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ABSTRACT

The systemic insecticide carbofuran was applied to the soil under planted loblolly pines in studies near Aiken, SC, at ages 2 through 5. As expected, the insecticide sharply reduced tip-moth damage and increased the height of 5-year-old saplings, compared with untreated controls. Untreated trees not only had more tip-moth injury but also had significantly more fusiform rust infections. Carbofuran itself did not have any fungicidal effect which could have been responsible for the lower incidence of rust among the treated trees. Since carbofuran treatment not only reduced damage from tip moth but also decreased rust infection, these results may prompt new interest in the economics of tip-moth control.

Keywords: *Pinus taeda*, *Cronartium quercuum* f. sp. *fusiforme*, *Rhyacionia frustrana*.

Loblolly pine (*Pinus taeda* L.) is the forest tree species most often planted from Maryland through Texas. In this area, growth of loblolly pine usually equals or exceeds that of other pine species, and it grows well on a wide variety of sites. Across much of this area, loblolly pine is subject to attack by both tip moth and fusiform rust. The tip-moth problem is caused by a complex of several closely related species, the most common of which is the Nantucket pine tip moth (*Rhyacionia frustrana* (Comstock)). Tip-moth damage often is so prevalent that it is difficult to find unaffected seedlings in young plantations. Fusiform rust is caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme*. Although fusiform rust infection is not quite as common as tip-moth attack, disease incidence as high as 95 percent occurs in the high-rust-hazard zone that extends from South Carolina through Georgia and into Alabama (Phelps 1973). The susceptible areas on the pine host for both pests are young, succulent shoot tissues.

There has been considerable interest in tip-moth damage because of its prevalence on loblolly pine. There seems little doubt that heavy attacks reduce height growth in the early years of a plantation (Cade and Hedden 1987). However, several studies have shown that height differences caused by tip-moth attack disappear between ages 15 and 20 (Beale 1967; Williston and Barras 1977). The study by Cade and Hedden also showed that treatment to control tip moth is marginally cost effective only in a thinned sawtimber regime. From a practical standpoint, they did not recommend operational tip-moth control. It was felt that even slight changes in insect damage levels, site productivity, interest rates, or other factors would cause the treatment to be uneconomical. At present, therefore, tip-moth damage is simply tolerated. Field control of fusiform rust with chemicals is also considered economically unfeasible. However, large-scale programs to develop rust-resistant pines have been underway for several years (Powers and others 1976; Zobel and others 1971), and rust-resistant strains of both loblolly and slash pines are now available for reforestation in high-rust-hazard areas.

One approach to this dual problem of insect and disease damage is to plant a species less susceptible than loblolly pine to tip-moth attack and rust infection. Slash pine (*Pinus elliottii* Englem. var. *elliottii*), the other southern species widely used in reforestation, is less frequently attacked by tip moth and has a growth advantage over loblolly in the early years of a plantation. Over a complete rotation, however, loblolly pine usually outgrows slash even when the loblolly has early tip-moth infestations. Unfortunately, both loblolly and slash pine are susceptible to fusiform rust, which is the most damaging disease of southern pines (Powers and others 1981). The mortality of slash pines due to fusiform rust is usually greater than that of loblolly pine except in the southernmost part of the loblolly range in Florida (Powers and others 1975). As a result, most forest managers live with the damage caused by tip moth and try to obtain rust-resistant loblolly pine seedlings to reduce damage from the disease.

Tip moth larva in a terminal shoot of loblolly pine.

This study was designed to determine what effect the control of tip moth by carbofuran, a systemic insecticide, would have on subsequent infection of both rust-resistant and susceptible strains of loblolly pine by the fusiform rust fungus.

Materials and Methods

Rust-resistant seedlings were grown from a mixture of seeds collected from 20 of the most rust-resistant loblolly pine clones in the South. Control seedlings were commercially available improved loblolly from a general production orchard. All seedlings were grown in a nursery by standard practices and planted on the Savannah River Plant facility near Aiken, SC. The field design was a split plot with 10 rows each of resistant and control seedlings as the main plots. Within each of two replications were eight randomized blocks, either with or without carbofuran treatment. Each carbofuran-treated or untreated block measured approximately 27 by 30 m, and originally contained 110 to 140 seedlings. Trees were machine planted approximately 2 m apart with 3 m between rows.

Carbofuran (10% A.I. formulation) was applied to the soil around designated seedlings at the rate of 30 g/seedling in March of the second through fifth years of the study. The carbofuran was incorporated into the soil with fire rakes. At the end of the fifth growing season, tree heights were measured, and rust infection and tip-moth damage were evaluated. Trees were recorded as either rust infected or healthy, based on whether any rust galls were present on either stems or branches. Tip-moth infestations were evaluated on the basis of whether or not damage occurred on any of 10 randomly sampled current-year shoots from each tree.

Carbofuran is taken up by seedling roots and translocated to the young shoot tissues that are the primary targets for rust infection. One possible mechanism for a reduction in rust incidence after insecticide application would be carbofuran toxicity to the mycelium of the rust fungus as it penetrates young shoot tissues. A greenhouse study with young seedlings was designed to evaluate this possibility. Ten trays, each with 20 loblolly seedlings, were assigned to each of four concentrations of carbofuran: 0, 1, 2,

and 4 g/tray. Carbofuran was applied approximately 1 month after seedling germination. Three weeks later the seedlings were artificially inoculated with the fusiform rust fungus by applying a highly concentrated spray of basidiospores (Powers and Matthews 1979). The aeciospores used to produce this inoculum were from a mass collection adjacent to the test site near Aiken, SC. Infection data were based on the number of seedlings with actively growing galls after 9 months.

Results

As expected, significantly fewer resistant than control saplings in the field test were infected with fusiform rust. Among all control saplings, 55.5 percent were infected with either stem or branch galls, compared with 25.4 percent of the resistant seedlings (table 1). Unexpected, however, was a highly significant difference in rust infection between carbofuran-treated and untreated saplings. Of the untreated saplings, 46.3 percent had evidence of rust infection, as opposed to 34.6 percent infection of treated saplings. The decrease in rust among saplings receiving carbofuran was evident for resistant as well as susceptible seed sources. Among resistant saplings, infection percentages were 18.5 percent for seedlings treated with carbofuran and 32.3 percent for the untreated ones. Among control saplings, percentages were 50.8 with carbofuran treatment and 60.3 percent without.

The carbofuran treatment also gave good control of tip moth. Only 17.9 percent of the trees treated with the insecticide had evidence of tip-moth damage. About two-thirds of the trees that did not receive carbofuran were damaged by tip moths. There was no significant difference in tip-moth infestation between the resistant and control seed sources.

Carbofuran application also produced a significant (0.05 level) increase in height. The carbofuran-treated trees averaged 3.7 m at age 5, compared with 3.2 m for the untreated trees. There was no significant difference in height between the rust-resistant and control trees.

In the greenhouse study, there were no differences in the amounts of rust infection on the seedlings after treatment with the different levels of carbofuran. Infection rates were high for all treatments (83-90% infection). The untreated control seedlings had almost as much infection (88%) as the seedlings with the highest level of carbofuran (90%).

Treatment	Trees infected with rust	Trees showing damage by tip moth	Tree height
	Percent	Percent	Meters
Carbofuran:	34.6[a]	17.9[a]	3.7[b]
Resistant trees	18.5	18.5	3.7
Control trees	50.8	17.3	3.7
Untreated Control:	46.3[a]	66.8[a]	3.2[b]
Resistant trees	32.3	65.5	3.3
Control trees	60.3	68.0	3.1
Resistant trees (Mean)	25.4[c]	42.0[d]	3.5[d]
Control trees (Mean)	55.5[c]	42.6[d]	3.4[d]

[a]Values for carbofuran-treated trees and untreated controls differ significantly at the 0.01 level.

[b]Values for carbofuran-treated trees and untreated controls differ significantly at the 0.05 level.

[c]Values for resistant and control trees differ significantly at the 0.01 level.

[d]Values for resistant and control trees do not differ significantly at the 0.05 level.

Discussion

The study was originally designed to detect any effect on rust incidence of controlling tip moths with carbofuran, and to test the rust resistance of the two seed sources. The differences in rust susceptibility between resistant and control seed sources were anticipated, as was the effectiveness of carbofuran in controlling tip moth (Nord 1978). The reduction in rust incidence on trees treated with carbofuran is more difficult to explain. It was assumed that carbofuran, which contains some nitrogen in its formulation, would probably stimulate growth, and it did do so. Anything that stimulates growth of the host, such as fertilizer application or intensive site preparation, increases the amount of rust-susceptible tissue and usually results in an increase in the incidence of rust. Therefore, an increase rather than a decrease in rust incidence was expected where carbofuran was applied.

The results of the greenhouse test demonstrated that the reduction in rust incidence among carbofuran-treated trees was not caused by any fungitoxic effect of the insecticide itself. In that test, rust incidence on the controls was very similar to that on seedlings receiving the highest rates of the insecticide. Therefore, some mechanism other than carbofuran toxicity to the fungus must be sought to explain reduced rust infections on carbofuran-treated trees in the field study.

It has been shown that tip moth attacks reduce the number of shoot tips and tip growth (Lashomb 1978), so additional target area for infection is not the reason for the increased rust incidence on the untreated trees. Some other possible explanations for this result are: (1) When primary shoots of untreated trees are killed by the tip moth, the resulting flush of secondary shoots may occur at a time of higher basidiospore production. (2) Tip-moth injury may provide an infection court for the fusiform rust pathogen. Evaluation of these alternative explanations will await further experimentation. Meanwhile, the interaction between these two pests may cause forest managers to consider controlling tip moth, because it is apparent that the untreated seedlings not only had more tip-moth damage but also considerably more rust. It may therefore be worthwhile to reevaluate the economics of field control of the tip moth.

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KEYWORDS: Pinus taeda, Cronartium quercuum f. sp. fusiforme, Rhyacionia frustrana.

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