	1600	270	260	150	t
40	3.1	1.28	168	4340	1800	1650	530	420	40	t
41	4.3	1.38	182	4320	1600	975	740	180	170	140
42	2.1	1.36	124	4000	1200	1400	450	520	210	160
43	2.2	1.78	198	5260	900	800	440	240	210	t
44	2.0	1.43	124	4360	1800	1175	700	140	150	t
45	2.1	1.02	142	4120	1700	1200	420	420	210	180
46	2.3	1.27	200	4580	1200	1400	710	320	60	60
47	1.9	1.04	142	3960	1100	1500	310	120	230	t
48	2.1	1.30	188	3680	900	1300	320	530	120	t
49	2.2	1.45	184	4420	1000	750	820	190	170	60
50	2.1	1.17	138	4860	1600	1100	550	160	240	140

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - Parts Per Million							- - - - - - - - - -
Basidiospore/Vermiculite Inoculation										
1†	0.8	0.90	168	6360	1700	1120	560	640	94	80
2†	0.4	0.96	200	7200	1500	800	500	400	100	t
3†	0.8	2.38	172	5760	1200	460	640	560	96	20
4†	0.4	1.36	196	7440	1800	720	620	400	96	t
5†	0.4	1.07	172	5280	1400	580	480	400	92	40
6†	0.4	0.96	160	5280	1650	700	450	720	80	80
7†	0.4	1.07	172	6240	1400	800	380	480	96	t
8†	0.4	0.85	164	6120	1700	720	520	560	100	40
9†	0.8	0.90	176	5580	1100	440	620	480	100	t
10†	0.4	1.02	164	4800	1450	480	500	400	72	100
11†	0.4	1.36	188	5280	1100	600	440	560	80	t
12†	0.4	1.19	168	5400	1500	480	620	400	108	40
13†	0.4	0.79	164	4020	1600	640	300	560	84	60
14†	2.4	1.02	176	4680	1200	560	460	400	96	40
15†	0.4	0.96	176	4260	1500	480	770	480	112	t
16†	1.2	1.24	180	4560	1600	480	750	400	40	100
17†	0.4	0.79	168	3600	1600	1000	520	720	100	40
18†	2.8	0.85	160	4080	1800	800	440	640	110	20
19†	2.8	0.68	128	2800	1600	800	300	400	80	60
20†	3.2	0.96	156	3840	1600	760	290	480	120	100
21†	3.2	1.19	140	3520	900	800	500	640	80	20
22†	3.2	1.02	156	3680	1750	840	280	560	100	80
23†	3.0	0.96	124	2400	1000	440	460	400	80	80
24†	2.5	0.90	128	2960	1700	760	400	400	80	20

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
25†	2.4	0.90	156	3200	1700	800	280	480	100	80
26	2.6	1.17	194	6340	1600	740	710	680	48	t
27	2.1	0.75	188	6700	1050	720	670	660	100	t
28	2.8	1.91	192	7080	1000	800	580	680	48	t
29	3.0	1.83	190	4200	1700	980	700	680	86	t
30	1.1	2.01	158	7380	1000	880	740	540	68	t
31	0.5	2.20	160	4800	1500	600	400	540	82	60
32	1.8	0.77	124	6920	1300	1020	310	400	80	40
33	1.2	2.35	150	6640	1450	780	530	500	66	80
34	2.2	1.07	126	4720	1400	520	430	400	76	60
35	2.3	2.12	194	6900	1200	520	600	700	62	20
36	2.8	1.98	144	4500	1400	1080	610	480	58	20
37	3.1	1.03	178	5140	1200	520	710	620	44	80
38	1.7	2.12	134	6300	1100	680	760	440	116	t
39	3.2	0.92	174	6160	1000	880	510	600	80	20
40	1.0	1.24	148	6060	1800	680	770	500	80	40
41	1.1	1.82	146	6340	1400	620	390	480	100	60
42	2.6	1.75	190	5420	1400	760	400	680	96	40
43	2.3	1.70	176	7140	1650	540	660	620	50	40
44	1.9	1.84	166	6200	1700	800	600	560	76	60
45	0.9	1.38	162	5400	1600	540	360	640	118	20
46	2.8	2.23	182	4420	1000	600	690	600	80	60
47	0.7	1.77	172	6580	1400	580	340	640	42	20
48	2.8	1.36	184	5000	1900	880	700	680	76	40
49	2.7	0.88	192	4340	1400	640	690	680	70	40
50	1.6	1.96	190	5040	900	460	490	600	80	80

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - -	- - - -	Parts Per Million	- - - -	- - - -	- - - -	- - - -	- - - -
Seedcoat Basidiospore Inoculation										
1†	2.4	1.19	140	3200	2100	920	260	680	90	t
2†	3.2	1.75	188	4800	2300	1120	350	240	50	t
3†	3.6	1.81	164	4640	2000	1320	270	400	100	60
4†	3.1	1.52	120	2800	1000	720	260	400	30	20
5†	2.8	1.75	132	4000	1300	880	380	400	40	40
6†	3.6	2.09	156	6400	1700	1020	480	320	100	60
7†	2.8	1.19	144	4080	2000	1240	350	400	100	200
8†	4.8	1.64	148	4080	2100	1420	330	400	80	t
9†	2.4	1.19	240	3000	2000	900	400	640	70	80
10†	2.8	1.75	200	3180	1700	1200	320	240	40	t
11†	2.8	0.85	400	3600	3000	1000	310	80	50	60
12†	2.8	1.53	160	3360	2700	1200	300	280	60	t
13†	3.6	1.53	360	4260	2000	1200	250	400	30	200
14†	3.2	1.64	240	4200	1800	1000	480	400	70	60
15†	3.6	1.47	200	4800	2000	1000	240	400	20	t
16†	2.4	1.47	160	3720	2400	900	420	400	20	t
17†	3.2	1.58	160	4200	2000	1200	400	520	110	40
18†	2.8	1.47	160	4320	1700	1000	400	320	100	120
19†	2.0	1.58	120	3060	2000	975	360	400	60	200
20†	3.2	1.58	240	4680	1500	1200	340	240	60	200
21†	3.2	2.15	200	4200	1500	1150	400	240	60	80
22†	2.4	1.19	120	3720	2000	900	370	320	60	120
23†	2.8	1.52	120	3840	2300	1000	410	320	90	100
24†	3.6	1.36	160	5400	2150	1000	560	120	120	60

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
25†	0.4	1.58	200	5520	2100	1250	260	160	100	40
26	0.8	1.09	290	3440	1500	1000	440	320	90	160
27	1.7	1.03	290	3260	1500	1000	480	200	50	120
28	0.8	1.43	150	6180	2500	1450	360	500	60	60
29	1.7	2.06	150	4920	1200	1200	320	460	80	t
30	0.8	1.01	240	5820	2800	1000	250	220	90	t
31	3.8	1.12	130	3780	1900	1100	370	340	50	t
32	3.8	1.18	180	5500	1100	1300	490	280	30	160
33	3.9	2.03	162	3120	2800	1075	410	200	70	180
34	2.3	1.45	260	3740	1300	900	350	240	120	60
35	4.2	2.06	196	6140	1350	1200	290	360	60	40
36	2.2	1.12	210	3400	1400	800	260	120	100	t
37	2.4	1.03	350	4060	1700	1000	270	280	30	t
38	0.6	1.43	354	5560	2600	1400	290	420	100	140
39	4.0	1.59	158	2860	2000	1450	270	400	50	t
40	4.4	1.77	360	5280	1700	1400	470	120	110	120
41	3.6	1.94	310	4300	1200	1000	580	280	70	140
42	1.6	1.80	150	3080	2800	1100	340	440	60	80
43	3.8	0.89	350	3820	2000	800	410	320	50	80
44	3.4	1.74	150	5960	1000	1300	290	320	80	t
45	1.3	1.40	180	4900	1400	1375	400	400	90	60
46	2.2	2.13	170	3020	2300	1200	360	100	110	100
47	3.8	1.50	300	3980	2100	1000	400	280	60	140
48	2.4	1.22	120	3180	2300	950	460	260	50	60
49	3.0	2.10	210	5280	2000	1000	340	420	50	t
50	0.6	1.54	140	3360	2600	900	560	320	30	t

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
Containerized Control										
1†	3.6	0.85	272	6000	3300	1280	464	500	100	80
2†	3.2	0.96	232	5200	3000	1200	208	300	80	40
3†	4.8	0.79	252	6000	2400	920	360	200	20	t
4†	4.0	1.02	240	4640	3600	1200	648	500	20	40
5†	2.4	0.79	252	4960	3000	1040	420	350	40	t
6†	2.4	0.96	260	5440	4200	1160	496	500	80	120
7†	2.8	1.19	272	5600	3600	1200	400	750	100	120
8†	1.2	1.53	272	2400	3000	760	300	100	50	120
9†	3.2	1.41	204	4960	3300	1200	500	500	50	t
10†	3.2	1.47	284	5200	5100	1200	360	500	20	t
11†	2.0	1.41	272	3680	3000	1120	344	550	120	t
12†	2.4	1.58	232	5680	3000	1080	296	500	80	t
13†	3.6	1.47	268	5280	3300	1240	520	400	80	t
14†	4.0	1.58	280	4160	3300	1120	312	600	80	t
15†	3.2	1.36	160	4000	3000	880	480	600	80	t
16†	2.4	1.53	160	4240	4200	1200	240	500	60	40
17†	2.4	1.36	268	3280	1800	880	240	200	60	80
18†	2.8	1.47	168	4120	4000	920	260	300	40	t
19†	1.2	1.41	184	4240	3000	1040	472	500	100	40
20†	3.6	1.30	152	4000	3600	940	248	500	80	120
21†	2.8	1.58	204	2400	3000	1000	384	150	50	t
22†	0.8	1.24	188	7800	2000	1340	450	800	88	50
23†	3.2	1.36	180	4220	3800	1100	460	400	70	t
24†	0.8	1.47	168	6240	2400	1340	320	800	64	40

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - - Parts Per Million							- - - - - - - - - -
25†	2.8	1.24	168	7800	2150	1250	500	720	60	20
26	1.0	0.86	266	4860	3600	920	462	400	50	t
27	2.0	1.12	214	5960	2100	1140	264	300	40	t
28	2.0	0.94	222	6000	4000	800	272	200	90	20
29	2.5	0.88	282	4860	4100	840	256	450	50	t
30	4.6	1.06	170	4660	2400	780	556	500	30	t
31	3.5	1.27	278	4800	2500	1340	352	420	30	t
32	3.8	1.05	190	2920	2200	1280	272	500	70	120
33	2.7	1.15	252	3540	3550	1000	312	700	50	80
34	1.0	1.35	200	4560	3500	1300	632	150	70	t
35	4.0	1.48	218	3100	4200	940	266	100	50	40
36	3.5	0.91	214	5440	3000	1140	218	500	40	40
37	4.1	0.86	194	2720	2800	1200	446	300	50	40
38	2.1	1.13	166	2580	1900	920	362	200	60	t
39	3.3	1.11	198	5100	2300	820	610	700	60	t
40	4.4	1.27	202	2520	3000	1200	536	300	100	t
41	3.7	1.50	186	4980	3300	1000	520	800	30	80
42	2.6	1.53	208	4760	1800	820	604	500	100	120
43	4.4	0.80	278	4660	3400	860	452	300	20	20
44	4.7	1.31	214	3940	3200	900	402	250	100	100
45	4.0	1.15	264	5200	3700	1160	552	300	120	t
46	2.0	1.21	206	5460	3300	840	414	500	70	80
47	1.1	1.39	258	2640	3900	1200	290	600	40	40
48	4.3	1.16	174	4060	2900	1040	240	600	30	40
49	3.2	1.39	240	5280	3600	820	350	700	50	80

(continued)

Table 6. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
50	3.4	1.52	254	5220	4200	820	410	500	70	20

t trace amount

Table 7. Root chemical analysis -- eight-month-old containerized shortleaf pine seedlings.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - Parts Per Million							- - - - - - - - - -
Cultured Mycelial Inoculation										
1†	9.6	1.30	240	4800	1700	1975	860	160	40	40
2†	12.4	0.90	180	3600	1350	2100	620	160	20	40
3†	15.2	0.96	228	4680	1500	2350	640	120	20	10
4†	15.2	1.13	244	5640	1600	2150	360	200	80	10
5†	10.8	1.07	204	6000	900	1350	600	160	110	t
6†	10.4	1.70	236	5520	1500	2275	300	160	120	200
7†	9.2	0.34	256	4680	1700	2250	980	80	70	80
8†	10.8	1.70	304	4440	1850	2550	1090	80	80	40
9†	7.2	1.02	204	4800	1300	1775	780	80	50	30
10†	7.2	0.85	220	5400	1300	2150	860	80	30	40
11†	6.8	0.85	248	7560	1400	2400	880	240	80	120
12†	9.6	1.30	244	7020	1250	1725	880	60	60	50
13†	10.0	0.79	164	3960	800	1400	890	100	40	10
14†	9.6	1.07	220	6120	1250	1850	820	20	60	50
15†	16.8	1.13	224	5640	1150	2400	900	160	40	100
16†	12.0	1.81	236	6360	1100	2000	960	120	100	20
17†	15.2	0.96	176	3840	1000	2000	620	80	40	20
18†	6.8	0.79	164	2640	800	1350	640	120	60	40
19†	6.8	0.96	160	2700	900	1400	640	150	25	20
20†	6.9	0.85	172	4020	900	1650	560	160	40	40
21†	12.4	1.19	204	3780	1900	2900	1080	80	90	180
22†	10.0	1.19	172	3240	1500	2250	650	120	60	40
23†	11.6	0.79	184	4680	1100	1600	880	80	70	40
24†	8.8	0.96	192	4080	975	1525	640	80	20	10

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - -	- - -	- Parts Per Million	- - -	- - - -	- - -	- - -	- - -
25†	8.0	0.96	204	4320	1025	1950	1140	80	50	20
26	6.8	1.19	264	6180	1100	2300	1100	20	90	70
27	11.8	0.54	208	4520	1200	1400	660	20	50	180
28	10.9	1.58	302	4140	950	1925	780	160	170	110
29	8.5	0.76	208	5000	950	1375	420	40	60	160
30	13.6	0.99	200	6300	1100	1500	980	220	180	150
31	15.4	1.31	254	6420	1800	2750	520	200	70	t
32	7.9	1.78	290	6880	1500	2300	1060	60	90	70
33	12.7	1.04	182	3220	1075	2100	600	60	60	10
34	6.9	1.56	214	7040	825	1600	540	200	25	10
35	12.1	0.80	210	6680	1500	2400	560	40	40	120
36	16.3	1.28	226	4180	1600	2650	760	120	90	20
37	13.0	1.79	200	3380	1450	2850	1100	140	110	70
38	12.0	1.81	252	4020	900	2600	340	120	30	100
39	9.7	0.89	204	4500	1600	2625	1100	160	40	180
40	8.2	0.48	258	3040	1275	1500	780	180	80	160
41	7.4	1.33	298	3480	1800	2400	460	120	90	190
42	15.6	0 62	292	4100	1300	2925	880	80	110	90
43	10.1	0.66	208	7020	1400	1500	1120	60	50	t
44	15.2	1.07	206	3500	1800	1700	340	100	100	140
45	10.5	0.55	302	5260	1600	2250	440	80	140	160
46	15.6	1.62	218	3200	1025	2600	600	40	50	100
47	15.6	0.91	224	7320	1200	1650	580	120	130	20
48	7.1	1.19	204	4220	1350	1900	780	80	100	130
49	6.8	1.37	268	6120	1625	1950	960	100	40	10
50	14.2	1.40	196	2680	1000	2200	900	60	40	80

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - Parts Per Million							
Basidiospore/Vermiculite Inoculation										
1†	13.6	0.57	164	3180	1500	1000	540	160	50	60
2†	7.6	1.24	188	3960	2900	1300	1020	100	100	60
3†	12.0	0.85	184	5760	2500	1200	915	80	60	60
4†	13.6	0.90	192	4680	2400	1050	660	240	40	100
5†	10.0	1.02	200	3720	2500	1200	780	90	60	20
6†	8.4	1.07	180	5640	1650	1100	690	200	80	80
7†	15.2	0.96	160	5160	1500	1000	660	160	60	40
8†	12.8	1.19	184	8880	1000	850	1200	240	80	40
9†	8.0	0.90	168	14400	1400	1100	450	240	60	t
10†	8.4	1.24	196	11520	2500	1300	960	240	40	120
11†	6.4	0.96	188	13400	1400	1000	240	240	70	40
12†	11.2	1.19	184	14100	2300	1200	300	30	40	10
13†	12.0	1.07	180	13200	1300	900	150	160	40	40
14†	11.2	0.79	156	4560	850	950	630	100	70	100
15†	10.0	0.96	164	4440	600	1000	670	180	80	80
16†	14.0	1.02	188	5040	1150	1100	600	80	80	40
17†	11.2	1.02	208	5160	1300	1000	620	20	70	40
18†	10.8	1.02	176	4200	1150	950	680	80	50	t
19†	13.6	0.85	180	4560	1000	850	860	80	50	20
20†	10.0	1.02	212	4320	1250	1000	800	80	50	60
21†	8.0	1.02	204	5400	1000	850	640	80	40	40
22†	11.2	1.36	240	5880	1350	950	740	160	50	20
23†	10.4	0.74	248	3960	800	800	440	160	50	20
24†	12.8	1.19	180	5100	1500	900	600	160	50	40

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
25†	12.0	0.11	192	5520	1000	750	690	160	60	10
26	11.7	1.36	210	4930	1250	1050	1140	140	90	40
27	12.0	1.14	242	8740	1100	1000	1160	190	100	60
28	10.7	1.25	234	8500	2100	1100	790	100	90	120
29	12.8	1.16	228	7280	900	1100	290	160	90	t
30	12.2	0.75	246	4520	2700	950	180	80	40	t
31	7.3	1.22	156	3620	2750	1150	1090	240	80	70
32	7.8	0.90	172	8780	2300	1050	790	180	100	110
33	9.9	0.77	156	4520	1550	700	180	160	40	30
34	7.5	1.21	174	4440	1500	1000	1030	30	50	110
35	9.9	1.00	216	3700	1300	1200	740	160	60	90
36	13.5	1.02	216	4700	2900	900	750	100	70	10
37	7.0	0.79	176	7880	1000	1200	1090	50	50	60
38	13.2	1.15	192	8520	900	900	680	60	80	60
39	11.3	0.75	182	4540	2550	900	610	160	50	20
40	6.8	0.89	162	7980	600	1150	745	220	80	10
41	9.3	1.31	200	5520	2700	1200	480	140	100	80
42	6.6	0.84	194	8440	2550	1000	340	220	70	100
43	8.1	0.96	208	7060	2400	1000	490	160	70	t
44	10.9	1.18	172	8300	2700	700	980	200	60	40
45	8.9	1.25	234	5280	1350	1050	620	100	60	60
46	12.0	0.94	212	7540	2300	900	1000	40	90	40
47	10.4	1.30	232	3740	1300	900	480	210	50	60
48	10.5	1.11	236	6300	1200	700	700	180	90	60
49	7.1	0.84	170	5500	900	1300	630	160	40	110
50	11.1	0.89	194	5580	1600	1200	370	140	50	20

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - -	Parts Per Million	- - - - - - - -					
Seedcoat Basidiospore Inoculation										
1†	14.0	0.85	148	4500	900	650	900	240	70	80
2†	10.8	0.90	184	4380	1300	900	1480	160	30	120
3†	9.6	0.74	168	5220	900	800	1000	80	60	100
4†	10.8	1.07	124	4260	1000	650	980	320	50	40
5†	15.6	1.02	148	4920	1600	700	900	400	70	80
6†	11.6	0.85	156	6000	1300	575	980	400	80	160
7†	12.0	0.96	168	5400	1500	400	900	400	50	120
8†	11.2	0.90	140	4920	800	400	900	240	60	160
9†	12.0	0.85	164	5160	1100	700	900	360	50	40
10†	7.2	0.85	136	4080	500	400	830	120	60	180
11†	8.8	0.90	220	3180	1300	500	1100	320	110	80
12†	11.6	0.51	116	3780	500	500	840	160	20	40
13†	14.0	1.02	188	4320	1500	1050	1300	80	20	40
14†	8.0	0.68	156	3600	850	300	1040	150	40	120
15†	8.4	0.85	140	4440	1600	575	800	120	40	200
16†	4.4	1.24	100	2160	500	325	600	80	30	40
17†	8.4	0.96	144	3000	3000	800	700	100	20	240
18†	13.2	0.74	124	4020	1150	500	1140	240	40	20
19†	12.4	0.96	168	6000	2000	1225	840	160	40	20
20†	12.8	1.13	172	4920	2000	1300	765	160	20	20
21†	13.6	0.96	180	3000	1800	1200	720	160	30	40
22†	9.6	0.85	148	3000	1800	1275	960	80	20	20
23†	12.8	0.74	124	1400	1350	900	720	80	30	100
24†	8.8	0.74	128	1560	1225	800	510	120	40	80

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - -	Parts Per Million	- - - - - - - - - - -					
25†	9.8	0.85	132	3720	3400	900	780	20	30	t
26	12.4	0.71	136	5520	800	1025	1270	160	20	t
27	14.1	1.07	180	1640	800	900	1260	120	100	220
28	13.3	0.58	174	5920	2775	500	1280	260	30	100
29	11.3	0.70	178	2440	800	1100	930	160	40	60
30	13.9	1.19	178	5300	2250	850	1370	200	40	180
31	14.8	0.63	140	4920	1550	400	910	380	50	20
32	7.1	0.77	142	2340	2100	400	970	750	90	80
33	5.0	1.07	100	5280	1900	1100	525	380	70	220
34	10.1	0.52	130	2040	1400	400	1310	120	50	220
35	7.7	1.01	102	2900	1800	600	1400	400	30	220
36	11.8	0.87	182	4480	1300	925	1230	340	100	100
37	11.9	0.57	124	4280	1225	600	800	120	60	140
38	14.2	0.72	164	4140	700	675	1280	380	20	20
39	15.3	1.15	110	4540	3200	700	1170	120	40	200
40	9.7	0.94	158	3280	2150	450	700	160	80	220
41	15.5	0.56	128	5600	1900	800	910	140	70	160
42	6.8	0.75	126	4340	2600	400	1280	320	80	100
43	7.2	0.59	178	3240	2500	500	960	80	70	40
44	13.2	1.01	160	1940	900	500	1090	200	90	80
45	11.8	0.63	144	4860	1800	950	560	100	50	60
46	6.2	0.66	166	2720	3300	600	990	140	50	60
47	13.8	0.97	156	1840	2100	300	1210	160	110	40
48	5.7	1.05	168	2760	600	1000	1200	320	90	220
49	14.0	0.77	178	1960	1800	900	640	100	40	140
50	13.8	0.69	176	2780	1700	1000	640	360	60	200

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
Containerized Control										
1†	12.0	1.24	192	3840	2000	1200	1000	80	40	t
2†	13.0	1.02	140	5640	1000	825	840	160	110	25
3†	16.0	0.96	168	5880	1300	1100	680	240	60	t
4†	16.0	0.68	148	5220	1225	500	740	170	50	40
5†	14.8	0.74	120	4260	1500	675	1000	240	40	40
6†	14.8	0.74	160	4920	1700	700	1000	160	60	80
7†	12.8	1.19	132	3960	1300	400	780	90	60	t
8†	8.4	1.02	180	4560	1550	625	900	120	130	80
9†	14.8	1.02	140	3840	1500	500	560	60	20	40
10†	9.6	1.13	140	5280	2000	600	1000	40	50	140
11†	10.0	0.74	148	5640	1025	730	840	120	30	40
12†	12.2	0.74	136	5160	900	500	520	160	20	70
13†	14.8	1.02	116	6240	825	425	600	160	60	40
14†	14.8	1.13	128	4740	900	300	620	240	80	20
15†	12.0	1.13	152	5760	1500	600	720	120	40	20
16†	12.4	1.02	152	5640	1125	600	680	120	100	40
17†	11.6	0.90	132	6240	1350	500	760	100	40	10
18†	10.8	1.13	144	5520	1900	700	920	40	45	80
19†	15.6	0.85	180	4080	1500	725	720	80	40	40
20†	13.6	1.02	136	5160	1000	500	680	90	130	t
21†	13.6	0.79	124	4260	1350	600	960	60	20	30
22†	10.0	1.41	124	4560	2000	800	840	170	50	40
23†	14.4	0.85	184	5220	1000	500	640	120	40	40
24†	8.0	2.21	180	4400	1150	800	800	40	80	20

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			- - - - - - - - - Parts Per Million							- - - - - - - - - -
25†	15.2	2.43	124	4020	1100	950	520	180	40	t
26	12.9	0.72	160	6200	1600	600	920	100	90	90
27	13.1	1.09	186	4400	1000	925	780	60	45	125
28	11.9	2.28	180	4360	1900	800	780	60	100	40
29	13.8	0.96	176	4060	1925	300	940	160	130	80
30	13.2	1.30	190	4480	1700	800	760	220	70	70
31	8.8	1.93	116	5820	1300	1100	720	140	80	90
32	9.2	2.11	130	6080	1200	500	780	220	60	80
33	11.2	1.23	116	4420	1275	1000	660	160	60	t
34	9.0	2.25	130	5860	2050	675	600	220	110	130
35	11.2	1.72	166	4820	1000	600	680	100	40	t
36	14.4	0.97	166	6040	1000	900	900	60	100	40
37	8.5	1.11	132	5460	1800	1150	740	220	20	80
38	14.2	1.82	144	6000	800	700	900	180	40	100
39	12.4	1.33	138	4720	1900	800	660	180	80	120
40	8.3	1.65	122	5680	1800	300	760	140	50	100
41	10.6	2.33	152	4080	1700	800	740	120	70	20
42	8.2	1.30	148	5160	1925	600	620	200	130	110
43	9.6	0.71	160	4820	1200	600	780	220	80	t
44	12.1	1.68	130	4840	1750	400	880	220	120	50
45	10.3	0.89	180	6100	1100	1200	820	180	40	30
46	13.1	2.42	162	6140	1100	1125	700	60	120	110
47	11.6	1.82	180	5300	1000	600	660	160	100	70
48	11.7	0.95	182	4160	1300	1200	1000	220	20	70
49	8.7	2.17	128	3900	1400	1100	880	40	60	30

(continued)

Table 7. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
50	12.3	1.64	148	5980	1400	900	840	60	70	100

t trace amount

Table 8. Root measurements -- 1-0 nursery-grown shortleaf pine seedlings.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1	7.66	182	TOTAL TOP HEIGHT** : 123 mm			
			10	207	50	21
			11	468	55	15
					74	
					113	
					92	
					52	
					39	
					68	
					28	
			14	316	75	43
					80	
					56	
					22	
			18	117	26	38
			23	335	66	10
					33	
					56	
					31	
					22	
			25	102	21	50
			34	75		31
			35	154	57	7
					41	
			37	194		14

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
1 (cont.)			40	60	21	11
			44	88		12
			61	67		22
			61	48		23
			66	40		8
			75	173		13
			78	122		7
						20
		TOTAL		2566	1178	345
TOTAL ROOT SYSTEM LENGTH:			3926 mm			
TOTAL NO. PRIMARY ROOTS:			16			
TOTAL NO. SECONDARY ROOTS:			23			
2	4.65	155	TOTAL TOP HEIGHT** :	150 mm		
			5	214	62	57
			5	223	33	95
					47	
			6	106	34	72
			8	150		15
			19	252	109	23
			20	163		10
			29	533		13
			30	71		40

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
2 (cont.)			34	123	131	61
					34	
					33	
			85	119		0
						55
		TOTAL		1954	483	441
TOTAL ROOT SYSTEM LENGTH:			2592 mm			
TOTAL NO. PRIMARY ROOTS:			10			
TOTAL NO. SECONDARY ROOTS:			8			
3	5.22	180	TOTAL TOP HEIGHT** :	142 mm		
			6	326	21	20
					125	
					69	
					98	
					53	
					32	
			13	378	43	34
					29	
			18	205	73	59
					93	
					45	
					46	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)					37	
					27	
			20	432	113	40
					44	
					55	
					58	
					32	
					43	
					33	
					27	
			23	120	47	
					31	
					63	
					58	
					28	
					47	
					52	
					88	
					22	
			29	190	20	15
					24	
			38	62		5
			39	126		14
			70	117		4
			80	106		10

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
3 (cont.)			101	64		21
			123	93		7
						37
		TOTAL		2219	1676	266
TOTAL ROOT SYSTEM LENGTH:			4075 mm			
TOTAL NO. PRIMARY ROOTS:			12			
TOTAL NO. SECONDARY ROOTS:			33			
4	4.39	137	TOTAL TOP HEIGHT** :	118 mm		
			13	118	53	53
					91	
					22	
					165	
					177	
			15	126	44	34
			27	57	219	41
					138	
			32	503	46	13
			33	102	20	27
			38	134	64	10
					23	
			42	366	72	29
					35	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
4 (cont.)					19	
					22	
						44
		TOTAL		1406	1210	251
TOTAL ROOT SYSTEM LENGTH:			2753 mm			
TOTAL NO. PRIMARY ROOTS:			7			
TOTAL NO. SECONDARY ROOTS:			16			
5	4.29	230	TOTAL TOP HEIGHT** :	183 mm		
			10	351	208	26
					45	
					16	
					19	
					27	
			12	364	39	15
					20	
					30	
			13	258	87	57
					32	
			19	355	32	31
					23	
					28	
					24	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
5 (cont.)					21	
			25	168		20
			33	138		49
			35	146		19
			36	85		8
			52	183		6
			68	77		13
			83	64		14
						21
		TOTAL		2189	641	279
TOTAL ROOT SYSTEM LENGTH:			3060 mm			
TOTAL NO. PRIMARY ROOTS:			11			
TOTAL NO. SECONDARY ROOTS:			15			
6	5.08	168	TOTAL TOP HEIGHT** :	176 mm		
			2	136	36	156
					58	
					30	
					23	
			3	357	50	168
					127	
					53	
					46	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
6 (cont.)					54	
					33	
					27	
					24	
					28	
					29	
					28	
					27	
			6	131	63	56
					34	
			12	172	39	93
					26	
					20	
					28	
			13	175		25
			18	61	34	39
					36	
			24	80		21
			29	158	24	27
					29	
			36	68		5
			42	53	21	24
					20	
			42	94		27

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
6 (cont.)			48	101		23
			56	104		30
			62	98		32
			68	47		16
						17
		TOTAL		1835	1047	759
TOTAL ROOT SYSTEM LENGTH:			3050 mm			
TOTAL NO. PRIMARY ROOTS:			15			
TOTAL NO. SECONDARY ROOTS:			28			
7	5.48	56	TOTAL TOP HEIGHT** :		120 mm	
			7	294	73	43
					73	
					92	
					46	
					82	
					68	
			10	263	131	31
					39	
					18	
			10	334	109	64
					54	
					103	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)					47	
					51	
					95	
					41	
					26	
					19	
					18	
					20	
			16	197	68	19
					50	
					58	
					75	
					26	
					45	
					29	
					40	
			18	472	66	21
					51	
					27	
			24	66		28
			27	67	30	7
			32	109		19
			34	55		12
			38	117		5
			40	70	15	11

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
7 (cont.)			60	55		7
						24
		TOTAL		2099	1783	291
TOTAL ROOT SYSTEM LENGTH:			3938 mm			
TOTAL NO. PRIMARY ROOTS:			12			
TOTAL NO. SECONDARY ROOTS:			33			
8	4.43	189	TOTAL TOP HEIGHT** :	175 mm		
			6	97	51	78
					73	
					47	
					63	
					38	
					21	
					44	
					27	
			7	207	58	107
					115	
					73	
					25	
					46	
					22	
					21	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)					37	
					24	
			9	179	86	115
					67	
					29	
					37	
					19	
			10	183	31	223
					37	
					60	
					38	
					82	
					24	
			31	98	21	59
					30	
			34	72		41
			37	80	20	69
					18	
			50	123	17	35
			55	75	15	26
			59	91	32	23
					18	
					19	
			113	97	20	10
						39

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
8 (cont.)						
		TOTALS		1302	1505	825
TOTAL ROOT SYSTEM LENGTH:			2996 mm			
TOTAL NO. PRIMARY ROOTS:			11			
TOTAL NO. SECONDARY ROOTS:			38			
9	3.58	143	TOTAL TOP HEIGHT**:		138 mm	
			6	190	40	67
					42	
					36	
					35	
					28	
					173	
			8	200	97	30
					36	
			13	80	95	81
					23	
					52	
					71	
					30	
			19	79	22	50
			20	122	200	16
					53	
					132	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
9 (cont.)					92	
					99	
					89	
					59	
			86	98		5
			90	81		7
						74
		TOTAL		850	1504	330
TOTAL ROOT SYSTEM LENGTH:			2497 mm			
TOTAL NO. PRIMARY ROOTS:			7			
TOTAL NO. SECONDARY ROOTS:			21			
10	3.19	145	TOTAL TOP HEIGHT** : 173 mm			
			14	280	58	17
					44	
					48	
					21	
					23	
					118	
					140	
					42	
					43	
					32	

(continued)

Table 8. Continued.

Plant No.	Total Volume* (ml)	Main Root Length (mm)	Primary Roots Position** (mm)	Primary Roots Length (mm)	Secondary Roots Length (mm)	Short Roots (#)
10 (cont.)					24	
					33	
			15	215	108	14
					92	
					85	
					127	
					79	
					55	
			18	97		9
			30	84		5
			32	90	63	7
			41	82		12
			70	69		8
						27
		TOTAL		917	1235	99

TOTAL ROOT SYSTEM LENGTH: 2297 mm
TOTAL NO. PRIMARY ROOTS: 7
TOTAL NO. SECONDARY ROOTS: 18

* Total root system volume determined by water displacement.
** Measured relative to root collar.

Table 9. Root and shoot dry weights of 1-0 nursery-grown shortleaf pine seedlings.*

Plant No.	Gram Dry Weights			Root/Shoot Ratio
	Root	Shoot	Total	
1†	2.05	2.51	4.56	0.82
2†	0.80	1.66	2.46	0.48
3†	0.97	1.52	2.49	0.64
4†	2.14	4.15	6.29	0.52
5†	0.67	3.07	3.74	0.22
6†	1.94	4.66	6.60	0.42
7†	1.27	2.98	4.25	0.43
8†	1.76	2.99	4.75	0.59
9†	0.51	1.81	2.32	0.28
10†	1.35	2.06	3.41	0.66
11†	1.08	2.28	3.36	0.47
12†	0.54	1.34	1.88	0.40
13†	1.00	1.45	2.45	0.69
14†	1.39	2.82	4.21	0.49
15†	1.17	3.05	4.22	0.38
16†	1.52	1.11	2.63	1.37
17†	1.22	1.98	3.20	0.62
18†	0.74	0.89	1.63	0.83
19†	1.08	2.40	3.48	0.45
20†	0.29	2.67	2.96	0.11
21†	0.79	1.66	2.45	0.48
22†	2.24	2.87	5.11	0.78
23†	1.13	1.27	2.40	0.89
24†	0.73	3.99	4.72	0.18
25†	0.85	2.85	3.70	0.30
26	1.10	3.90	5.00	0.28
27	1.77	3.22	4.99	0.55
28	0.71	2.02	2.73	0.35
29	1.41	3.00	4.41	0.47
30	1.03	4.03	5.06	0.26
31	1.51	4.46	5.97	0.34
32	1.27	1.84	3.11	0.69
33	0.93	3.15	4.08	0.30
34	1.12	3.68	4.80	0.30
35	0.93	2.93	3.86	0.32
36	1.34	1.06	2.40	1.26
37	2.33	4.05	6.38	0.58
38	0.94	3.78	5.72	0.25
39	0.97	2.86	3.83	0.34

(continued)

Table 9. Continued.

Plant No.	Gram Dry Weights Root	Shoot	Total	Root/Shoot Ratio
40	1.19	2.75	3.94	0.43
41	1.88	5.47	7.35	0.34
42	0.83	3.81	4.64	0.22
43	1.98	1.06	3.04	1.87
44	0.90	2.53	3.43	0.36
45	2.10	3.57	5.67	0.59
46	0.92	3.32	4.24	0.28
47	2.79	2.90	5.69	0.96
48	1.27	4.24	5.51	0.30
49	1.35	1.65	3.00	0.82
50	1.33	3.04	4.37	0.44

*Plants disected at the root collar.

Table 10. Foliage chemical analysis -- 1-0 nursery-grown shortleaf pine seedlings.

Plant No.	Ash Content (%)	%N	Parts Per Million P	K	Ca	Mg	Na	Mn	Zn	Cu
1†	5.2	1.53	156	8880	800	560	5000	525	80	t
2†	7.2	1.02	104	5760	1100	480	3900	450	40	t
3†	6.4	1.02	112	5400	1000	400	4600	300	20	t
4†	4.0	1.02	100	7080	600	440	4300	375	10	t
5†	4.0	1.36	132	8040	700	480	4000	375	10	t
6†	5.6	0.90	128	9840	300	360	5200	550	40	t
7†	5.2	1.24	116	6240	700	360	3200	250	10	t
8†	4.4	1.02	108	5960	600	400	3600	400	20	t
9†	7.6	1.02	108	8160	600	320	4000	400	25	t
10†	8.0	1.13	116	8160	500	440	3300	475	20	t
11†	4.1	1.00	120	8140	400	400	4400	500	80	t
12†	5.3	1.37	144	8480	400	500	4000	550	30	t
13†	4.9	1.41	128	7900	900	380	4600	525	60	t
14†	4.3	1.45	112	5520	500	360	4800	200	60	t
15†	4.5	1.35	142	9080	400	540	3600	500	50	t
16†	6.9	1.51	154	8360	1100	480	5000	375	50	t
17†	6.8	1.12	114	7920	1100	440	3600	375	30	t
18†	4.7	1.23	104	7980	1000	540	4000	400	40	t
19†	6.2	1.09	140	9000	500	560	4400	450	60	t
20†	4.7	1.20	128	5440	1100	340	3600	200	40	t
21†	7.2	1.05	110	5840	800	320	5000	500	20	t
22†	7.2	0.92	144	7000	1000	540	5000	450	80	t
23†	5.6	1.41	132	8160	700	360	3600	450	30	t
24†	5.0	1.06	118	6540	900	540	4600	225	20	t
25†	7.1	1.46	134	8200	400	340	4200	500	40	t
26	7.9	1.23	106	8900	600	540	4000	375	60	t

(continued)

Table 10. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
27	6.5	1.33	154	7820	700	360	4200	500	75	t
28	6.2	1.25	142	7740	1000	420	4400	400	120	t
29	6.8	1.19	108	6240	600	400	5200	450	20	t
30	5.5	1.30	138	6280	800	340	3200	350	20	t
31	7.2	1.15	100	8980	300	420	4200	425	80	t
32	7.3	1.45	122	6040	800	480	4400	550	30	t
33	4.7	1.09	104	8040	500	520	4000	400	50	t
34	6.7	1.37	118	6320	500	340	4000	400	80	t
35	5.2	1.25	108	6320	700	320	4000	300	110	t
36	6.9	0.93	126	6340	600	520	4600	400	80	t
37	5.6	1.41	124	8580	900	360	4400	500	50	t
38	4.7	1.19	132	6620	900	380	4600	200	30	t
39	4.5	1.20	124	8880	400	520	4800	325	25	t
40	5.6	0.96	100	8480	1000	440	4400	400	30	t
41	7.0	0.99	120	9180	400	360	4800	350	70	t
42	5.3	1.10	146	5460	800	400	4200	375	30	t
43	4.4	1.45	138	9480	900	360	4800	400	70	t
44	4.1	0.93	120	8020	700	420	3600	300	40	t
45	5.3	1.16	116	6260	1000	400	4800	550	50	t
46	7.9	1.20	122	8100	700	440	4800	200	50	t
47	5.8	1.08	106	5580	700	460	3400	400	20	t
48	6.3	1.42	116	7400	800	520	5000	200	60	t
49	4.2	1.06	132	5520	800	420	5900	300	50	t
50	7.0	1.28	118	6420	500	460	4600	500	20	t

t trace amount

Table 11. Root chemical analysis -- 1-0 nursery-grown shortleaf pine seedlings.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
1†	8.0	1.13	84	7920	300	320	3040	140	20	t
2†	6.8	0.28	80	7560	200	320	4160	560	10	t
3†	10.8	0.57	84	6000	500	440	3600	500	t	t
4†	11.2	0.45	68	5760	400	320	2560	80	t	t
5†	8.0	0.85	104	6960	500	360	3280	340	t	t
6†	7.2	0.28	104	7560	200	320	3840	240	20	t
7†	5.2	0.51	96	6960	400	240	3360	440	10	t
8†	6.8	0.57	100	6840	300	280	3280	560	20	t
9†	7.2	0.51	84	7680	300	360	3200	360	10	t
10†	7.2	0.51	68	6840	500	280	4400	300	20	t
11†	7.6	0.39	102	6060	500	360	2780	300	60	t
12†	6.4	0.54	74	7440	300	340	2140	240	t	t
13†	11.0	0.55	96	6000	500	320	4220	160	30	t
14†	8.2	0.74	80	6600	400	300	2960	340	50	t
15†	7.0	0.54	76	6820	400	240	4220	420	t	t
16†	6.3	0.91	72	6500	500	300	3380	180	30	t
17†	7.6	0.51	96	6820	300	320	2380	380	t	t
18†	10.2	0.78	88	6260	500	280	3200	320	t	t
19†	6.3	0,78	84	6040	300	260	2560	540	t	t
20†	5.3	0.64	92	6180	200	280	3900	380	t	t
21†	7.3	0.92	88	6060	500	340	2060	520	t	t
22†	8.2	1.10	80	6380	300	320	2020	300	t	t
23†	6.6	0.70	76	7340	400	360	2200	380	t	t
24†	8.1	0.41	98	6260	500	280	2020	240	50	t
25†	7.7	1.07	68	6440	500	240	2380	260	60	t

(continued)

Table 11. Continued.

Plant No.	Ash Content (%)	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
			Parts Per Million							
26	5.8	0.30	79	6180	400	320	3860	200	50	t
27	8.4	0.44	98	7540	300	300	3740	200	t	t
28	6.5	1.05	94	6080	300	240	3720	80	t	t
29	8.4	0.42	90	6540	300	300	4020	60	20	t
30	8.7	0.36	104	6680	500	240	4340	400	t	t
31	10.5	0.61	78	7520	400	280	3000	100	t	t
32	6.8	0.70	102	6100	400	340	2760	400	t	t
33	7.1	0.77	86	7460	500	240	1780	80	30	t
34	10.5	0.71	98	5880	200	300	1640	140	70	t
35	10.7	0.97	70	7720	300	280	3340	400	t	t
36	9.0	1.01	98	6080	500	300	2560	340	30	t
37	8.6	0.74	98	7400	600	280	3240	280	t	t
38	5.5	1.04	70	5980	600	300	2740	120	30	t
39	5.8	0.64	78	7640	500	360	3380	180	t	t
40	7.1	0.33	76	7520	300	240	3400	560	70	t
41	10.2	0.56	100	7460	300	240	4280	540	t	t
42	10.0	0.79	92	6260	600	260	3920	200	t	t
43	8.7	1.09	92	7240	200	280	4120	80	70	t
44	8.4	0.33	74	7700	300	300	2820	520	50	t
45	7.7	0.49	98	6580	200	240	2580	260	50	t
46	6.1	0.79	76	7840	400	300	3320	400	60	t
47	8.1	0.37	74	6560	600	320	3000	560	80	t
48	5.8	0.39	72	7520	400	240	2840	460	t	t
49	8.5	0.79	104	7840	600	320	3080	80	t	t
50	10.4	0.99	86	6880	300	340	3000	380	t	t

t trace amount

Table 12. Total heights and root collar diameters for shortleaf pine seedlings planted on lignite stripmine spoils in Panola County, Texas.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - - MINED PLOT #1 - - - - - - -							
Containerized Cultured	1	10.5	--		2.47	--	
Mycelial Inoculation		14.7	25.2	10.5†	3.26	5.50	2.24†
(23.3%)		13.5	--		2.14	--	
		13.7	--		2.17	--	
		10.3	--		3.94	--	
	2	7.8	--		3.26	--	
		11.6	--		2.22	--	
		8.6	--		3.16	--	
		12.6	--		3.95	--	
		9.3	--		3.84	--	
	3	9.0	--		3.88	--	
		12.5	--		2.11	--	
		14.1	--		4.53	--	
		9.7	--		3.96	--	
		8.3	--		2.44	--	
	4	10.1	--		3.59	--	
		12.0	--		3.91	--	
		11.9	--		2.66	--	
		16.8	--		3.40	--	
		14.0	--		2.64	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
				MINED PLOT #1			
	5	9.0	--		3.00	--	
		10.2	--		2.67	--	
		12.1	--		3.28	--	
		16.6	--		3.77	--	
		9.3	17.0	7.7†	3.41	5.15	1.74†
	6	14.6	17.4	2.8†	4.19	5.08	0.89†
		10.2	18.3	8.1†	4.64	4.90	0.26†
		7.2	12.5	5.3	3.16	4.77	1.61
		9.7	18.0	8.3	4.21	5.47	1.26
		10.9	24.4	13.5†	4.47	4.95	0.48†
Containerized Basidiospore/ Vermiculite Inoculation (60.0%)	1	12.1	22.6	10.5†	3.25	4.59	1.34†
		20.0	--		2.87	--	
		14.5	--		2.86	--	
		14.1	28.7	14.6†	3.61	3.86	0.25†
		19.5	24.4	4.9	3.37	5.45	2.08
	2	18.6	24.5	5.9†	3.02	5.75	2.73†
		18.9	26.1	7.2	3.16	4.97	1.81
		14.8	20.2	5.4	3.14	3.71	0.57
		17.0	26.0	9.0	3.80	5.81	2.01
		14.9	26.1	11.2	2.79	4.32	1.53
	3	21.4	32.1	10.7	2.67	4.32	1.65

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - - MINED PLOT #1 - - - - - - -							
	3	23.4	32.4	9.0	2.60	4.91	2.31
		19.3	20.7	1.4	2.56	4.55	1.99
		17.6	25.6	8.0	3.79	5.64	1.85
		11.5	15.7	4.2	2.40	5.05	2.65
	4	20.0	31.4	11.4†	1.54	5.27	3.73†
		16.9	--		2.65	--	
		17.6	--		2.21	--	
		15.5	22.9	7.4	2.94	2.96	0.02
		13.0	18.3	5.3	2.86	3.45	0.59
	5	18.2	--		3.66	--	
		15.2	26.7	11.5	3.06	3.95	0.89
		14.9	--		3.46	--	
		17.8	--		2.81	--	
		19.4	--		3.55	4.93	1.38
	6	16.4	32.8	16.4†	2.98	5.56	2.58†
		14.6	--		3.51	--	
		14.6	--		3.96	--	
		13.7	--		3.62	--	
		15.3	--		3.48	--	
Containerized Seedcoat Basidiospore Inoculation (53.3%)	1	11.1	--		3.24	--	
		15.4	--		3.19	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 1							
	1	14.4	--		3.98	--	
		9.2	--		3.07	--	
		9.5	--		2.41	--	
	2	11.2	--		3.68	--	
		11.0	--		3.37	--	
		10.1	--		2.07	--	
		11.2	20.1	8.9†	2.09	5.68	3.59†
		13.1	--		3.75	--	
	3	13.5	--		2.36	--	
		16.5	--		2.27	--	
		13.6	23.1	9.5†	2.72	5.31	2.59†
		17.0	30.6	13.6	2.29	4.97	2.68
		13.9	22.0	8.1	3.10	5.68	2.58
	4	14.0	22.6	8.6†	2.60	4.79	2.19†
		9.1	23.5	14.4	2.80	4.79	1.99
		15.0	25.6	10.6	3.13	4.66	1.53
		15.9	30.2	14.3	3.48	4.45	0.97
		11.8	26.3	14.5	2.66	4.42	1.76
	5	15.6	21.1	5.5†	2.22	4.64	2.42†
		22.0	31.8	9.8	2.81	4.67	1.86
		19.1	25.1	6.0	2.80	5.31	2.51

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - MINED PLOT # 1 - - - - - -							
	5	19.9	28.2	8.3	2.67	5.53	2.86
		12.1	18.3	6.2	2.42	3.38	0.96
	6	11.9	22.4	10.5	3.69	5.20	1.51
		19.2	27.0	7.8†	2.49	5.21	2.72†
		17.6	--		2.53	--	
		10.8	--		2.46	--	
		9.1	--		3.21	--	
Containerized Control (43.3%)	1	21.0	--		2.66	--	
		21.0	25.6	4.6†	2.61	4.40	1.79†
		22.1	23.2	1.1	3.78	3.93	0.15
		21.1	29.1	8.0	3.40	4.19	0.79
		20.5	34.2	13.7	2.79	3.70	0.91
	2	21.9	28.4	6.5†	3.55	4.83	1.28†
		23.0	33.3	10.3	3.70	4.82	1.12
		14.4	21.6	7.2	3.72	3.90	0.18
		15.5	--		3.07	--	
		18.1	30.4	12.3	3.32	4.57	1.25
	3	20.5	--		3.97	--	
		21.4	28.8	7.4†	3.04	4.46	1.42†
		18.4	24.8	6.4	3.33	4.51	1.18
		21.5	--		2.39	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm)			DIAMETER (mm)		
		Mar.	Nov.	Δ	Mar.	Nov.	Δ
MINED PLOT #1							
	3	19.8	--		2.17	--	
	4	16.9	--		3.71	--	
		16.0	--		2.66	--	
		16.7	21.6	4.9†	2.81	5.11	2.30†
		23.3	33.9	10.6	3.38	5.11	1.73
		17.3	16.6	9.3†	3.59	4.42	0.83†
	5	15.9	--		2.20	--	
		15.9	--		3.72	--	
		17.1	--		3.25	--	
		17.7	--		2.76	--	
		21.7	--		3.51	--	
	6	18.4	--		3.37	--	
		14.1	--		3.75	--	
		15.6	--		2.69	--	
		14.0	--		2.84	--	
		16.3	--		3.44	--	
Bare-Root Basidiospore/ Vermiculite Inoculation (6.7%)	1	21.0	--		4.89	--	
		18.1	--		4.59	--	
		22.2	--		4.56	--	
		18.0	--		3.76	--	
		23.9	--		4.68	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - - - - - - - - - - - - -		MINED PLOT #1 - - - - - - - - - - - - - - - - -					
	2	24.9	--		4.30	--	
		17.3	--		4.40	--	
		24.8	--		4.48	--	
		21.7	--		4.18	--	
		20.0	--		4.81	--	
	3	21.1	--		4.40	--	
		18.2	--		4.39	--	
		15.0	--		3.04	--	
		26.5	--		4.58	--	
		13.5	--		2.47	--	
	4	18.2	--		4.29	--	
		15.8	--		4.12	--	
		14.0	22.0	8.0†	4.39	6.78	2.39†
		18.5	--		4.89	--	
		16.6	--		3.99	--	
	5	28.0	--		4.40	--	
		21.1	29.7	8.6†	4.66	6.50	1.84†
		24.2	--		4.85	--	
		23.4	--		5.06	--	
		13.0	--		4.44	--	
	6	12.5	--		3.00	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT #1							
	6	17.9	--		3.18	--	
		21.1	--		4.78	--	
		25.8	--		4.79	--	
		24.7	--		4.53	--	
Bare-Root Cultured Mycelial Inoculation (16.7%)	1	19.0	--		4.68	--	
		23.1	--		4.09	--	
		25.4	--		4.31	--	
		20.2	--		4.56	--	
		20.6	--		4.98	--	
	2	23.1	--		4.46	--	
		19.9	--		3.95	--	
		21.9	--		4.09	--	
		17.0	--		4.84	--	
		24.0	--		4.43	--	
	3	19.2	--		4.48	--	
		16.1	--		4.65	--	
		19.0	--		4.46	--	
		18.0	--		4.45	--	
		15.9	--		4.74	--	
	4	21.0	--		3.59	--	
		23.0	--		4.81	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - MINED PLOT # 1 - - - - - -							
	4	14.8	--		3.68	--	
		22.4	--		4.53	--	
		13.4	--		4.47	--	
	5	26.5	--		4.08	--	
		19.1	22.1	3.0†	4.62	6.64	2.02†
		17.6	--		3.62	--	
		13.2	--		4.57	--	
		17.1	27.2	10.1†	4.71	6.24	1.53†
	6	11.0	17.9	6.9†	5.01	7.37	2.36†
		19.2	25.0	5.8†	3.52	6.93	3.41†
		13.1	19.9	6.8†	4.40	6.61	2.21†
		17.0	--		3.45	--	
		16.9	--		4.38	--	
Bare-Root Nursery Stock Control (6.7%)	1	17.5	--		4.50	--	
		16.5	--		3.27	--	
		20.5	--		4.59	--	
		19.0	--		4.42	--	
		18.4	--		4.95	--	
	2	19.1	--		4.08	--	
		17.9	--		4.35	--	
		21.6	--		4.12	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 1							
	2	21.0	--		4.53	--	
		24.5	--		3.80	--	
	3	17.6	--		4.97	--	
		24.4	--		4.41	--	
		19.7	--		4.38	--	
		16.9	--		4.59	--	
		23.8	--		3.94	--	
	4	22.5	--		4.37	--	
		25.4	--		4.20	--	
		19.9	--		4.44	--	
		25.6	--		4.58	--	
		24.4	--		4.86	--	
	5	26.0	27.4	1.4†	4.67	6.82	2.15†
		20.6	--		4.35	--	
		17.5	--		4.40	--	
		11.7	--		4.45	--	
		25.3	--		4.64	--	
	6	12.0	--		5.15	--	
		12.2	--		4.29	--	
		27.0	--		4.57	--	
		18.2	--		3.03	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- MINED PLOT # 1 -							
	6	13.8	16.4	2.6	4.74	6.21	1.47
- MINED PLOT # 2 -							
Containerized Cultured Mycelial Inoculation (73.3%)	1	6.9	--		3.86	--	
		7.7	--		3.88	--	
		8.8	--		3.76	--	
		8.4	13.2	4.8	3.35	5.29	1.94†
		9.6	--		3.16	--	
	2	5.6	15.2	9.6	3.50	4.83	1.33†
		9.6	19.9	10.3	3.21	5.83	2.62
		5.2	16.4	11.2	3.83	5.59	1.76
		6.4	16.6	10.2	2.93	3.63	0.70
		6.2	17.0	10.8	2.46	3.69	1.23
	3	11.2	21.8	10.6	2.33	4.80	2.47†
		11.9	28.2	16.3	2.95	3.71	0.76
		9.9	17.7	7.8	4.21	5.49	1.28
		9.5	18.8	9.3	3.73	4.91	1.18
		11.7	28.2	16.5	3.81	4.05	0.24
	4	11.7	17.7	6.0	3.07	5.23	2.16†
		11.9	20.0	8.1	3.93	4.71	0.78
		12.7	16.2	3.5	3.40	5.45	2.05

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
		MINED PLOT # 2					
	4	10.3	21.3	11.0	3.64	4.92	1.28
		7.6	19.9	12.3	3.84	5.38	1.54
	5	10.7	24.0	13.3	3.45	4.11	1.66
		10.0	18.9	8.9	3.95	4.13	0.18
		14.0	23.9	9.9	3.11	4.16	1.05
		10.9	17.8	6.9	3.80	5.04	1.24
		15.0	17.2	2.2	3.08	4.97	1.89
	6	12.0	--		3.92	--	
		13.8	21.9	8.1†	2.52	3.00	0.48†
		10.1	--		3.65	--	
		11.1	--		3.10	--	
		7.4	--		3.30	--	
Containerized Basidiospore/ Vermiculite Inoculation (83.3%)	1	16.6	27.2	10.6†	2.29	5.32	3.03†
		16.3	31.9	15.6	3.63	4.83	1.20
		15.4	26.6	11.2	2.55	4.12	1.57
		17.2	30.4	13.2	2.53	5.02	2.49
		12.6	--		3.16	--	
	2	15.9	28.3	12.4†	2.69	4.01	1.32†
		19.7	26.4	6.7	3.14	4.82	1.68
		22.3	31.6	9.3	2.45	5.02	2.57
		18.2	--		2.96	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 2							
	2	19.4	28.9	9.5†	3.68	5.56	1.88†
	3	15.3	25.4	10.1†	3.21	5.49	2.28†
		19.8	26.9	7.1	3.31	4.76	1.45
		18.5	26.0	7.5	2.55	6.54	3.99
		16.6	27.9	11.3	2.62	4.98	2.36
		13.8	21.5	7.7	2.85	5.82	2.97
	4	17.3	27.0	9.7	2.67	4.33	1.66
		19.9	29.6	9.7	2.60	4.53	1.93
		14.0	--		2.08	--	
		20.8	29.1	8.3	3.40	4.61	1.21
		20.1	28.2	8.1	2.19	4.26	2.07
	5	19.8	--		2.99	--	
		19.3	27.1	7.8	2.66	4.59	1.93
		18.7	37.1	18.4	2.71	4.43	1.72
		16.4	27.6	11.2	2.82	5.11	2.29
		15.5	25.5	10.0	3.15	4.40	1.25
	6	11.5	--		2.29	--	
		11.1	20.1	9.0	2.77	4.26	1.49
		14.6	24.5	9.9	3.53	5.28	1.75
		16.5	28.4	11.9	3.46	5.09	1.63
		14.1	23.2	9.1†	2.50	3.40	0.90†

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - MINED PLOT # 2 - - -							
Containerized Seedcoat Basidiospore Inoculation (83.3%)	1	8.0	16.1	8.1†	3.82	5.14	1.32†
		7.2	16.2	9.0	3.71	4.60	0.89
		13.4	30.1	16.7	3.11	4.79	1.68
		8.7	19.4	10.7	3.77	4.97	1.20
		6.0	14.8	8.8	2.30	4.74	2.44
	2	4.8	13.4	8.6†	3.06	4.92	1.86†
		12.9	28.4	15.5	2.66	5.51	2.85
		10.6	22.4	11.8	3.49	5.18	1.69
		6.6	15.0	8.4	3.40	4.56	1.16
		11.7	20.4	8.7	3.46	4.38	0.92
	3	9.0	17.4	8.4	3.82	4.77	0.95
		14.1	26.1	12.0	2.89	5.91	3.02
		19.3	30.6	11.3	2.85	5.48	2.63
		17.2	27.1	9.9	2.75	4.76	.01
		14.0	27.9	13.9	2.57	5.92	3.35
	4	8.4	--		2.35	--	
		8.4	--		3.33	--	
		8.0	16.0	8.0†	2.70	3.59	0.89†
		14.6	--		2.60	--	
		8.9	--		3.33	--	
	5	9.4	14.2	4.8	3.59	5.09	1.50

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	HEIGHT (cm) Nov.	HEIGHT (cm) Δ	DIAMETER (mm) Mar.	DIAMETER (mm) Nov.	DIAMETER (mm) Δ
MINED PLOT # 2							
	5	7.4	--		3.43	--	
		8.0	13.3	5.3	2.85	4.36	1.51
		10.1	14.0	2.9	2.57	4.56	1.99
		11.5	21.2	9.7	2.49	6.05	3.56
	6	8.4	13.6	5.2	2.12	4.85	2.73
		8.0	15.8	7.8	2.72	4.43	1.71
		9.5	16.6	7.1	2.66	4.90	2.24
		7.9	13.3	5.4	2.81	3.82	1.01
		10.9	20.8	9.9†	2.85	4.15	1.30†
Containerized Control (80.0%)	1	27.3	--		2.03	--	
		26.4	28.7	2.3†	2.20	3.72	1.52†
		15.4	--		2.30	--	
		14.7	--		3.38	--	
		11.2	--		2.59	--	
	2	17.7	--		2.78	--	
		13.1	21.0	7.9†	2.95	4.93	1.98†
		16.3	22.4	6.1	3.53	5.31	1.78
		20.6	34.8	14.2	3.23	5.38	2.15
		21.3	23.4	2.1	3.54	5.54	2.00
	3	17.7	--		2.48	--	
		20.4	29.9	9.5†	2.53	4.65	2.12†

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm)			DIAMETER (mm)		
		Mar.	Nov.	Δ	Mar.	Nov.	Δ
MINED PLOT # 2							
	3	18.4	25.7	7.3	3.82	4.23	0.41
		17.3	26.1	8.8	2.15	2.68	0.53
		16.9	25.2	8.3	2.57	3.63	1.06
	4	16.0	21.4	5.4†	2.46	4.21	1.75†
		19.0	23.4	4.4	2.13	5.08	2.95
		15.6	20.5	4.9	3.78	4.70	0.92
		16.1	24.1	8.0	4.46	5.74	1.28
		17.8	26.2	8.4	3.09	4.54	1.45
	5	17.6	27.0	9.4	3.69	4.07	0.38
		18.2	28.3	10.1	3.04	4.85	1.81
		16.5	25.5	9.0	2.87	5.76	2.89
		21.0	31.8	10.8	3.32	4.52	1.20
		16.9	26.5	9.6	2.54	2.89	0.35
	6	17.3	30.0	12.7	3.42	5.53	2.11
		15.1	22.4	7.3	2.87	4.60	1.73
		20.7	35.0	14.3	3.16	4.16	1.00
		19.8	26.7	6.9	3.92	4.41	0.49
		17.5	28.5	11.0†	3.04	4.65	1.61†
Bare-root Basidiospore/ Vermiculite Inoculation (40.0%)	1	21.2	27.1	5.9†	4.69	6.93	2.24†
		23.5	28.4	4.9	4.64	6.57	1.93
		18.0	25.9	7.9	5.12	6.79	1.67

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 2							
	1	12.8	--		3.72	--	
		16.1	--		4.62	--	
	2	20.1	--		4.49	--	
		13.6	--		4.32	--	
		19.4	--		4.47	--	
		19.5	29.8	10.3†	4.45	6.47	2.02†
		20.8	--		4.46	--	
	3	17.1	--		4.33	--	
		20.6	29.2	8.6†	4.70	6.91	2.21†
		11.8	18.4	6.6	4.32	5.67	1.35
		18.6	--		3.28	--	
		14.6	--		3.93	--	
	4	22.2	--		4.73	--	
		24.4	30.6	6.2†	4.57	7.10	2.53†
		18.6	31.0	12.4	4.58	7.04	2.46
		18.3	24.7	6.4	4.70	6.39	1.69
		14.1	--		4.74	--	
	5	21.5	26.4	4.9	4.25	6.65	2.40
		16.3	21.1	4.8	4.67	6.04	1.37
		20.6	27.0	6.4†	4.76	6.98	2.22†
		20.5	--		4.47	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 2							
	5	18.2	--		4.45	--	
	6	14.1	--		3.99	--	
		18.2	--		4.92	--	
		13.4	--		5.58	--	
		16.5	--		5.21	--	
		17.6	--		4.13	--	
Bare-root Cultured Mycelial Inoculation (33.3%)	1	16.0	23.0	7.0†	4.79	6.36	1.57†
		15.7	17.8	2.1	5.66	6.72	1.06
		14.9	--		4.99	--	
		14.3	--		5.62	--	
		16.7	--		4.33	--	
	2	17.3	21.7	4.4†	4.43	6.63	2.20†
		16.6	--		5.56	--	
		12.3	--		3.62	--	
		17.0	23.1	6.1†	3.60	6.36	2.76†
		14.7	19.5	4.8	4.89	6.34	1.45
	3	18.3	--		4.45	--	
		17.5	--		4.01	--	
		21.4	30.9	9.5†	4.89	6.45	1.56†
		14.8	--		4.67	--	
		15.5	23.5	8.0	4.05	7.31	3.26

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - MINED PLOT # 2 - - - - - -							
	4	23.1	30.3	7.2	5.71	6.26	0.55
		16.5	19.1	2.6	4.44	7.11	2.67
		19.8	29.5	9.7†	4.34	6.44	2.10†
		19.6	--		4.11	--	
		16.8	--		5.71	--	
	5	13.3	--		5.25	--	
		11.5	--		5.32	--	
		14.6	--		4.45	--	
		16.2	--		3.65	--	
		15.5	--		4.05	--	
	6	18.0	--		4.92	--	
		16.1	--		3.90	--	
		13.1	--		4.65	--	
		16.5	--		4.23	--	
		13.9	--		5.48	--	
Bare-root Nursery Stock Control (46.7%)	1	15.5	--		4.73	--	
		18.9	26.5	7.6†	3.76	6.37	2.61†
		21.1	25.7	4.6	5.55	6.24	0.69
		19.3	24.2	4.9	3.55	6.48	2.93
		16.8	--		5.27	--	
	2	19.2	--		4.15	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm)			DIAMETER (mm)		
		Mar.	Nov.	Δ	Mar.	Nov.	Δ
MINED PLOT # 2							
	2	15.4	19.7	4.3†	5.33	6.41	1.08†
		13.4	--		5.03	--	
		9.4	--		3.51	--	
		17.3	10.6	3.3	3.78	6.57	2.79
	3	16.5	--		4.00	--	
		13.9	--		5.58	--	
		17.0	--		5.69	--	
		11.2	--		5.02	--	
		13.6	--		5.31	--	
	4	22.9	--		4.07	--	
		15.7	19.0	3.3†	4.82	5.11	0.29†
		14.4	--		5.00	--	
		15.0	20.5	5.5	4.46	6.65	2.19
		10.5	13.4	3.1	4.74	7.18	2.44
	5	18.3	25.0	6.7†	4.86	6.93	2.07†
		13.7	--		3.80	--	
		19.1	--		4.59	--	
		12.0	22.8	10.8	4.26	6.59	2.33
		19.5	24.1	4.6	4.20	6.23	2.03
	6	23.0	--		5.74	--	
		16.0	18.9	2.9	4.02	7.44	3.42

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 2							
	6	17.9	24.9	7.0	5.45	6.92	1.47
		14.8	--		3.71	--	
		18.4	22.0	3.6†	3.96	6.80	2.84†
MINED PLOT # 3							
Containerized Cultured Mycelial Inoculation (26.7%)	1	15.2	30.4	15.2†	2.53	3.90	1.37†
		19.0	--		3.94	--	
		18.9	31.2	12.3	2.29	3.88	1.59
		18.3	--		3.59	--	
		20.7	35.2	14.5	2.25	5.05	2.80
	2	19.6	31.8	12.2†	2.52	4.47	1.95†
		18.5	--		3.52	--	
		13.6	--		3.64	--	
		14.3	--		3.89	--	
		17.3	33.0	15.7†	2.86	5.99	3.13†
	3	15.6	--		2.07	--	
		14.0	--		2.67	--	
		14.7	--		2.14	--	
		16.7	--		2.43	--	
		13.3	--		2.94	--	
	4	11.0	--		2.95	--	
		17.7	--		3.92	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 3							
	4	16.0	--		3.10	--	
		11.4	--		3.66	--	
		13.0	--		2.26	--	
	5	15.4	--		3.97	--	
		19.4	--		2.15	--	
		16.5	--		3.72	--	
		16.6	--		2.10	--	
		16.4	--		3.32	--	
	6	10.8	--		3.29	--	
		16.9	26.4	9.5†	3.39	5.66	2.27†
		17.0	27.0	10.0	3.28	5.98	2.70
		16.6	30.5	13.9†	3.50	4.52	1.02†
		14.5			3.28	--	
Containerized Basidiospore/ Vermiculite Inoculation (53.3%)	1	14.2	--		2.11	--	
		14.2	--		3.67	--	
		9.9	--		3.07	--	
		8.0	--		2.28	--	
		9.6	--		3.84	--	
	2	10.9	30.4	19.5†	3.65	5.32	1.67†
		7.5	--		3.52	--	
		9.6	--		3.41	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 3							
	2	8.0	39.1	31.1	3.81	3.92	0.11
		12.2	28.1	15.9	3.62	4.19	0.57
	3	11.5	24.4	12.9†	1.18	4.91	3.73†
		13.6	33.9	20.3	2.28	4.40	2.12
		18.7	40.7	22.0	3.45	5.55	2.10
		17.2	34.4	17.2	3.53	5.49	1.96
		13.0	23.5	10.5	3.86	5.30	1.44
	4	15.4	32.5	17.1†	3.88	5.18	1.30†
		13.5	27.1	13.6	3.97	5.72	1.75
		13.8	--		3.98	--	
		9.5	--		3.86	--	
		8.4	--		3.30	--	
	5	11.4	33.6	22.2†	3.20	5.21	2.01†
		12.5	25.5	13.0	3.49	4.79	1.30
		14.1	26.5	12.4	3.57	5.65	2.08
		21.0	--		2.49	--	
		14.0	26.0	12.0	2.67	3.74	1.07
	6	14.1	34.8	20.7	2.71	4.72	2.01
		17.5	32.5	15.0†	2.82	4.41	1.59†
		15.0	--		2.79	--	
		18.4	--		3.64	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT # 3							
	6	15.6	--		3.75	--	
Containerized Seedcoat Basidiospore Inoculation (40.0%)	1	19.9	--		2.74	--	
		14.0	--		3.00	--	
		15.0	--		3.76	--	
		8.8	--		2.45	--	
		10.1	--		2.32	--	
	2	10.5	--		2.19	--	
		9.2	--		2.41	--	
		10.5	--		2.63	--	
		9.9	--		2.77	--	
		12.3	--		2.40	--	
	3	17.4	--		2.61	--	
		11.2	--		3.54	--	
		9.1	--		2.33	--	
		8.7	--		2.08	--	
		13.8	--		3.65	--	
	4	14.4	23.2	8.8†	2.40	4.93	2.53†
		12.1	21.9	9.8	2.85	4.43	1.58
		20.9	31.5	10.6†	3.89	5.62	1.73†
		7.0	17.2	10.2	2.22	4.06	1.84
		11.0	--		2.06	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
		MINED PLOT #3					
	5	14.7	32.9	18.2†	2.66	4.94	2.28†
		9.8	16.1	6.3	2.42	3.62	1.20
		12.9	19.8	6.9	2.45	5.95	3.50
		12.0	19.5	7.5	2.86	4.84	1.98
		12.7	--		2.18	--	
	6	16.3	26.5	10.2†	2.88	5.61	2.73†
		14.3	--		3.85	--	
		12.6	19.2	6.6	2.40	5.15	2.75
		15.0	30.4	15.4	2.61	4.59	1.98
		14.1	19.1	5.0†	3.54	3.88	0.34†
Containerized Control (43.3%)	1	13.7	--		3.76	--	
		7.0	25.5	18.5†	3.50	4.14	0.64†
		11.9	--		2.91	--	
		6.0	--		3.44	--	
		8.1	--		3.49	--	
	2	16.0	34.5	18.5†	2.96	5.30	2.34†
		13.0	24.9	11.9	3.80	4.88	1.08
		17.8	32.8	15.0	2.20	2.72	0.52
		16.7	29.0	12.3	2.01	4.03	2.02
		11.2	23.8	12.6	3.04	4.00	0.96
	3	11.6	32.0	20.4†	3.62	4.03	0.41†

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - - - - - MINED PLOT # 3 - - - - - - - - - -							
	3	15.3	--		2.70	--	
		9.5	24.2	14.7	3.46	4.14	0.68
		16.6	--		3.72	---	
		18.7	37.3	18.6	2.33	4.57	2.24
	4	10.5	--		3.66	--	
		10.6	24.1	13.5†	3.64	4.67	1.03†
		13.9	33.2	19.3	2.98	4.72	1.74
		16.9	31.0	14.1	3.32	4.12	0.80
		16.5	16.8	0.3†	3.63	4.52	0.89†
	5	14.5	--		3.50	--	
		11.4	--		3.50	--	
		13.0	--		3.69	--	
		18.6	--		3.20	--	
		16.7	--		4.46	--	
	6	13.0	--		2.72	--	
		10.9	--		2.07	--	
		8.1	--		3.68	--	
		14.5	--		2.77	--	
		19.1	--		2.44	--	
Bare-root Basidiospore/ Vermiculite Inoculation (40.0%)	1	20.2	--		3.79	--	
		14.8	--		3.55	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT #3							
	1	16.6	--		4.30	--	
		13.6	--		5.22	--	
		21.3	--		5.47	--	
	2	20.0	--		3.28	--	
		18.9	--		4.92	--	
		15.4	--		5.30	--	
		13.4	--		4.97	--	
		14.1	--		5.45	--	
	3	19.7	--		3.41	--	
		18.8	29.7	10.9†	3.89	6.55	2.66†
		14.8	20.0	5.2	3.27	6.86	3.59
		15.8	27.5	11.7	4.82	6.64	1.82
		13.5	25.1	11.6	5.02	5.51	0.49
	4	18.4	--		4.80	--	
		18.9	--		4.28	--	
		12.2	21.2	9.0†	5.05	6.89	1.84†
		14.3	20.1	5.8	5.67	6.83	1.16
		10.5	25.0	14.5	4.14	6.28	2.14
	5	17.3	24.5	7.2†	3.98	6.79	2.81†
		16.5	23.9	7.4	5.26	6.32	1.06
		15.1	--		3.80	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
			MINED PLOT #3				
	5	11.9	22.6	10.7	3.72	6.53	2.51
		17.4	--		4.46	--	
	6	21.0	--		5.66	--	
		25.8	31.4	5.6†	5.15	6.31	1.16†
		17.3	--		4.45	--	
		19.0	--		3.81	--	
		13.0	22.0	9.0†	5.66	7.00	1.34†
Bare-Root Cultured Mycelial Inoculation (26.7%)	1	21.0	--		3.81	--	
		15.5	--		4.65		
		18.4	--		3.83	--	
		10.9	--		5.73	--	
		14.8	--		4.45	--	
	2	20.7	--		3.50	--	
		16.9	--		3.89	--	
		15.0	--		4.67	--	
		13.5	--		4.84	--	
		17.7	--		5.17	--	
	3	14.1	--		5.42	--	
		17.0	--		4.26	--	
		22.2	--		5.50	--	
		15.5	--		4.19	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - - - - - MINED PLOT #3 - - - - - - - - - -							
	3	16.1	--		4.75	--	
	4	16.0	--		4.42	--	
		16.9	--		4.78	--	
		15.4	--		4.49	--	
		8.0	--		5.30	--	
		16.8	--		3.48	--	
	5	12.5	29.5	17.0†	4.71	5.00	0.29†
		13.2	21.6	8.4†	4.08	7.17	3.09†
		16.0	29.1	13.1†	4.99	6.41	1.42†
		14.6	29.5	14.9	4.62	7.30	2.68
		16.4	--		3.68	--	
	6	13.0	--		4.93	--	
		18.4	35.4	17.0†	5.30	6.05	0.75†
		12.0	25.2	13.2	3.90	6.60	2.70
		19.6	29.0	9.4	5.48	6.53	1.05
		22.1	37.1	15.0†	3.38	5.61	2.23†
Bare-Root Nursery Stock Control (30.0%)	1	16.9	--		4.30	--	
		15.1	24.0	8.9†	4.47	6.72	2.25†
		15.5	22.2	6.7	3.61	6.59	2.98
		14.4	23.1	8.7	5.03	6.76	1.73
		15.9	25.7	9.8	4.45	6.53	1.08

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT #3							
	2	18.8	27.1	8.3†	4.62	6.81	2.19†
		19.2	25.0	5.8	3.94	6.90	2.96
		16.0	29.4	13.4†	4.48	7.26	2.78†
		17.5	--		3.58	--	
		15.1	--		4.76	--	
	3	16.5	--		3.70	--	
		17.4	--		4.07	--	
		16.3	--		5.25	--	
		18.1	--		4.70	--	
		18.5	--		3.39	--	
	4	15.5	24.9	9.4†	4.60	6.78	2.18†
		19.0	33.9	14.9†	4.16	6.66	2.50†
		18.2	--		3.39	--	
		19.5	--		3.35	--	
		19.0	--		5.52	--	
	5	13.6	--		3.43	--	
		16.0	--		3.47	--	
		14.8	--		4.19	--	
		18.9	--		3.38	--	
		21.5	--		3.94	--	
	6	12.5	--		4.80	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
MINED PLOT #3							
	6	15.3	--		5.08	--	
		14.0	--		3.93	--	
		12.9	--		5.39	--	
		10.8	--		5.24	--	
UNMINED PLOT #1							
Containerized Cultured Mycelial Inoculation (60.0%)	1	14.1	44.5	30.4†	3.91	4.98	1.07†
		13.0	--		2.66	--	
		15.2	--		3.47	--	
		18.6	--		2.50	--	
		19.1	53.8	34.7	3.13	5.40	2.27
	2	14.1	52.2	38.1†	3.70	5.80	2.10†
		10.5	46.8	36.3	2.71	4.64	1.93
		15.5	--		3.48	--	
		13.5	36.9	23.4	3.73	5.88	2.15
		10.0	56.1	46.1	3.74	6.11	2.37
	3	15.2	--		3.53	--	
		16.3	--		3.03	--	
		14.1	51.1	37.0†	3.02	5.98	2.96†
		13.3	--		2.53	--	
		11.5	58.6	47.1	3.94	4.21	0.27
	4	13.7	43.1	29.4	3.02	4.03	1.01

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - - - - - - - - - - - - UNMINED PLOT #1 - - - - - - - - - - - - - - - - -							
	4	12.0	41.8	29.8	3.72	4.85	1.13
		11.6	--		4.29	--	
		14.2	--		3.02	--	
		13.7	38.6	24.9†	3.46	4.91	1.45†
	5	11.5	45.6	34.1	3.50	4.17	0.67
		11.6	44.3	32.7	3.63	4.25	0.62
		11.2	--		2.13	--	
		11.0	--		3.75	--	
		10.2	54.4	44.2	2.93	4.20	1.27
	6	13.9	35.0	21.1	3.64	6.98	3.34
		12.0	38.3	26.3	3.16	5.14	1.98
		11.5	33.3	21.8	3.59	5.75	2.16
		16.1	35.9	19.8†	3.96	5.42	1.46†
		11.4	--			--	
Containerized Basidiospore/ Vermiculite Inoculation (36.7%)	1	15.0	36.5	21.5†	2.61	4.96	2.35†
		17.3	--		2.02	--	
		17.7	42.7	25.0	3.29	5.43	2.14
		17.0	37.7	20.7	3.38	5.93	2.55
		18.0	36.1	18.1	3.32	4.62	1.30
	2	14.4	--		3.13	--	
		15.2	45.8	30.6†	3.46	4.61	1.15†

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 1							
	2	14.3	52.7	38.4	3.58	4.79	1.21
		17.0	--		3.18	--	
		14.5	--		3.22	--	
	3	15.0	--		3.07	--	
		14.9	--		3.09	--	
		18.0	--		3.56	--	
		14.7	--		3.45	--	
		12.5	51.7	39.2†	3.77	5.67	1.90†
	4	11.5	--		3.42	--	
		12.9	--		3.54	--	
		13.3	--		3.74	--	
		14.6	--		2.61	--	
		13.3	--		3.43	--	
	5	14.2	--		3.96	--	
		14.4	--		2.29	--	
		15.0	--		2.91	--	
		19.6	--		3.10	--	
		18.0	44.0	26.0†	3.09	6.18	3.09†
	6	19.6	--		3.66	--	
		18.2	40.2	22.0	3.31	4.69	1.38
		18.0	41.4	23.4	3.12	4.52	1.40

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	HEIGHT (cm) Nov.	HEIGHT (cm) Δ	DIAMETER (mm) Mar.	DIAMETER (mm) Nov.	DIAMETER (mm) Δ
UNMINED PLOT #1							
	6	16.1	50.3	34.2†	3.66	5.50	1.84†
		19.2	--		2.05	--	
Containerized Seedcoat Basidiospore Inoculation (50.0%)	1	11.4	36.8	25.4†	3.78	4.77	0.99†
		12.2	--		2.05	--	
		13.4	47.7	34.3	3.53	5.11	1.58
		13.9	--		2.78	--	
		14.0	37.9	23.9	3.01	6.39	3.38
	2	15.0	54.5	39.5†	2.02	6.66	4.64†
		16.6	53.4	36.8	3.12	4.25	1.13
		11.7	49.1	37.4	3.97	4.31	0.34
		10.0	--		2.30	--	
		11.9	43.0	31.1	3.69	4.18	0.49
	3	13.0	49.8	36.8†	2.10	5.29	3.19†
		14.4	49.5	35.1	3.56	4.43	0.87
		14.6	52.6	38.0	2.34	5.06	2.72
		14.9	--		3.63	--	
		15.5	56.0	40.5	2.66	5.77	3.11
	4	18.4	46.6	28.2†	3.95	5.55	1.60†
		12.5	32.0	19.5	3.29	4.83	1.54
		12.8	47.9	35.1	2.27	5.62	3.35
		9.6	--		3.14	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 1							
	4	10.7	34.2	23.5†	3.95	5.15	1.20†
	5	17.5	--		3.75	--	
		11.0	--		3.03	--	
		11.2	--		2.08	--	
		8.5	--		2.52	--	
		15.0	--		3.78	--	
	6	13.6	--		3.89	--	
		14.8	--		2.28	--	
		14.7	--		3.74	--	
		18.4	--		3.19	--	
		15.1	--		2.53	--	
Containerized Control (50.0%)	1	11.2	37.6	26.4†	2.18	4.24	2.06†
		11.0	--		3.16	--	
		14.7	48.3	33.6	3.09	5.44	2.35
		19.8	--		2.83	--	
		17.9	--		2.55	--	
	2	9.9	--		3.60	--	
		12.4	--		3.00	--	
		11.8	--		3.38	--	
		12.5	--		3.70	--	
		11.0	--		3.80	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 1							
	3	12.9	55.2	42.3†	2.34	4.25	1.91†
		12.3	--		3.06	--	
		22.5	--		2.69	--	
		13.1	42.0	28.9	2.04	5.47	3.43
		14.6	--		3.75	--	
	4	10.5	39.6	29.1†	2.09	5.01	2.92†
		11.0	46.2	35.2	2.89	5.49	2.60
		11.0	--		2.79	--	
		17.5	51.9	34.3	2.31	5.79	3.48
		14.4	--		1.76	--	
	5	6.7	42.0	35.3†	3.53	4.27	0.74†
		17.5	34.7	17.2	3.32	4.44	1.12
		18.1	47.5	29.4	2.83	6.20	3.37
		12.7	46.6	33.9	2.55	5.02	2.47
		14.4	--		2.09	--	
	6	11.3	44.5	33.2	2.05	4.10	2.05
		14.1	42.6	28.5	2.73	5.74	3.01
		15.0	34.7	19.7	2.24	5.55	3.31
		10.0	33.6	23.6†	3.12	4.48	1.36†
		13.9	--		3.39	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 1							
Bare-root Basidiospore Vermiculite Inoculation (33.3%)	1	12.7	--		3.30	--	
		12.1	--		3.36	--	
		14.4	--		5.01	--	
		15.9	--		3.90	--	
		14.1	43.0	28.9†	4.49	8.28	3.79†
	2	9.5	--		4.47	--	
		16.4	32.0	15.6†	3.89	8.43	4.54†
		14.7	47.5	32.8	4.91	8.75	3.84
		17.6	39.8	22.2	4.64	7.24	2.60
		17.0	40.6	23.6	4.96	8.84	3.88
	3	15.5	43.1	27.6†	5.47	8.71	3.24†
		18.2	35.9	17.7	5.12	8.26	3.14
		11.1	33.1	22.0	4.04	5.25	1.21
		15.0	--		3.78	--	
		16.5	30.2	13.7†	4.97	8.09	3.12†
	4	15.1	--		3.73	--	
		14.4	--		3.57	--	
		19.3	--		5.60	--	
		16.9	--		4.63	--	
		17.7	--		4.12	--	
	5	20.0	--		3.58	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
			UNMINED PLOT #1				
	5	12.1	43.4	31.3†	5.70	8.81	3.11†
		16.0	--		5.48	--	
		15.6	--		3.85	--	
		17.1	--		4.75	--	
	6	13.8	--		4.62	--	
		12.9	--		5.24	--	
		14.6	--		3.94	--	
		15.2	--		5.28	--	
		12.3	--		3.89	--	
Bare-root Cultured Mycelial Inoculation (56.7%)	1	12.2	41.2	29.0†	4.89	8.41	3.52†
		12.0	55.7	43.7	5.07	8.18	3.09
		13.0	--		4.78	--	
		16.3	--		4.14	--	
		12.0	49.8	37.8	4.93	7.73	2.80
	2	20.0	--		3.65	--	
		20.1	42.7	22.6†	3.64	4.75	1.11†
		17.2	--		5.69	--	
		15.2	--		5.22	--	
		14.5	43.9	29.4	4.57	7.89	3.32
	3	8.7	37.0	26.3†	4.58	8.58	4.00†
		13.0	27.0	14.0	5.31	8.74	3.43

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- - - - - - - - - - - - - - - - - - UNMINED PLOT # 1 - - - - - - - - - - - - - - - - - -							
	3	14.4	44.8	30.4	5.73	8.50	2.77
		17.3	--		3.72	--	
		17.8	32.2	14.4	3.87	9.15	5.28
	4	16.0	42.2	26.2†	4.79	8.18	3.39†
		15.7	--		5.69	--	
		14.0	--		4.30	--	
		18.6	49.1	30.5	4.00	8.57	4.57
		18.7	40.3	21.6	3.46	8.37	4.91
	5	15.7	23.7	8.0	4.53	7.84	3.31
		18.5	40.3	21.8	5.21	8.12	2.91
		17.0	20.6	3.6	3.31	8.64	5.33
		14.2	34.5	20.3	3.30	8.69	5.39
		16.5	47.2	30.7†	5.70	7.91	2.21†
	6	15.5	--		4.15	--	
		12.5	--		5.07	--	
		16.8	--		5.35	--	
		21.6	--		5.58	--	
		18.5	--		3.72	--	
Bare-root Nursery	1	17.4	--		4.11	--	
Stock Control		12.7	33.8	21.1†	3.74	8.62	4.88†
(63.3%)		13.5	54.1	40.6	3.53	9.06	5.53

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 1							
	1	14.9	63.4	48.5	3.71	8.30	4.59
		14.9	54.1	39.2	4.69	5.47	0.78
	2	16.9	--		4.80	--	
		15.5	48.7	33.2†	5.33	9.03	3.70†
		16.0	54.1	38.1	3.60	6.95	3.35
		19.9	--		3.87	--	
		17.6	--		3.63	--	
	3	13.5	--		5.50	--	
		16.0	--		3.43	--	
		11.5	36.6	25.1†	3.46	8.80	5.34†
		14.0	--		3.97	--	
		13.9	--		4.04	--	
	4	15.7	20.6	4.9	3.55	9.37	5.82
		17.0	--		4.21	--	
		16.8	--		4.57	--	
		14.8	38.5	23.7	3.61	8.55	4.94
		21.5	58.6	37.1	4.64	8.45	3.81
	5	13.3	42.1	28.8†	4.42	8.46	4.04†
		17.2	44.3	27.1	3.92	7.37	3.45
		8.2	32.9	24.7	4.83	8.04	3.21
		13.3	31.6	18.3	5.71	8.40	2.69
		14.0	--		5.64	--	

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	HEIGHT (cm) Nov.	HEIGHT (cm) Δ	DIAMETER (mm) Mar.	DIAMETER (mm) Nov.	DIAMETER (mm) Δ
UNMINED PLOT # 1							
	6	15.8	39.9	24.1	4.95	6.03	1.08
		13.0	33.8	20.8	5.16	8.19	3.03
		20.6	38.6	18.0	4.09	8.39	4.30
		19.4	29.6	10.2	4.11	8.75	4.64
		17.6	56.5	38.9†	4.29	6.29	2.00†
UNMINED PLOT # 2							
Containerized Cultured Mycelial Inoculation (100.0%)	1	16.3	34.8	18.5†	3.23	4.07	0.84†
		13.7	42.3	28.6	3.12	6.18	3.06
		15.4	38.6	23.2	2.07	4.36	2.29
		14.4	59.2	44.8	3.12	5.08	1.96
		8.2	30.2	22.0	3.39	4.49	1.10
	2	14.1	56.7	42.6†	3.25	4.21	0.96†
		13.6	60.4	46.8	3.03	4.72	1.69
		10.2	50.3	40.1	2.31	4.97	2.66
		13.7	40.4	26.7	3.83	4.41	0.58
		12.5	61.8	49.3	2.98	5.25	2.27
	3	13.7	45.5	31.8†	3.89	4.30	0.41†
		15.3	41.1	25.8	3.70	5.46	1.76
		19.1	29.2	10.1	3.17	4.44	1.27
		16.6	38.8	22.2	2.41	5.83	3.42
		17.4	35.3	17.9	2.18	4.68	2.50

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 2							
	4	13.0	29.1	16.1†	3.20	6.41	3.21†
		13.8	21.2	7.4	2.85	5.04	2.19
		13.0	40.5	27.5	3.83	4.59	0.76
		14.1	32.7	18.6	3.64	4.79	1.15
		16.1	37.7	21.6	3.17	5.32	2.15
	5	15.1	32.3	17.2	3.80	4.08	0.28
		16.1	47.6	31.5	3.29	4.94	1.65
		19.9	48.3	28.4	3.62	4.16	0.54
		16.5	48.2	41.7	3.06	5.53	2.47
		18.7	51.0	32.3	3.25	4.35	1.10
	6	15.6	39.2	23.6	3.70	5.10	1.40
		12.1	23.9	11.8	3.90	4.00	0.10
		11.5	30.3	18.8	3.02	4.91	1.89
		16.2	50.4	34.2	3.01	4.65	1.64
		13.7	29.7	16.0†	3.41	4.55	1.14†
Containerized Basidiospore/ Vermiculite Inoculation (96.7%)	1	19.6	49.0	29.4†	3.70	4.79	1.09†
		15.5	35.1	19.6	3.38	5.12	1.74
		15.3	42.0	26.7	3.72	5.12	1.40
		18.2	54.8	36.6	2.54	4.24	1.70
		19.1	40.6	21.5	2.94	4.51	1.57
	2	17.1	44.8	27.7†	2.72	5.12	2.40†

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	HEIGHT (cm) Nov.	HEIGHT (cm) Δ	DIAMETER (mm) Mar.	DIAMETER (mm) Nov.	DIAMETER (mm) Δ
UNMINED PLOT # 2							
	2	16.2	51.1	34.9	2.56	6.00	3.44
		11.6	29.6	18.0	2.65	5.03	2.38
		17.7	33.7	16.0	2.15	4.55	2.40
		16.8	41.2	24.4	3.26	6.33	3.07
	3	19.9	37.5	17.6†	3.32	4.46	1.14†
		22.3	28.4	6.1	3.14	4.34	1.20
		17.1	42.5	25.4	3.63	5.82	2.19
		18.0	38.6	20.6	3.32	4.74	1.42
		18.5	38.3	19.8	2.32	4.71	2.39
	4	18.1	43.3	25.2†	3.77	4.16	0.39†
		18.0	37.2	19.2	3.00	5.91	2.91
		18.9	42.1	23.2	3.87	5.26	2.39
		21.3	50.7	29.4	3.33	6.16	2.83
		17.9	32.5	14.6	3.06	4.79	1.73
	5	22.1	--		3.29	--	
		23.2	54.4	31.2	2.62	4.70	2.08
		16.6	48.2	31.6	2.53	5.47	2.94
		22.4	54.3	31.9	3.59	4.08	0.49
		16.7	37.2	20.5	3.86	5.70	1.84
	6	21.8	52.0	30.2	3.17	5.09	1.92
		21.1	49.5	28.4	3.50	5.01	1.51

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 2							
	6	17.8	48.6	30.8	2.94	5.07	2.13
		21.2	41.5	20.3	3.27	4.24	0.97
		18.8	36.2	17.4†	3.05	4.94	1.89†
Containerized Seedcoat Basidiospore Inoculation (96.7%)	1	16.0	53.8	37.8†	2.28	4.32	2.04†
		6.0	--		2.31	--	
		15.1	42.5	27.4	2.89	4.46	1.57
		9.6	39.1	29.5	2.85	4.20	1.35
		7.0	33.0	26.0	3.74	5.24	1.50
	2	14.4	52.3	37.9†	2.30	4.29	1.99†
		12.1	56.3	44.2	2.71	5.18	2.47
		14.1	55.7	41.6	2.40	4.10	1.70
		12.6	51.0	38.4	2.19	4.90	2.71
		9.8	31.4	21.6	2.01	6.75	4.74
	3	10.7	36.9	26.2†	2.77	4.35	1.58†
		10.4	40.4	30.0	3.34	4.54	1.20
		12.6	30.5	17.9	3.17	4.63	1.46
		13.9	53.0	39.1	3.97	5.30	1.33
		12.4	54.1	41.7	3.19	4.78	1.59
	4	13.6	20.8	7.2†	2.95	4.22	1.27†
		12.1	29.2	17.1	3.95	5.38	1.43
		10.6	20.5	9.9	3.32	5.22	1.90

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- -		UNMINED PLOT # 2	- - - - - - - - - - - - - - - - - - - -				
	4	8.9	30.4	21.5	2.28	4.39	2.11
		14.4	37.7	23.3	2.31	5.90	3.59
	5	10.6	25.1	14.5	2.89	6.00	3.11
		18.9	39.0	20.1	2.85	4.89	2.04
		10.0	37.2	27.2	3.74	5.05	1.31
		10.4	28.3	17.9	2.30	5.78	3.48
		9.6	27.8	18.2	2.71	4.14	1.43
	6	12.2	36.9	24.7	2.40	4.55	2.15
		12.1	35.3	23.2	2.19	4.58	2.39
		12.0	30.7	18.7	1.10	5.34	4.24
		10.4	28.0	17.6	3.68	4.59	0.91
		12.5	41.4	28.9†	2.79	5.73	2.94†
Containerized Control (93.3%)	1	13.5	48.7	35.2†	3.86	4.87	1.01†
		15.5	51.2	36.3	3.49	4.54	1.05
		12.1	--		2.92	--	
		14.7	37.7	23.0	3.84	5.58	1.74
		12.4	32.4	20.0	3.90	4.30	0.40
	2	9.6	48.1	38.5†	2.50	5.86	3.36†
		9.9	33.1	23.2	3.34	5.60	2.26
		15.0	54.4	39.4	3.12	6.36	3.24
		10.1	27.3	17.2	3.44	7.06	3.62

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
- UNMINED PLOT # 2 -							
	2	15.0	50.6	35.6	3.60	6.98	3.38
	3	21.4	37.0	15.6†	3.88	5.65	1.77†
		13.4	35.3	21.9	2.79	4.99	2.20
		16.4	41.5	25.1	3.75	6.08	2.33
		13.5	37.5	24.0	3.04	7.11	4.07
		13.6	--		3.48	--	
	4	18.3	38.0	19.7†	2.02	4.67	2.65†
		11.7	43.6	31.9	2.43	5.10	2.67
		9.0	19.7	10.7	3.08	6.51	3.43
		8.5	40.3	31.8	3.54	6.07	2.53
		11.6	47.5	35.9	2.22	5.17	2.95
	5	16.1	24.7	8.6	2.98	6.96	3.98
		10.6	32.8	22.2	3.90	5.39	1.49
		10.5	33.2	22.7	3.00	6.06	3.06
		12.2	37.9	25.7	2.91	3.61	0.70
		12.1	40.9	28.8	3.47	4.50	1.03
	6	9.5	50.9	41.4	3.69	6.04	2.35
		9.7	46.4	36.9	3.71	6.69	2.98
		9.1	50.5	41.4	2.92	5.69	2.77
		10.1	48.6	38.5	2.83	5.84	3.01
		11.2	50.2	39.0†	3.46	4.87	1.41†

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
		UNMINED PLOT # 2					
Bare-root Basidiospore/ Vermiculite Inoculation (50.0%)	1	12.1	26.1	14.0†	3.66	8.33	4.67†
		14.0	--		4.45	--	
		18.8	32.2	13.4	5.00	8.28	3.28
		15.2	--		5.61	--	
		23.0	50.7	27.7	5.46	8.32	2.86
	2	21.3	54.2	32.9†	3.75	8.89	5.14†
		21.5	43.4	21.9	3.79	8.30	4.51
		17.6	46.0	28.4	5.04	6.20	1.16
		22.5	51.5	29.0	5.53	9.29	3.76
		18.0	40.7	22.7	3.42	9.03	5.61
	3	19.6	--		4.50	--	
		15.1	34.9	19.8†	4.76	8.52	3.76†
		15.4	--		3.45	--	
		22.3	32.8	10.5	3.95	7.86	3.91
		15.6	--		3.64	--	
	4	21.5	--		5.72	--	
		22.5	--		4.52	--	
		21.2	--		3.62	--	
		15.6	--		4.19	--	
		20.0	23.8	3.8	3.84	8.51	4.67
	5	14.4	34.8	20.4	3.99	9.02	5.03

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
		UNMINED PLOT # 2					
	5	17.8	--		5.58	--	
		11.0	--		5.37	--	
		15.0	--		4.29	--	
		17.6	29.4	11.8†	3.55	8.76	5.21†
	6	17.0	35.7	18.7	3.93	8.51	4.59
		15.9	--		5.03	--	
		14.0	--		4.96	--	
		14.1	--		4.19	--	
		16.9	34.2	17.3†	4.26	8.33	4.07†
Bare-root Cultured Mycelial Inoculation (70.0%)	1	19.0	53.2	34.2†	4.03	8.44	4.41†
		14.6	42.3	27.7	3.26	8.39	5.13
		16.0	50.8	34.8	4.80	7.77	2.97
		26.1	54.9	28.8	3.59	5.17	1.58
		14.5	50.4	35.9	3.72	8.94	5.22
	2	17.8	39.5	21.7†	3.47	8.73	5.26†
		18.5	50.5	32.0	4.80	8.27	3.47
		10.7	37.4	26.7	5.60	8.37	2.77
		19.8	30.6	10.8	4.04	8.27	4.23
		24.7	38.2	13.5	3.72	8.31	4.59
	3	19.0	19.9	.9	3.83	3.85	0.02
		14.9	20.8	5.9	4.84	4.95	0.11

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 2							
	3	23.4	26.5	3.1	4.97	8.35	3.38
		15.0	--		4.80	--	
		13.5	18.1	4.6	3.47	7.03	3.56
	4	18.0	36.4	18.4†	4.82	8.64	3.82†
		16.4	--		5.49	--	
		14.4	47.5	33.1	5.06	8.41	3.35
		17.3	39.1	21.8	4.12	8.11	3.99
		15.9	34.2	18.3	3.69	7.91	4.22
	5	18.7	--		4.93	--	
		12.8	--		3.39	--	
		18.7	30.1	11.4	5.66	8.25	2.59
		17.6	26.7	9.1	3.83	6.11	2.28
		16.9	25.2	8.3†	4.35	8.50	4.15†
	6	16.1	--		4.99	--	
		16.4	--		3.93	--	
		21.0	--		5.74	--	
		21.1	--		5.75	--	
		13.0	--		4.65	--	
Bare-root Nursery Stock Control (86.7%)	1	16.6	--		4.39		
		14.5	39.2	24.7†	4.19	8.15	3.96†
		20.4	25.5	5.1	5.58	8.86	3.28

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm) Mar.	Nov.	Δ	DIAMETER (mm) Mar.	Nov.	Δ
UNMINED PLOT # 2							
	1	20.1	--		5.21	--	
		19.6	33.1	13.5	3.87	5.52	1.65
	2	19.6	25.7	6.1†	3.40	8.78	5.38†
		15.1	33.8	18.7	3.44	8.86	5.42
		23.7	54.6	30.9	5.08	8.73	3.65
		13.1	36.3	23.2	5.19	8.92	3.73
		18.9	52.2	33.3	5.04	8.41	3.37
	3	17.1	31.0	13.9†	5.30	8.74	3.44†
		16.0	46.9	30.9	3.62	8.57	4.95
		14.7	29.2	14.5	4.24	8.73	4.49
		18.5	53.0	34.5	5.42	8.63	3.21
		15.7	34.4	18.7	4.18	7.99	3.81
	4	21.3	30.0	8.7†	4.33	4.39	0.06†
		21.4	30.9	9.5	4.18	7.94	3.76
		14.0	26.2	12.2	3.70	8.32	4.62
		18.5	--		5.54	--	
		12.5	30.9	18.4	3.40	8.08	4.68
	5	16.9	30.8	13.9	3.36	4.67	1.31
		14.3	17.7	3.4	4.62	5.29	0.67
		23.2	--		5.06	--	
		17.0	21.8	4.8	5.05	8.61	3.56

(continued)

Table 12. Continued.

TREATMENT (% Survival)	Row No.	HEIGHT (cm)			DIAMETER (mm)		
		Mar.	Nov.	Δ	Mar.	Nov.	Δ
- UNMINED PLOT # 2 - - - - - - - - - - - - - - - - - -							
	5	19.6	27.6	8.0	4.62	7.33	2.71
	6	17.0	47.3	30.3	4.81	8.76	3.95
		16.1	40.6	14.5	5.71	7.85	2.14
		19.4	37.7	18.3	4.01	6.15	2.14
		11.2	34.4	23.2	4.41	8.94	4.53
		14.2	40.6	26.4†	4.95	8.60	3.65†

Table 13. Foliage chemical analysis -- shortleaf pine seedlings planted on lignite stripmine spoils in Panola County, Texas.

Plot	Row Sample *	Ash Content %	%N	- - - - - - - - Parts Per Million							- - - - - - - -
				P	K	Ca	Mg	Na	Mn	Zn	Cu
- - - - - - - - - - - CONTAINERIZED CULTURED MYCELIAL INOCULATION - - - - - - - - -											
Mined #1	1†	3.4	0.59	220	4020	2600	3200	1590	280	10	t
	2										
	3										
	4										
	5†	2.3	0.64	190	4150	3175	3000	1500	530	10	t
	6										
Mined #2	1†	3.2	0.79	192	6100	2800	3250	1230	560	20	t
	2†	2.7	0.73	192	5130	3300	3375	800	100	15	t
	3	2.8	0.74	210	4310	1800	2775	1030	220	20	t
	4	3.3	0.83	218	4770	2025	3375	1330	460	30	t
	5	1.1	0.41	218	4530	2675	3800	1150	180	20	t
	6	3.1	0.81	190	4930	2500	2175	930	470	20	t
Mined #3	1†	2.0	0.88	200	4500	1700	2150	1110	180	20	t
	2†	2.1	0.60	230	3590	1875	3350	1670	610	25	t
	3										
	4										
	5										
	6	2.3	0.64	216	7220	2475	3700	1140	260	20	t
Unmined #1	1†	2.4	1.41	144	7900	2100	800	70	420	30	t
	2†	2.4	1.10	154	7890	1900	725	80	310	30	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - - - Parts Per Million - - - - - - - - -							
- - - - - - - - - - - - - CONTAINERIZED CULTURED MYCELIAL INOCULATION - - - - - - - - - - - -											
Unmined #1	3	2.5	0.49	136	7730	1325	775	90	310	30	t
	4	2.5	0.87	116	7800	1700	750	70	200	30	t
	5	2.6	1.84	118	7820	1600	750	60	340	30	t
	6	2.2	2.49	168	7940	1775	775	80	440	30	t
Unmined #2	1†	2.6	1.50	100	7800	1500	750	90	220	30	t
	2†	2.6	2.24	118	7760	2000	725	80	550	30	t
	3	2.4	1.30	146	7840	2500	725	70	340	30	t
	4	2.4	1.53	82	7740	1700	775	90	250	35	t
	5	2.6	2.01	78	7820	1625	875	80	410	30	t
	6	2.4	0.83	88	7830	2300	800	90	260	30	t
- - - - - - - - - - - CONTAINERIZED BASIDIOSPORE/VERMICULITE INOCULATION - - - - - - - - -											
Mined #1	1†	2.6	0.65	232	7100	2500	2500	600	300	20	t
	2†	2.4	1.12	230	6170	3100	1000	1150	590	25	t
	3	2.6	1.06	234	8220	2300	2700	660	500	25	t
	4	2.6	1.12	248	6770	2200	3175	460	840	30	t
	5	2.7	0.68	236	4180	1400	2400	1490	540	25	t
	6	2.1	1.04	220	7680	2300	1350	430	470	20	t
Mined #2	1†	2.8	0.76	216	4920	3000	3000	1080	640	25	t
	2†	2.7	0.87	248	7000	1100	1300	420	290	20	t
	3	2.4	0.73	246	6390	3100	2900	250	490	20	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - - - Parts Per Million - - - - - - - - -							
- - - - - - - - - CONTAINERIZED BASIDIOSPORE/VERMICULITE INOCULATION - - - - - - - - -											
Mined #2	4	2.4	0.63	208	7700	1700	1950	480	690	20	t
	5	2.7	0.95	204	7830	2500	2700	780	300	25	t
	6	2.5	0.80	220	5860	1150	5550	150	600	20	t
Mined #3	1										
	2†	2.4	1.02	248	7700	1500	1600	140	640	20	t
	3†	2.3	0.43	218	6100	1700	2700	300	380	20	t
	4	2.4	0.93	254	7120	2825	3150	490	510	25	t
	5	2.7	0.99	254	6830	3200	2800	660	430	25	t
	6	2.9	0.63	250	6540	2825	2700	1030	470	20	t
Unmined #1	1†	2.8	1.13	120	7300	2600	800	100	460	30	t
	2†	2.4	1.30	122	5740	1800	850	100	420	35	t
	3	2.6	1.49	134	7530	1600	800	110	360	30	t
	4										
	5	1.7	1.19	120	6010	1200	800	100	400	30	t
	6	2.1	1.21	120	7090	2650	850	100	430	30	t
Unmined #2	1†	2.2	1.39	128	6300	1500	850	100	380	30	t
	2†	2.4	1.38	132	6790	1400	900	90	390	25	t
	3	1.7	1.50	126	7740	1800	850	100	550	25	t
	4	2.4	1.03	118	6060	2375	825	80	360	35	t
	5	2.0	1.43	124	5530	2100	800	100	460	30	t
	6	3.4	1.25	126	6480	1400	775	90	400	25	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				Parts Per Million							
CONTAINERIZED SEEDCOAT BASIDIOSPORE INOCULATION											
Mined #1	1										
	2†	3.0	0.54	204	8200	2400	2650	840	400	10	t
	3†	2.5	0.78	208	7200	2650	2725	4410	460	25	t
	4	3.1	0.79	200	4950	1800	2650	970	320	15	t
	5	3.6	0.83	210	6600	2600	2800	1110	460	5	t
	6	3.0	0.53	214	5560	2000	2400	2510	720	10	t
Mined #2	1†	3.2	0.68	216	5400	2700	2750	2340	660	20	t
	2†	3.2	0.73	212	7750	2000	2800	1430	380	15	t
	3	3.2	0.68	206	8300	2400	2900	1880	440	5	t
	4	2.9	0.54	218	6650	2800	2675	970	640	30	t
	5	2.9	0.60	202	7900	2200	2700	1060	420	t	t
	6	2.7	0.74	210	7900	2050	2725	1220	560	15	t
Mined #3	1										
	2										
	3										
	4†	2.4	0.79	208	5280	2000	2800	720	520	10	t
	5†	3.5	0.80	208	6100	3000	2600	1250	600	15	t
	6	2.5	0.56	210	3800	2200	2600	1420	560	15	t
Unmined #1	1†	2.6	1.30	100	8200	1800	850	210	320	10	t
	2†	2.3	1.33	98	7260	1700	850	320	340	50	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - -	- - Parts	Per Million	- - - -	- - - -	- - - -		
- - - - - - - - - - - CONTAINERIZED SEEDCOAT BASIDIOSPORE INOCULATION - - - - - - - - -											
Unmined #1	3	2.4	1.31	130	8440	1350	800	20	260	10	t
	4	2.6	1.36	92	9420	1500	850	160	560	30	t
	5										
	6										
Unmined #2	1†	2.4	1.41	124	7300	1500	950	60	500	30	t
	2†	2.7	1.34	104	8180	1800	900	20	320	35	t
	3	2.1	1.45	124	7180	1700	800	200	320	15	t
	4	2.5	1.37	142	7080	1600	850	40	180	5	t
	5	2.3	1.36	110	8420	1400	900	160	540	30	t
	6	2.6	1.25	118	6180	1500	900	320	520	35	t
- - - - - - - - - - - - - - - CONTAINERIZED CONTROL - - - - - - - - - - - - - - -											
Mined #1	1†	2.6	0.65	240	4620	2800	2550	1770	500	30	t
	2†	2.1	0.64	230	5640	2500	2100	2300	520	40	t
	3	2.3	0.60	232	4740	2400	2400	1350	360	20	t
	4	2.4	0.76	256	4740	2100	1950	1975	300	15	t
	5										
	6										
Mined #2	1†	2.6	0.62	248	4800	2100	2400	1800	200	20	t
	2†	2.5	0.59	214	5460	1900	2100	680	620	15	t
	3	1.6	0.73	250	5040	2800	2500	1700	300	30	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				Parts Per Million							
CONTAINERIZED CONTROL											
Mined #2	4	2.5	0.72	234	4600	2000	2650	5400	280	20	t
	5	2.1	0.74	260	5000	2500	2500	1700	240	25	t
	6	2.1	0.63	234	5020	2400	2100	2300	300	25	t
Mined #3	1†	2.0	0.71	216	5340	2400	2050	150	340	15	t
	2†	2.6	0.71	234	5420	2900	1875	1800	400	20	t
	3	2.2	0.67	252	4800	2000	2200	1700	200	35	t
	4	1.9	0.64	238	5340	1800	2150	1600	240	20	t
	5										
	6										
Unmined #1	1†	2.4	1.30	168	7900	1200	700	90	700	40	t
	2										
	3†	2.4	1.31	126	2260	1800	950	90	640	15	t
	4	2.5	1.27	120	8020	600	600	140	720	30	t
	5	2.5	1.33	140	6900	1800	700	140	780	40	t
	6	2.3	1.33	136	5900	1400	900	200	720	15	t
Unmined #2	1†	2.2	1.33	140	4500	1700	950	160	560	20	t
	2†	2.3	1.29	182	8040	1400	850	150	880	35	t
	3	2.4	1.29	182	8260	1000	700	120	760	20	t
	4	2.0	1.32	176	5040	1400	750	130	620	30	t
	5	2.2	1.34	164	5420	900	500	50	580	25	t
	6	2.3	1.31	148	7100	1800	900	180	600	25	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - -	- Parts Per Million	- - - - - - - -					
- - - - - - - - - - - - BARE-ROOT BASIDIOSPORE/VERMICULITE INOCULATION - - - - - - - - - - - -											
Mined #1	1										
	2										
	3										
	4†	2.0	0.96	176	4140	1900	2150	1350	660	15	t
	5†	1.7	0.82	198	4180	2000	1875	980	460	25	t
	6										
Mined #2	1†	2.6	0.88	204	4320	2000	2250	960	160	30	t
	2†	2.0	0.87	202	5050	2000	2550	610	240	25	t
	3	2.0	0.75	176	4940	2100	1975	990	320	35	t
	4	2.3	0.86	170	3800	2000	2375	870	560	25	t
	5	2.3	0.80	194	3660	2100	2250	860	720	25	t
	6										
Mined #3	1										
	2										
	3†	1.6	0.82	188	5100	2100	2400	310	460	25	t
	4†	1.6	1.04	206	4180	2000	2600	740	460	25	t
	5	1.7	0.78	184	4060	1800	2000	870	620	15	t
	6	2.3	1.00	186	5240	2100	1800	710	280	35	t
Unmined #1	1†	2.4	1.50	160	7200	2000	800	90	520	15	t
	2†	2.2	1.56	184	7720	1700	990	70	480	20	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - - -	Parts Per Million	- - - - - - - - -					
- - - - - - - - - - - - BARE-ROOT BASIDIOSPORE/VERMICULITE INOCULATION - - - - - - - - - -											
Unmined #1	3	2.3	1.41	84	6940	2000	780	90	1060	20	t
	4										
	5	2.5	1.53	168	5940	2050	900	90	500	35	t
	6										
Unmined #2	1†	2.4	1.41	104	5300	1600	950	110	320	25	t
	2†	2.6	1.47	130	8820	1700	710	80	580	15	t
	3	2.5	1.43	192	5580	1700	790	110	520	15	t
	4	2.4	1.39	132	5640	1900	940	80	500	15	t
	5	2.4	1.50	134	8240	1850	1000	100	480	20	t
	6	2.5	1.45	174	6720	1800	940	100	560	25	t
- - - - - - - - - - - - - - BARE-ROOT CULTURED MYCELIAL INOCULATION - - - - - - - - - - -											
Mined #1	1										
	2										
	3										
	4										
	5†	2.4	0.79	248	4320	2900	2500	1950	440	15	t
	6†	2.3	0.80	284	4860	2150	2400	1820	740	20	t
Mined #2	1†	2.6	0.82	204	3540	2200	2100	1680	640	25	t
	2†	2.4	0.77	230	4080	1400	2350	2030	560	15	t
	3	2.4	0.85	206	4160	1900	2200	1160	300	15	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - -	Parts Per Million	- - - - - - - -					
BARE-ROOT CULTURED MYCELIAL INOCULATION											
Mined #2	4	2.6	0.78	222	3860	3000	2700	1850	480	20	t
	5										
	6										
Mined #3	1										
	2										
	3										
	4										
	5†	2.2	0.73	232	4560	1700	2500	1050	280	15	t
	6†	2.7	0.77	234	3860	1900	2100	1520	380	25	t
Unmined #1	1†	2.4	1.50	116	6400	2000	950	90	700	20	t
	2†	2.6	1.08	118	6920	1600	1000	95	850	20	t
	3	2.5	1.31	166	6740	1900	1000	100	560	20	t
	4	2.4	1.54	112	7500	1800	1000	100	780	40	t
	5	2.3	1.10	140	7240	2000	1000	90	780	20	t
	6										
Unmined #2	1†	2.4	1.19	140	7300	1800	1000	100	300	30	t
	2†	2.4	1.43	122	6740	2150	950	105	480	25	t
	3	2.3	1.19	120	6860	1950	1000	85	80	25	t
	4	2.5	1.32	140	8060	2000	975	95	620	15	t
	5	2.4	1.24	150	7020	2000	950	95	740	30	t
	6										

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - - - Parts Per Million - - - - - - - - -							
- - - - - - - - - - - - - - - BARE-ROOT NURSERY STOCK CONTROL - - - - - - - - - - - - - -											
Mined #1	1										
	2										
	3										
	4										
	5 †	2.6	0.70	238	5200	2600	2550	1940	520	25	t
	6 †	2.4	0.69	236	3420	2900	2150	950	500	25	t
Mined #2	1 †	2.8	0.71	232	4020	2100	2450	2130	540	30	t
	2 †	2.8	0.75	236	4600	2775	3350	2330	500	30	t
	3										
	4	3.0	0.69	240	7060	2900	2050	2560	500	25	t
	5	2.6	0.69	238	3880	3475	2800	1200	500	25	t
	6	2.8	0.72	240	4400	2700	2800	430	550	30	t
Mined #3	1 †	2.8	0.68	248	6400	3100	2950	410	480	30	t
	2 †	2.7	0.70	252	6400	1800	2700	2260	520	25	t
	3										
	4	2.7	0.71	236	4250	2100	2500	820	510	25	t
	5										
	6										
Unmined #1	1 †	2.6	1.27	164	8800	1900	800	60	600	25	t
	2 †	2.3	1.32	128	6200	1400	790	50	520	20	t

(continued)

Table 13. Continued.

Plot	Row Sample *	Ash Content %	%N	P	K	Ca	Mg	Na	Mn	Zn	Cu
				- - - - - - - - - Parts Per Million - - - - - - - - -							
- - - - - - - - - - - - - - - BARE-ROOT NURSERY STOCK CONTROL - - - - - - - - - - - - - - -											
Unmined #1	3	2.6	1.34	178	5600	1100	850	90	440	20	t
	4	2.9	1.20	120	8100	2100	860	120	720	25	t
	5	2.4	1.32	130	6000	1300	930	110	420	20	t
	6	2.5	1.24	106	8750	1300	620	70	680	15	t
Unmined #2	1†	2.2	1.33	116	6700	1300	950	100	480	20	t
	2†	2.3	1.27	152	5200	900	910	80	660	25	t
	3	2.2	1.33	116	6500	2000	760	100	680	25	t
	4	2.7	1.32	150	8300	1900	790	25	480	20	t
	5	3.1	1.29	148	9750	1600	920	50	640	20	t
	6	2.6	1.26	136	6700	2700	810	70	560	25	t

* Each sample represents a composite of foliage from all surviving seedlings in a row.

t trace amount

PISOLITHUS TINCTORIUS MYCOBIONT INOCULATIONS AS A FACTOR IN PERFORMANCE OF CONTAINERIZED AND BARE-ROOT SHORTLEAF PINE SEEDLINGS ON LIGNITE MINESOILS IN PANOLA COUNTY, TEXAS

APPROVED:

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Dissertation Director

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Dean of the Graduate School

PISOLITHUS TINCTORIUS MYCOBIONT INOCULATIONS AS A FACTOR IN PERFORMANCE OF CONTAINERIZED AND BARE-ROOT SHORTLEAF PINE SEEDLINGS ON LIGNITE MINESOILS IN PANOLA COUNTY, TEXAS

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Presented to the Faculty of the Graduate School of
Stephen F. Austin State University
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For the Degree of
Doctor of Forestry

STEPHEN F. AUSTIN STATE UNIVERSITY
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ABSTRACT

The effects of artificial soil infestation with basidiospores and vegetative mycelia of the fungal symbiont *Pisolithus tinctorius* on ectomycorrhizae development of shortleaf pine (*Pinus echinata*) seedlings grown in styroblock containers were tested in the greenhouse. These preliminary tests showed that both spores and mycelia will produce satisfactory ectomycorrhizae development. Various methods of inoculation had little effect on growth and development of containerized seedlings or on the accumulation of N, P, K, Ca, Mg, Na, Mn, Zn, or Cu in foliage and lateral roots. The styroblock containerization system used in conjunction with sandy loam soil/vermiculite (2:1 v/v) potting-mix produced excellent quality shortleaf pine seedlings with strong primary and secondary lateral root development.

Ultrastructural examination of inoculated roots revealed that a Basidiomycete and another fungus were mycotrophic, full Hartig-net and mantle development were common, and apparent host and mycobiont physiological activity was positively influenced by intimate symbiotic relationship. Evolution of mycorrhizae progressed from an obvious infection process at the host epidermis and

outer cortical cells, to a balanced symbiosis in the Hartig-net region of the deep cortex.

The inoculated containerized shortleaf pine seedlings with their far better initial ectomycorrhizae development survived significantly better than 1-0 bare-root nursery-grown seedlings following the first growing season after outplanting on minesoils at the Martin Lake lignite strip-mine in Panola County, Texas. Inoculation treatments of bare-root seedlings with *P. tinctorius* basidiospores and vegetative mycelia at time of planting had no significant effect on survival or growth. After the first growing season, foliar concentrations of N, P, K, Ca, Mg, Na, Mn, Zn, and Cu were little affected by inoculation treatments.

VITA

Hoy Lee Bryson, Jr., the son of Mr. and Mrs. Hoy L. Bryson, was born in Enid, Oklahoma, on December 31, 1943. He graduated from Enid High School in May, 1962. He joined the United States Marine Corps in September, 1964, and was trained as an Airborne Armament Control and Missile Guidance Technician, and Electronics Counter-Measures Technician. He was honorably discharged as a Sergeant E-5 in November, 1968.

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