Triadimefon on Controls White Pine Blister Rust on Sugar Pine in a Greenhouse Test

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Seven systemic fungicides were applied to sugar pine (Pinus lambertiana Dougl.) seedlings, as foliar sprays, to determine their efficacy against white pine blister rust-the major limiting factor in regenerating sugar pine. Benodanil and triadimefon showed strong protection after the initial inoculation, with triadimefon showing residual protection for up to 6 months. This protection was verified by a followup test. Tree Planters' Notes 43(1):7-10;1992.

Sugar pine *(Pinus lambertiana* Dougl.) is one of the most important and valuable timber species in California. However, it is highly susceptible to white pine blister rust, caused by *Cronartium ribicola* J. C. Fisch. in Rabenh. Since its introduction into the Pacific Northwest in 1910, white pine blister rust has become the major limiting factor in the natural and artificial regeneration of sugar pine. Seedlings and young saplings (figure 1) are most susceptible to lethal infection, especially when environmental conditions favor disease development.

A systemic fungicide effective against *C. ribicola* could be a useful tool in the management of young sugar pine plantations and could possibly be used in combination with cultural methods, such as pruning. The potential for fungicide use has been demonstrated in another host-pathogen system. In the southeastern United States, fusiform rust *(Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. fusi*forme) is* a serious disease in southern pine nurseries (Kelley 1978b, Mexal and Snow 1978). Use of systemic fungicides has been effective in controlling this disease (Kelley 1978a & b, Kelley and Williams 1985, Mexal and Snow 1978, Rowan 1982 & 1984).

This paper reports the results of a greenhouse test of seven fungicides applied as foliar sprays to sugar pine seedlings to determine their efficacy against *C. ribicola.* The test was conducted at the Institute of Forest Genetics, Pacific Southwest Research Station, USDA Forest Service, Placerville, California.

Figure 1—*Sugar pine sapling showing aecial infection and pycnial scarring from white pine blister rust.*

Methods

After 90 days of cold stratification (Schopmeyer 1974), seeds from an open-pollinated sugar pine parent known to be susceptible to white pine blister rust were sown (September 1984) into a peat-vermiculite mix (Redi-Gro Corporation, Sacramento, California) in Leach Super Cells (Ray Leach "ConeTainer" Nursery, Canby, Oregon) in a greenhouse. Seedlings subsequently were transferred to a lath-house to overwinter and, in April 1985, returned to the greenhouse under a 16-hour photoperiod regime to encourage secondary needle production. In July 1985 they were returned to the lath-house for 3 months, whereupon 400 healthy seedlings were

selected and divided into eight groups of 50 for treatment.

Seven fungicides were selected for testing: benodanil (MF-654), diniconazole (Spotless®), myclobutanil (Systhane®), oxycarboxin (Plantvax®), propiconazole (Tilt®), triadimefon (Bayleton®), and triforine (Funginex®). These products were selected for their systemic action and efficacy against rust fungi. Formulations and application rates are listed (table 1). All fungicide applications were made on the same day (October 1985), using a .7-liter (3-pint) hand-held garden sprayer with the nozzle adjusted to deliver a heavy mist; the single application was applied to runoff for each fungicide. Although several techniques have been used to apply fungicides for control of fusiform rust (Kelley 1978a, Kelley and Williams 1985, Rowan 1982 & 1984), a foliar application is the most practical for use against *C. ribicola* in the field (especially on young seedlings) and was our choice for this test. After treatment, seedlings remained in the lath-house, under ambient conditions and overhead irrigation, until inoculation.

The experimental design for the inoculation was a complete block consisting of seven treatments (fungicides) plus an untreated control, with 50 replicates in single tree plots. Seedlings were randomly arranged into 50 replicates of 8 seedlings each (1 seedling from each treatment per replication). Five containment racks were required to hold the seedlings.

Three weeks after treatment, the seedlings were inoculated with *C. ribicola* using procedures already described (Kinloch and Comstock 1980). Briefly, teliabearing European black currant (*Rites nigrum* L.) leaves were suspended over the seedlings in a moist inoculation/incubation chamber for 48 hours. One inoculation was required to expose the five racks of seedlings to *C. ribicola*. Temperature in the chamber ranged from 20 to 25.5 °C (68 to 78 °F) with relative humidity ranging between 98 and 100%. Inoculum density, measured by five glass slide traps, was 98 ± 48 basidiospores/mm^2. The target spore density desired to attain full inoculation, based on prior experience, was 100 spores/ mm^2. Spore traps were located within each rack of seedlings (1 trap per rack, each trap covering an area equivalent to that of 3 seedlings); spore trap locations were randomly assigned. After inoculation, the seedlings were returned to the lath-house for overwintering.

In February 1986 the seedlings were brought back into the greenhouse to expedite development and expression of the disease. In March 1986, seedlings were scored for severity of infection. Seedlings were examined for needle symptoms, yellow or red needle spots (susceptible response), and necrotic needle flecks (resistant response) (Kinloch and Comstock 1980). Absence of needle symptoms was used as an indicator of fungicidal effectiveness. Because seedlings escaping fungal penetration and those lacking symptoms due to fungicidal efficacy are indistinguishable from each other, the control seedlings provided us with an estimate of the proportion of escapes that might have occurred within the treatments.

Results

Of the seven treatment groups, only triadimefon treated and benodanil-treated seedlings did not develop detectable needle symptoms (table 2). The remaining treated seedlings, with the exception of those treated with myclobutonil, expressed needle symptoms comparable to or greater than the control group. Although the myclobutanil treatment had fewer infected seedlings than did the control group, we attributed that result to seedlings escaping fungal penetration, not effectiveness of the fungicide. Regardless, 25 seedlings without symptoms out of 48 (23 infected) was not considered adequate protection in this test. Escapes for the benodanil and

Table 1—*Fungicide formulations and application rates tested*

Active ingredient	Trade name	Rate/gallon
Triadimefon	Bayleton 50W	.08 oz
Propiconazole	Tilt 1.1E	.16 oz*
Benodanil	MF-654 50W	.32 oz
Myclobutanil	Systhane 40W	.12 oz
Oxycarboxin	Plantvax 75W	.24 oz
Triforine	Funginex 18.2E	.16 oz*
Diniconazole	Spotless 12.5W	.08 oz

All fungicides were applied once as a foliar spray.
*In liquid ounces; other measurements in dry weights.

Table 2—*Infected seedlings by treatment group (seedlings were inoculated 3 weeks after fungicide application)*

Treatment	No. of seedlings	No. Infected	% Infected
Control	50	38	76
Triadimefon	50	0	0
Propiconazole	50	48	96
Benodanil	50	0	0
Myclobutanil	48*	23	48
Oxycarboxin	50	34	68
Triforine	50	38	76
Diniconazole	50	39	78

*Two seedlings died before evaluation from causes other than rust.

triadimefon treatments were not determinable because of the efficacy of the fungicides; it is highly unlikely that all 50 seedlings in both of these treatment groups escaped fungal penetration, considering the random placement of seedlings within racks.

Rechallenge. To determine residual potential, we rechallenged the seedlings treated with triadimefon and benodanil. Two seedlings, one from each treatment, died from causes other than rust before the second inoculation.

Seedlings were reinoculated in April 1986, nearly 6 months after the initial challenge, using procedures previously described. Spore trap counts were 189 ± 72 basidiospores/mm^2. All of the control seedlings (12 control seedlings without symptoms from the first inoculation plus 13 residual seedlings from the original sowing) and 88% of the seedlings receiving an initial treatment with benodanil became infected (table 3). The six benodanil-treated seedlings not infected may have been escapes. The one triadimefon-treated seedling that became infected did not express any needle symptoms but did develop stem symptoms in spring 1987 (see below).

One year after the initial application of fungicide, in October 1986, 23 triadimefon-treated seedlings, 6 benodanil-treated seedlings, and 4 controls (residual stock for the original sowing) were inoculated a third time (second rechallenge). Spore trap counts were 272 ± 85 basidiospores per square millimeter. Three triadimefon-treated seedlings died after the second inoculation from causes other than rust; the remaining 23 seedlings were withheld from the third inoculation to serve as checks against latent infection from the second inoculation. Residual activity was greatly reduced compared with the protection observed following the second inoculation at 6 months (table 3). All of the controls and benodanil-treated seedlings developed needle infections, as did most of the triadimefon-treated seedlings (the 5 seedlings not infected may have been escapes). One of the withheld checks developed stem symptoms from the second inoculation, and two died from causes other than rust. The remaining 20 seedlings did not develop any rust symptoms. The results indicate residual activity of triadimefon protects sugar pine seedlings from *C. ribicola* for up to 6 months after treatment.

Verification of test results. To verify our findings, another test was conducted in 1987. Forty-nine triadimefon-treated seedlings were paired with 49 untreated controls; all seedlings were from the same open-pollinated source used in our initial test. Sowing, treatment, and inoculation procedures followed those previously described. The first inoculation was in December 1987 followed by a rechallenge 6 months later in May 1988. Spore trap counts were 202 ± 50 and 279 ± 57 basidiospores/mm^2, respectively. Results of the 1987 test were very similar to those from 1985 (table 4). One change from our original procedure was to withhold 10 seedlings from the second inoculation to be examined for latent symptom development. None of these seedlings developed stem symptoms by the time of their final evaluation, nearly 9 months after inoculation.

Table 3—*Infected seedlings after second and third challenge of 1985 treatments*

Treatment	No. of seedlings	No. Infected	% Infected
Second challenge			
Control	25	25	100
Benodanil	49*	43	88
Triadimefon	49*	1	2
Third challenge			
Control	4	4	100
Benodanil	6	6	100
Triadimefon	23†	18	78

Second challenge was 6 months after treatment; third challenge was 1 year after treatment.
*One seedling died from causes other than rust before the second inoculation.
†Three seedlings died from causes other than rust before the third inoculation; 23 seedlings were withheld to observe for latent symptom expression resulting from the second inoculation.

Discussion and Conclusion

Important considerations in the selection of any pesticide are timing of application and resulting efficacy. Treatment effectiveness is enhanced by extended residual activity, which minimizes the need for application to coincide with pest exposure.

Triadimefon and benodanil showed promising protection against white pine blister rust, and triadimefon demonstrated apparent residual activity, lasting at least 6 months. Although these results need to be verified under field conditions, our tests indicated a strong potential for protecting young sugar pine

Table 4—*Infected seedlings in verification test (1987)*

Treatment	No. of seedlings	No. Infected	% Infected
First challenge			
Control	49	45	92
Triadimefon	49	0	0
Second challenge			
Control	10	9	90
Triadimefon	39	1	3

Initial inoculation was 3 weeks after treatment; second was 6 months after treatment.

stock with a single annual application of triadimefon, if it is strategically timed. Since *C. ribicola* normally infects sugar pine in the fall, a late summer application (end of August or early September), before fall rains and cooler temperatures prevail, should be optimum.

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