"Fall Mosaic" of Loblolly Pine in a Forest Tree Nursery

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*A mosaic pattern of yellow and green seedlings has been observed in loblolly pine (*Pinus taeda *L.) seedbeds in the fall at several forest nurseries in the southern United States. Seedlings in green areas appear to be associated with mycorrhizal symbionts. Sampling at one nursery in Alabama confirmed a strong relationship between* Pisolithus tinctorius *(Pers.) Coker & Couch and green seedlings. It is hypothesized that stressing seedlings by undercutting can result in differential seedling response according to the degree of mycorrhizal infection.* Tree Planters' Notes 40(1): 19-22; 1989.

A mosaic pattern of yellow and green seedlings has been observed in the fall in forest nurseries in the southern United States. The term *fall mosaic* has been coined to describe this phenomenon. In October 1983, fall mosaic was observed in one area of the Robert Mitchell Nursery near Camden, AL. The green and yellow areas were delineated, and soil and seedlings were sampled in an effort to document the problem.

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Materials and Methods

Study area. The study area consisted of four adjacent beds in compartment 9 of the Robert Mitchell Nursery. The sandy loam soil was not fumigated and was sown with loblolly pine seed (Livingston Parish) on April 27, 1983. Prior to seedbed preparation, 50 kg/ha of nitrogen was applied to the soil with an EZEE Flow spreader. Weeds were controlled with herbicides, and fusiform rust (*Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* Burdsall and Snow) was controlled with a systemic fungicide. Final density on the beds was approximately 280 seedlings/m^2.

On July 7, 34 kg/ha of nitrogen was applied to the seedlings with a Gandy spreader. On August 9, three beds (adjacent to an irrigation sprinkler line) were undercut (fig. 1). The fourth bed (next to a nursery road) was not undercut because seedling growth was not as advanced as in beds closer to the irrigation line. Approximately 1.25 cm of irrigation water was applied on the same day following undercutting and 1.4 cm of rain fell during the next 2 days. Several days after undercutting, the lateral roots were pruned.

According to soil tensiometer readings, soil moisture was lowest 26 days after the August undercutting (a reading of 54 kPa on September 4 was the highest recorded from July 20 to November 14). On September 21, all four beds were undercut and were irrigated with approximately 1.25 cm of water. Soil and seedlings in the study area were sampled in October.

Sampling procedures. In each of the four beds, two plots (30 m long) were established. The plots were mapped according to seedling color (fig. 1). Fruiting bodies of *Pisolithus tinctorius* (Pt) were counted and their positions noted on the map. In plots that were undercut in August, samples of seedlings and of soil were collected from areas exhibiting green seedlings and from areas exhibiting yellow seedlings. No yellowing was present in the plots not undercut in August; therefore, only green seedlings and soil samples from these areas were collected. One-hundred and twenty seedlings were sampled from each plot: 60 were used for morphological measurements and 60 for assessing mycorrhizal development.

Seedling and soil analyses. Morphological measurements included root-collar diameter, shoot height, shoot weight, and root weight. Seedlings were evaluated for mycorrhizal development at the USDA Forest

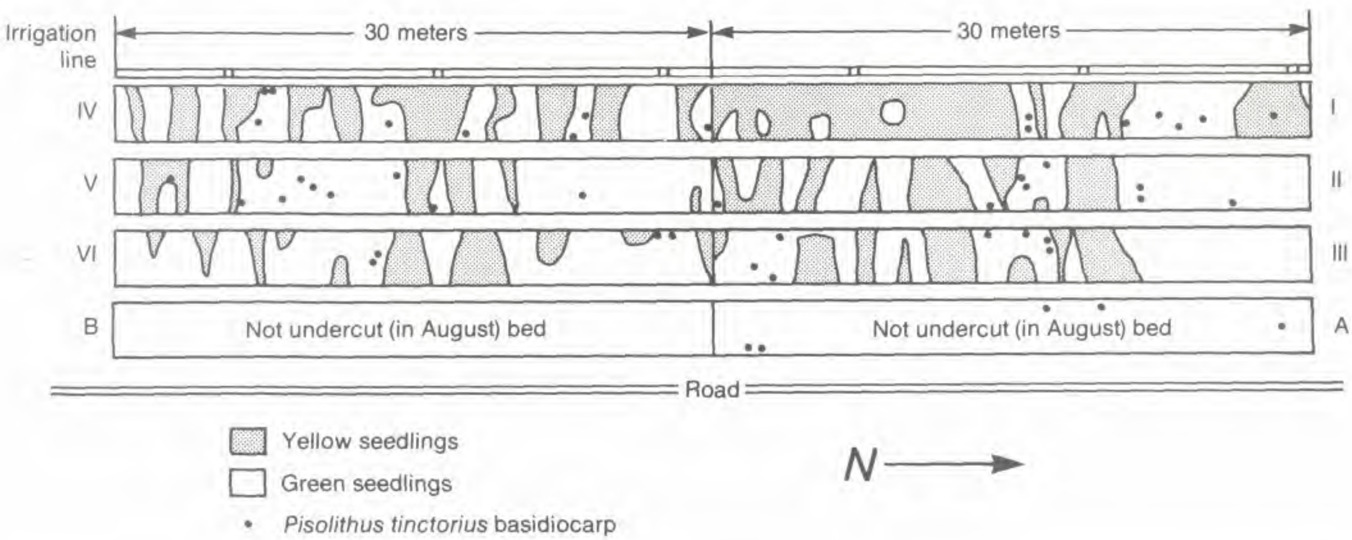

Figure 1—*Map of the fall mosaic study area at the Robert Mitchell Nursery, October 1983.*

Service, Institute of Mycorrhizal Research and Development, Forestry Sciences Laboratory, Athens, GA. In assessing the seedlings, the number of seedlings with Pt and the average percentage of short roots with mycorrhizae were recorded. In addition, the percentage of total mycorrhizae due to Pt was also estimated. Soil samples were sent to A&L Laboratories (Memphis, TN) for analysis of macronutrients and micronutrients, soil acidity, and organic matter.

Statistical analysis. Student's t-test was used to compare soil and seedling characteristics between paired samples from green and yellow areas within plots on beds undercut in August. Statistics were not used to compare seedlings undercut in August with those not undercut in August.

Results

The two plots not undercut in August did not exhibit the fall mosaic pattern and contained a total of only five Pt fruiting bodies. Plots located in undercut beds exhibited clearly defined areas of fall mosaic. Areas exhibiting fall mosaic were determined from the scale map of the study plots. Yellow seedlings occupied an area equal to 37% of the plots that were undercut; the remaining area contained green seedlings. Forty-five fruiting bodies of Pt were counted within the six undercut plots. Of these, 43 were in the green areas and two were in yellow areas.

Seedlings from green areas were heavier and larger in root-collar diameter than those from yellow areas (table 1). Seedlings from the green areas had higher percentages of mycorrhizal roots and these roots contained a higher proportion of Pt (table 1). Soil collected from green areas in undercut plots generally contained fewer extractable cations than did soil from yellow areas (table 2).

Table 1—*Morphology of seedlings from the study area at the Robert Mitchell Nursery in 1983*

Characteristic	Plots undercut in August: Yellow area	Plots undercut in August: Green area	Plots not undercut in August
Diameter (mm)	3.3**	3.6	3.3
Height (cm)	23.1	23.8	22.7
Shoot dry weight (g)	1.56**	1.91	1.70
Root dry weight (g)	.49	.55	.50
% of seedlings with Pt	9**	67	35
% of Pt on seedlings with Pt	1**	28	8
% Total mycorrhizae	31**	51	50
Pt index	1**	42	13

**Significantly different from "green area" at 0.01 level of probability.
Pt = *Pisolithus tinctorius* mycorrhizae.

Table 2—*Soil characteristics for areas having green and yellow seedlings in beds undercut in August in study area at the Robert Mitchell Nursery in 1983*

Characteristic	Yellow area	Green area
pH	5.9	5.8
Cation exchange capacity (mEq)	3.5**	3.1
Organic matter (%)	1.4	1.4
Phosphorus (weak Bray) (ppm)	97	81
Potassium (ppm)	108	107
Magnesium (ppm)	55**	43
Calcium (ppm)	404	352
Sodium (ppm)	26	25
Sulfur (SO^4) (ppm)	8*	5
Zinc (ppm)	38	28
Manganese (ppm)	50	46
Iron (ppm)	21	19
Copper (ppm)	1	1
Boron (ppm)	0.7	0.7

*Significantly different from "green area" at 0.05 level of probability.
**Significantly different from "green area" at 0.01 level of probability.

Discussion

We can make no conclusions as to the underlying cause of the fall mosaic phenomenon. Although past experiences have allowed us to observe differences in seedling growth due to pathogens and from irregular irrigation or fertilization patterns, none of these appear to adequately explain the fall mosaic pattern. Although not conclusive, data and observations from this study suggest that fall mosaic may be correlated with differences in mycorrhizal colonization of seedling roots.

It may be that a certain combination of environmental and cultural practices are required before symptoms of fall mosaic are expressed. These circumstances may involve a certain soil condition, a certain distribution of mycorrhizae, use of a certain systemic fungicide, a certain level of soil moisture, undercutting at a certain time, and irrigating at a certain time. If a particular combination of factors is required, then it may be very difficult to reproduce the phenomenon with a planned experiment.

The fact that fall mosaic was observed only in plots that had been undercut in August suggests that this practice may play a role in this phenomenon. However, not all beds undercut in August at this nursery exhibited the fall mosaic pattern. It is believed that internal drainage of the study area was greater than the remainder of the nursery, and thus moisture stress resulting from undercutting may have been greater at this location. One hypothesis is that the fall mosaic pattern observed in the study area resulted from a combination of at least three factors.

1. The undercutting subjected the seedlings to moisture stress.
2. The study area was well

drained and moisture could have been a limiting factor.
3. Mycorrhizae on seedlings in yellow areas were either not as well developed in August or were separated from the seedlings during the undercutting and lateral root pruning.

It has been demonstrated that undercutting can stress seedlings. In fact, undercutting is often practiced in nurseries to decrease height growth. The presence of Pt has been shown to decrease moisture stress in pine seedlings *(1).* The observed decrease in the amount of soil nutrients from areas in plots with green seedlings infers that absorption of water and nutrients by these seedlings was greater than by the yellow seedlings. Undercutting to a soil depth of 18 cm not only reduced the amount of roots but also initially confined the remaining root mass to the upper 18 cm of soil.

Limiting seedling roots to the upper layer of soil can result in a reduction of available water, which under certain conditions could result in seedling stress. If seedlings with abundant mycorrhizae are more efficient in absorbing water and nutrients, then they may have been less affected by stress imposed by undercutting.

Fall mosaic has been observed in portions of other nurseries where Pt was not the mycorrhizal species involved. This suggests that other mycorrhizal symbionts may play a similar role in the fall mosaic phenomenon. Although we have attempted to document that fall mosaic exists in forest nurseries, we do not know all the factors that contribute to its cause. In addition, we do not know the potential economic impact of planting chlorotic seedlings from the fall mosaic area. We hope that making others aware of this phenomenon will eventually result in the collection of data required to answer these questions.

Literature Cited

1. Walker, R.F.; West, D.C.; McLaughlin, S.B. *Pisolithus tinctorius* ectomycorrhizae reduce moisture stress of Virginia pine on a southern Appalachian coal spoil. In: Thielges, B.A., ed. Proceedings, 7th North American Forest Biology Workshop; 1982; University of Kentucky, Lexington, KY.