Interactions Between Seedbed Mulches and Seedling Disease Development[1]

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Abstract – Seedbed mulches might be thought to have little influence on disease relationships in forest tree nurseries. In fact, mulches may serve as sources of pathogenic inoculum, or provide conditions that either favor or prevent the development of seedling diseases. This paper highlights aspects of mulch-disease interactions and summarizes a Florida study in which mulching provided useful control of *Rhizoctonia* seedling blight of longleaf pine *(Pinus palustris).* A basic understanding of the biology of soilborne pathogenic and beneficial microorganisms and the influence that cultural practices such as mulching may have on disease development is both needed and encouraged.

Mulching of seedbeds immediately after seed sowing has been and remains a common practice in the production of bare root seedlings in forest tree nurseries. A good mulch provides an important cover for newly sown seeds, enhances seedbed soil stability, facilitates seed germination via maintenance /retention of adequate soil moisture, and buffers seed and seedlings from extremes in soil surface temperatures. Organic mulches provide the added benefit of building or maintaining desirable levels of soil organic matter, which in turn enhance soil structure, water and nutrient relations, and soil microbiological interactions (Adams 1966, Bollen and Glennie 1961, Davey and Krause 1980, Mannering and Meyer 1963, Van Nierop and White 1958).

Although not commonly perceived as a contributor to disease development or a control for nursery seedling diseases, mulches may, depending upon a variety of factors, be either. In this paper we

1 highlight reports from the literature where mulches were known or believed to have influenced seedling diseases (esp. in forest tree nurseries)

2 allude to mechanisms involved in mulch-disease interactions

3 consider criteria for mulch selection with respect to disease relations, and

4 review a case history from a Florida forest nursery where mulching has been employed successfully for control of *Rhizoctonia* blight of longleaf pine *(Pinus palustris* Mill.).

INVOLVEMENT OF MULCHES IN NURSERY DISEASES: A LITERATURE PERSPECTIVE

Mulches as sources of inoculum.

The type and source of available mulching materials and their potential for carrying pathogenic organisms are issues that need to be considered when selecting a mulch for nursery seedbeds. Certain materials have a higher probability of being contaminated with pathogenic organisms than others (Bloomberg 1963,1985, Hoitink *et al.* 1976, Schönhar 1968). For instance, the fungus *Sphaeropsis sapinea* (Fr). Dyko & Sutton can infect and sporulate on cones, needles, and branches of Ponderosa pine *(Pinus ponderosa* Dougl. ex Laws) and red pine (Pinus resinosa Ait.) (Sinclair *et al.* 1987), and one should avoid use of these materials as mulches where susceptible species are grown (Peterson and Nichols 1989). Sand and peat moss can carry pathogenic species of *Pythium* and *Fusarium* (Sutherland 1984), and warnings have been issued to Southern nursery managers about the potential for

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pine needles to carry *Fusarium* spp. and the charcoal root rot fungus, *Macrophomina phaseolina* (Tassi) Goid. (Cordell and Lantz, U.S.D.A. Forest Service, FIDM Letter to Southeastern Forest Nurserymen, February 29, 1980). Needles of some conifer species may carry needle cast fungi such as *Meria laricis* Vaill. and *Lophodermium* spp. and should be avoided where diseases caused by such fungi pose a hazard to seedling crops (Sutherland 1984, Staley and Nichols 1989).

Influence of mulches on disease development

In addition to the possibility of introducing pathogenic fungi into nurseries, certain types of organic matter may differentially favor the development of pathogenic and beneficial fungus populations. For example, Bloomberg (1963) found that species of *Trichoderma* predominated on hemlock sawdust, but species of *Alternaria* were favored by straw. *Trichoderma* spp. are generally believed to restrict the growth of pathogenic spp., but *Alternaria* spp. are regarded as pathogens in some situations. Table 1 provides an overview of some mulch-disease interactions on various seedling crops as reported in the literature. Note that the influence of mulches can be variable, sometimes promoting and sometimes preventing disease development. Mechanisms involved in such influences are myriad, often subtle, complex and may be biological, chemical, and/or physical in nature (Table 2).

Table 2. Some ways in which mulches may influence disease development.

Biologically	promote/suppress pathogen activity
	stimulate competitive/antagonistic microflora
Chemically	pH alterations
	nutrient relations
	direct phytotoxicity
	pesticidal (suppression)
Physically	soil stability
	temperature
	H_2O
	aeration
	flotation

Soil moisture and temperature relationships

Mulches influence soil temperature and soil moisture. Such

Table 1. Some examples of mulch-disease interactions on various seedling crops.

Mulch Material	Crop	Effect	Ref.
Sawdust	Longleaf Pine	Decreased D.O.[1] (Rhizoctonia)	Davis 1941
Sphagnum	-----	Decreased D.O.	Winters 1949
Coir Dust	Mahogany	Decreased D.O.	Barnard 1950
Doug-fir Sawdust	Strawberries	Increased Phytophthora	Vaughan et al. 1954
Various	Ginko	Decreased M. phaseolina	Fang et al. 1956
Sawdust/Wood Chips	-----	Increased Nematodes	Van Nierop & White 1958
"Dark" Sawdust	Douglas-Fir	Increased Heat Lesions	Salisbury & Long 1959
Pine Sawdust/Bark	Pinus sp.	Decreased D.O.	Vaartaja & Bumbieris 1965
Sawdust	Ginger	Decreased Root-Knot Nematodes	Colbran 1974
Redwood Bark/Sawdust	Red Fir & Douglas-Fir	Decreased Phoma Blight	Kliejunas et al. 1985
Hardwood Bark/Wood Chips	Longleaf Pine	Decreased Rhizoctonia	Gilly et al. 1985

[1]D.O. = damping-off

Table 3. Some factors to consider when selecting mulching materials for forest nursery seedlings.	
Availability	Cost
Timing	Rate
Material	natural/synthetic organic/inorganic
Age/Condition	fresh/aged/ composted chemistry (phyto-toxicity, C:N ratio)
Color	temperature relations
Texture	stability H_2O relations aeration
Source/ Handling	contaminant/ pathogenic organisms beneficial/microorganisms

influences can indirectly influence the development of biotic diseases, either positively or negatively, depending on particular host-pathogen relationships. For example, Vaughan *et al.* (1954) found that increased soil moisture and reduced soil temperatures associated with the use of Douglas-fir sawdust mulch increased red-stele disease in strawberries caused by the water mold fungus, *Phytophthora fragariae* Hickman. In contrast, the use of mulches has been credited with the control of charcoal root rot on ginkgo *(Ginko biloba L.)* seedlings (Fang *et al.* 1956). In this instance, the use of a mulch on nursery beds maintained soil temperatures below those considered optimal (c. 32°C) for infection by the pathogen, *Macrophomina phaseolina*.

Alternatively, the influence of mulches on soil and/or soil surface temperatures can directly affect seedlings by causing or preventing abiotic injuries or "diseases". For example, dark colored mulches may absorb solar heat, and thereby increase the chances of heat injury (Barnard 1990, Boyce 1961, Peace, 1962). The use of light colored mulches, on the other hand, can reduce heat injury by reflecting insolation and dispersing heat. However, under certain circumstances, light colored or reflective mulches also may contribute to heat injury of seedlings. Richards (1970) found that the use of fiberglass and spruce needles as mulches could greatly increase temperatures immediately above seedbeds and that these elevated temperatures were damaging to white spruce [*Picea glauca* (Moench) Voss] and Norway spruce [*P. abies* (L.) Karst.].

Physical relationships

The ability of a mulch to act as a barrier against wind and rain and hold a soil in place can play a significant role in the prevention of some diseases. Kliejunas *et al.* (1985) reported that mulch composed of redwood bark and sawdust reduced soil splash, soil cone formation and the incidence of Phoma blight caused by *Phoma eupyrena* Sacc. in fir and Douglas-fir seedbeds in a California nursery. Soil splash that normally occurred during winter months led to soil cone formation around seedlings. This soil cover was believed to reduce seedling vigor and provide an environment favorable to disease development. The use of a mulch in Florida nurseries has produced a similar beneficial effect with regard to the development of *Rhizoctonia* blight of longleaf pine (see Case History below).

Chemical relationships

Chemicals that are naturally associated with certain types of organic matter (...mulches) can suppress growth and development of soilborne pathogens. Extracts from sawdust of *Pinus banksiana* Lamb., *Populus* spp. (Carlson and Belcher 1970), and hardwood bark compost (Kai 1990) can inhibit the growth of certain species of root-infecting fungi. Spencer and Bensen (1982) found that extracts of pine bark suppressed the growth of *Phytophthora cinnamomi* Rands, but noted that the suppressive effects of extracts from hardwood bark compost were stronger and more consistent.

The exact mechanisms by which chemical exudates from organic matter affect specific soilborne fungi are not always clear. In some instances, it appears that the leachates can inhibit the vegetative growth of fungi (Huang and Kuhlman 1991), but in other cases, the chemical extracts may interrupt stages in the life cycle of the fungus. For instance, Hoitink *et al.* (1977) found that leachates from composted hardwood bark could inhibit sporangium formation and lyse germ tubes of zoospores of *P. cinnamomi*, thus preventing host infection. Zoospore production in another water mold, *Pythium aphanidermatum* (Edson) Fitz. has been shown to be inhibited by extracts from pine bark (Huang and Kuhlman 1990).

Water soluble extracts that are leached from various types of mulches can be highly beneficial to seedlings when they suppress fungal pathogens. However, caution is advised in the selection and handling of organic mulches because some organic materials may be phytotoxic. Organic materials that receive insufficient oxygen during storage or composting can undergo anaerobic breakdown and the resulting fermentation products may be toxic to seedlings (Bollen and Lu 1970, Hoitink and Fahey 1986). Reindeer-moss has been reported to be phytotoxic to jack pine (*P. banksiana)* and white spruce [*Picea glauca* (Moench) Voss] (Fisher 1979), and grain straw residues proved to have deleterious effects on black spruce seedlings [*P. mariana* (Mill.) B.S.P.] (Jobidon *et al.* 1989) in instances where these materials were used as mulches. In both cases, phytotoxicity was apparently indirect via disruption of mineral nutrient uptake (P in the former case, and Mn in the later case). Fisher (1979) postulated that the reduction in P uptake may have resulted from an alteration of mycorrhizal symbiosis.

Biological relationships

Other processes through which mulches may be beneficial in the prevention of seedling diseases involve numerous mechanisms which may be collectively referred to as biological control. Populations and activity of soilborne pathogens are often suppressed by the action of competitive, antagonistic, or hyperparasitic microorganisms which may be stimulated by either the food base or environmental niche provided by certain organic materials and/or mulches. A detailed treatise of specific mechanisms involved in these often complex processes is well beyond the scope of this paper. Accordingly, interested readers are referred to any number of excellent overviews (Adams 1990, Baker 1987, Baker 1968, Baker and Snyder 1970, Baker and Cook 1974, Boland 1990, Campbell 1989, Cook and Baker 1983, James *et al.* 1992).

USE OF MULCHES TO CONTROL *RHIZOCTONIA* BLIGHT OF LONGLEAF PINE: A FLORIDA CASE HISTORY

In the southeastern U.S. longleaf pine *(Pinus palustris)* seedling crops are frequently damaged by *Rhizoctonia* spp. which appear to opportunistically infect seedlings impacted by "sand splash" (Davis 1941, English and Barnard 1989, English *et al.* 1986). Davis (1941) reported reduced damage when seedling crops were mulched with sawdust. Faced with unacceptable losses in the late 1970's and early 1980's at the Florida Division of Forestry's Andrews Nursery, Gilly *et al.* (1985) initiated a field trial to evaluate the influence of cultural practices (i.e., seedling density and mulching materials) and fungicidal sprays on the growth and development of longleaf pine seedlings and the incidence and severity of *Rhizoctonia* blight in longleaf pine seedbeds. Results of the fungicide trials were inconsistent, whereas mulching with hardwood (bark and wood) chips provided consistent reductions in the occurrence of disease with no detrimental effects on seedling production. In the following paragraphs, we review aspects of the mulching trial and present a summary and discussion of pertinent results.

Table 4. Mulches tested for effects on the development of Rhizoctonia Blight of longleaf pinea

Material	Rate
Pine straw (1X)	Operationally applied (6-12 mm layer)
Pine straw (2X)	2X operational rate (12-25 mm layer)
Hardwood bark/ wood chips	12-25 mm layer
Hydromulch®	1180 kg/h [a]

[a] All applied immediately after seeding.

Materials & Methods

Seedbeds were prepared according to customary procedures which included soil fumigation with methyl bromide (98% active ingredient @ 393 kg/ha) and a pre-plant incorporation of 15-0-15 fertilizer at 225 kg/ha). Seeds were sown at densities of 350 seeds/m2 (high) and 150 seeds/m2 (low). Four mulch treatments (Table 4) were applied in each of four replicate plots (ca. 60 X 1.25 m each) distributed in a randomized complete block fashion within each of the two seedbed planting densities.

Systematically located 0.37 m^2 life history plots (1 per test plot) were utilized to monitor treatment effects on seed germination and seedling survival. The number of seeds (or seedlings) in each plot was recorded

1 immediately following seed sowing,
2 34 days later, and
3 at the end of the growing season.

Table 5. Production parameters as affected by planting density and mulch treatment [a]

Mulch Treatment	Germination %	Seedlings/m3	Total Oven Dry Weight (g)	Root Collar Diameter (mm)
Low Density Planting (150 seed/m²)				
Hydromulch™	26.2a	30.5a	8.6a	9.2a
Hardwood chips	54.7c	86.5b	7.6a	8.6a
1X pine straw	40.2b	76.5b	8.3a	8.8a
2X pine straw	58.3c	82.4b	8.4a	8.8a
High Density Planting (350 seed/m²)				
Hydromulch™	31.1a	90.1	5.6a	7.4a
Hardwood chips	53.3c	164.c	4.9a	7.3a
1X pine straw	42.2b	125.b	5.4a	7.3a
2X pine straw	54.4c	158.c	5.4a	7.1a

[a] Values within columns and seedbed planting densities followed by same letter are not significantly different at $P \leq 0.05$. Oven dry weight and RCD's differed significantly ($P \leq 0.05$) between low and high density plantings.

All test plots were carefully examined for evidence of *Rhizoctonia* blight on each of six dates between July 5 and November 11. Wooden markers were placed in the ground beside each diseased seedling, and at the end of the test periods, the total number of markers in each infection center (i.e., 1 or more seedlings showing symptoms of infection) were recorded. Incidence and severity of *Rhizoctonia* blight were evaluated by

1 the number of *Rhizoctonia* infection centers/10 m of bed length,
2 the average number of infected seedlings/infection center,
3 the total number of infected seedlings/10 m bed length, and
4 average percentage seedling loss.

At the end of the nursery growing season, two 0.37 m² subplots were systematically established in each density-mulch plot. The number of seedlings in each of these subplots were counted and ten seedlings were randomly selected from each subplot for determinations of a) root collar diameters (RCD) and b) oven-dry weights.

Results and Discussion

Differences in germination between mulch treatments were significant (Table 5). Highest germination occurred in beds mulched with hardwood chips and 2X pine straw, followed by 1X pine straw and Hydromulch®. This order was consistent in both planting densities. Germination in Hydromulch® plots was so low that end-of-season seedbed stocking (i.e., seedlings per unit area) in "high planting density" Hydromulch® plots was comparable to that in the "low planting density" plots of the other three mulches. Not surprisingly, seedlings grown in sparsely stocked Hydromulch® plots were somewhat larger than seedlings grown in plots with other mulches. Within each planting density, seedlings from beds mulched with hardwood chips were slightly smaller than seedlings from 1X or 2X pine straw plots, even though seedbed densities were comparable. These differences, however, were not statistically significant. Within all mulch treatments, seedlings attained greater oven-dry weights and RCD's when grown at the lower planting density.

Table 6 summarizes results with respect to disease incidence and severity within treatment plots, based on observations performed at the end of the growing season. In both seedbed planting densities the highest losses to disease were sustained in plots mulched with pine straw at the 1X rate. In contrast, losses in plots mulched with hardwood chips were lowest among all four

Table 6. Effects of planting density and mulches on Rhizoctonia Blight of longleaf pine.

Mulch Treatment	No. Inf. Centers/ 10m Bed [a]	Mean No. Seedlings/ Inf. Center a	No. Dead Seedlings/ 10m Bed	Seedling Loss (%)
Low Density Planting (150 seed/m^2)				
Hydromulch™	6.6a	1.5a	9.9	2.7
Hardwood chips	3.3a	1.6a	5.3	0.5
1X pine straw	6.8a	5.3a	36.0	3.9
2X pine straw	4.5a	6.7a	30.2	3.0
High Density Planting (350 seed/m^2)				
Hydromulch™	7.1 ac	5.5a	39.1	3.5
Hardwood chips	5.5a	6.4a	35.2	1.7
1X pine straw	11.6bc	14.8a	171.7	11.3
2X pine straw	5.1a	10.6a	54.1	2.8

[a] Values within columns and seedbed planting densities followed by same letter do not significantly differ at $P \leq 0.05$.

treatments. Losses indicated for Hydromulch®-treated plots are deceptively low and misleading due to the very poor germination/stand survival which occurred in this treatment (Table 5). Considering both production parameters (Table 5) and disease occurrence data (Table 6), it is clear that the hardwood chip mulch provided the best treatment overall.

Davis (1941) reported reduced incidence of *Rhizoctonia* infections when longleaf pine seedbeds were mulched with 6-12 mm of sawdust and suggested that mulching might provide useful disease control. Our results support this contention, and of the materials we tested, hardwood chips are clearly the material of choice. While we cannot, on the basis of our studies, eliminate the possibility of some type of biological control being active here, it appears likely that simple physical or mechanical control of sand splash is clearly involved. In this regard, our findings parallel those of Kliejunas *et al.* (1985).

CONCLUSIONS

Results of the case study (above), together with the results and observations reported by others, should encourage forest nursery managers to learn all they can regarding the biology of pathogens causing problems in their respective nurseries. In some instances, the control of diseases caused by pathogenic organisms may be effected via alteration of cultural practices such as seedbed mulching. In Florida, nursery managers have learned that even "re-mulching " longleaf pine seedbeds (i.e. applying a second application of mulch to seedbeds, months after seed germination) is beneficial with respect to reducing losses to *Rhizoctonia* spp. (unpublished data and observations).

One must keep in mind, however, that nature and events are not always predictable, and that even the best of techniques can have an "Achilles heal". In one Florida situation, *Rhizoctonia* caused a foliage blight of loblolly pine (*P. taeda* L.) because the material used for mulch on seedbeds floated up to and lodged in the needles of seedlings during heavy rains, thus facilitating the transfer of inoculum from the soil surface to susceptible needles. Although damage was minor and primarily restricted to low-lying areas of seedbeds, the situation was nonetheless disconcerting for the nursery manager.

A basic understanding of pathogen biology and disease epidemiology (development) coupled with a keen sense of observation and a willingness to experiment are advocated as useful tools in the nursery managers constant battle to develop and maintain healthy seedling crops.

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