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Increasing Endomycorrhizal Fungus Inoculum in Forest Nursery Soil With Cover Crops

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Abstract
Corn, millet, sudex, and sorghum were all effective cover crops for increasing inoculum density of vesicular-arbuscular fungi (Glomus spp.) in nursery soils. Spore production was increased approximately 7 to 12 times, depending on the cover crop used. Sweetgum seedlings did not differ significantly in size on plots previously planted with any of the four cover crops. Eighty-nine percent of the sweetgum seedlings grown after cover cropping had root-collar diameters exceeding the minimum (0.25 inch) recommended for outplanting of this species.

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Paul P. Kormanik, W. Craig Bryan, and Richard C. Schultz

ABSTRACT. Corn, millet, sudex, and sorghum were all effective cover crops for increasing inoculum density of vesicular-arbuscular fungi (Glomus *spp.) in nursery soils. Spore production was increased approximately 7 to 12 times, depending on the cover crop used. Sweetgum seedlings did not differ significantly in size on plots previously planted with any of the four cover crops. Eighty-nine percent of the sweetgum seedlings grown after cover cropping had root-collar diameters exceeding the minimum (0.25 inch) recommended for outplanting of this species.*

A reliable supply of high-quality seedlings is a prerequisite for successful artificial hardwood regeneration. Unfortunately, forest tree nurseries have not consistently produced seedlings of the commercially important hardwood species that form vesicular-arbuscular (VA) mycorrhizae. Development of such mycorrhizae early in the growing season is beneficial to seedling development and can result in consistent production of high-quality seedlings (Bryan and Kormanik 1977, Kormanik *et al.* 1976, South 1977). One method of increasing nursery soil inoculum levels is to plant cover crops having fibrous roots that are hosts for VA mycorrhizal fungi. Of course, crops which are preferred hosts for commonly occurring pathogenic fungi in nursery soils should be avoided.

Periodic fumigation is necessary in most nurseries; however, it simultaneously eliminates or reduces beneficial mycorrhizal fungi, as well as the root pathogens and weed seeds which are the targets of fumigation. It takes at least one growing season after fumigation to build up the inoculum potential of the VA fungi to effective levels. In an extensive study of various forest tree nurseries in the southeastern United States, Barnard (1977) reported that nurseries employing soil fumigation were characterized by low VA inoculum densities.

The purpose of this study was to determine the capacity of some common cover crops for increasing VA inoculum density in nursery soils and to determine how inoculum densities might affect the subsequent crop of hardwood seedlings.

METHODS

The study was established in 1973 at the Whitehall Experimental Forest maintained by the Forest Service in cooperation with the University of Georgia in Athens. Two experimental nursery beds (4 × 20 feet) were filled with a fumigated soil mixture consisting of a loamy forest topsoil, sand, and finely ground pine bark at a 1 : 1 : 1 ratio. These beds were inoculated with chopped sorghum roots obtained from greenhouse cultures known to contain a mixture of VA fungi (*Glomus* spp.). Two similarly constructed beds were filled with identical soil but were not inoculated. For two years, either sycamore (*Platanus occidentalis* L.) or sweetgum (*Liquidambar styraciflua* L.) seedlings were produced in these beds for various experimental purposes. In 1975, all seedlings were lifted and soil from the two inoculated beds was used to infest the two nursery beds which had remained nonmycorrhizal for two growing seasons. Sweetgum was then planted in all four beds.

Sweetgum seedlings were lifted in January 1976, and in April the four beds were assayed for endomycorrhizal spore density. Spores were extracted from the soil with a flotation apparatus for nematode extraction described by Oostenbrink (1960). The spores retrieved on a 45-micron sieve were further separated from soil and root debris by the centrifugal-flotation technique (Jenkins 1964). Spore count, which is indicative of the endomycorrhizal inoculum density, showed that the beds contained approximately 50 spores/100 cm^3 of soil. This count is much lower than the mean of 14 spores/gram of soil reported to occur in eight recently fumigated southeastern nurseries (Barnard 1977).

In 1976, each of the four beds was divided into four equal compartments (4 × 5 feet) by inserting three steel plates across the width of each bed to a depth of approximately 24 inches. In early May, each compartment was sown with either corn, millet, sudex, or sorghum. All cover crops were fertilized and maintained under identical conditions. They were given an initial application of 10-10-10 fertilizer equivalent to 250 lb/acre. In addition they received three applications of ammonium nitrate (NH_4NO_3) during the growing season; equivalent rate for these three applications was 1,500 lb/acre. During the second year (1977), the same fertility regime was maintained for seedling production except that the NH_4NO_3 was applied every 10 days with appropriate reductions in the rate at each application.

Spore counts were made according to the previously described method at the end of the first growing season. Cover crops were turned under, and the beds lay fallow throughout the winter. In May 1977 half of each bed was sown with seed from one of two sweetgum mother trees. Seedling density was maintained at approximately six/ft^2. Height and root-collar diameters were measured on all seedlings at the end of the growing season. The study was analyzed as a split plot with nursery beds as the whole plot; cover crops and mother trees were the subplots.

RESULTS

All four cover crops induced appreciable numbers of *Glomus* spp. spores, although sorghum, with its more fibrous root system, induced a higher mean density of spores than any other crop (Table 1). Spore production was increased approximately 7 to 12 times, depending on the cover crop used. However, no correlation was observed between spore production and whether the beds had been the source of inoculum or had previously been in the nonmycorrhizal test sequence.

Although statistical differences were observed in both height and root-collar diameter among sweetgum seedlings grown in compartments planted with the different cover crops, these differences were of little practical significance. Mean height of sweetgum seedlings from the two mother trees in the various treatments varied from 25 to 27 inches. Mean root-collar diameters varied from 0.28 to 0.31 inch. The seedlings were of uniform quality with a coefficient of variation for total height of only 13 percent and for root-collar diameter of 16 percent. Of the 1,440 seedlings in the test, 89 percent had root-collar diameters greater than 0.25 inch, the minimum size recommended for successful outplanting of this species (Belanger and McAlpine 1975).

Table 1. Spores extracted per 100 cm^3 of soil at the end of the growing season.[1]

Bed no.	Corn	Millet	Sudex	Sorghum
1	603	568	362	906
2	360	474	342	669
3	209	284	535	305
4	214	509	675	603
Mean	346	459	479	621

[1] *Initially, the soil contained 50 spores per 100 cm^3. Variation among replicates of different crop types eliminated statistical significance of different spore levels.*

DISCUSSION

Any of the cover crops in this test could be used to increase the inoculum potential of endomycorrhizal fungi in nurseries by at least 7 times. Because we have tested these crops on a *Glomus* mixture, we cannot speculate on their ability to work with a specific root symbiont or another mixture that might be present in a given forest nursery. There is little doubt, however, that these plants will be effective with many species of endomycorrhizal fungi; they are frequently used as nursery crops to increase inoculum for research purposes.

Corn was the least desirable of the four cover crops tested. Spore production on this crop, while not statistically different from the other crops, was numerically the lowest, probably because corn has a coarser, less fibrous and dense root system. Inoculum density not only includes spore production but is affected by infested roots that remain after the cover crop has matured. Since the other three cover crops leave a heavier root mass in the soil, their inoculum densities are greater than that of corn. Sudex, millet, and sorghum also mature much later in the season than corn, yielding a longer period for effective root growth and concomitant spore production.

Spore production was apparently adequate with all cover crops to assure endomycorrhizal development early in the season. Although sweetgum seed were sown almost 2 months later than desirable for the Athens area and had an effective growing season of only 18 weeks, 89 percent of the seedlings had root-collar diameters exceeding the minimum (0.25 inch) recommended for outplanting. If the growing season had been 26 weeks, undoubtedly more than 89 percent of the seedlings would have exceeded the 0.375-inch root-collar diameter preferred by many foresters for sweetgum planting stock.

It must be emphasized that the use of any cover crop after fumigation must be accompanied by careful monitoring of destructive root pathogens that may occur in different nursery soils. In nurseries with soil-borne disease problems, even good fumigation will probably leave viable inocula of pathogenic fungi. It would be preferable to determine which cover crop is the least desirable host for root pathogens in a specific nursery.

Soil fumigation must precede the sowing of the cover crop, since fumigation after cover cropping will eliminate or reduce the endomycorrhizal fungus inocula. Thus, if a cover crop is planted, fumigation for weed control must be replaced by the use of herbicides. Unfortunately, little is currently known about the effects of specific herbicides on endomycorrhizal inocula. Continued monitoring should also accompany successive tree rotations to detect buildup of root pathogens.

If cover cropping is adopted in hardwood nurseries, more research will be needed on how soil types, fertilizer regimes, and herbicides affect the density of endomycorrhizal inoculum, production of quality seedlings, and pathogen populations. This need for additional work should not discourage nurserymen from implementing the best management practices currently available to improve production of important species [*i.e.*, sweetgum, green ash (*Fraxinus pennsylvanica* Marsh.), sycamore, yellow-poplar (*Liriodendron tulipifera* L.) and walnut (*Juglans nigra* L.)].

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Analysis of a Virginia Pine Seed Source Trial In the Interior South

John Talbert, Gordon White, and Charles Webb

*ABSTRACT. In a comparison of three diverse seed sources of improved Virginia pine (*Pinus virginiana *Mill.) planted at two locations in north Alabama and south-central Tennessee, only stem straightness differences were statistically significant at six years of age. Families and seed sources tended to maintain the same ranking relative to each other at both locations. A majority of families performed significantly better than a Virginia pine commercial check lot, indicating substantial improvement in growth and straightness characteristics in one generation of selection. Two improved loblolly pine (*Pinus taeda *L.) seed orchard mixes from the South Carolina Piedmont showed a 27-percent height advantage over the Virginia pine at age 6.*

Virginia pine has received much interest recently as a viable candidate for plantation forestry, especially for the more northern extremities of the