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EFFECT OF CALCIUM, MAGNESIUM, AND ALUMINUM-IRON ON THE SUSCEPTIBILITY OF LOBLOLLY PINE SEEDLINGS TO FUSIFORM RUST

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ABSTRACT.-The susceptibility (percentage of seedlings infected) of *Pinus taeda* seedlings to infection by *Cronartium quercuum* f. sp. *fusiforme* was not affected by fertilization with calcium, magnesium, or aluminum-iron. Fertilization with Al as $Al_2(SO_4)_3$ and Fe as $FeCl_3$, however, significantly reduced seedling height growth during the first 8 weeks after seedling emergence and increased numbers of fusiform rust galls per unit of seedling height present at time of inoculation.

Keywords: *Pinus taeda*, *Cronartium quercuum*, rust testing, disease resistance.

The susceptibility of slash (*Pinus elliottii* Engelm. var. *elliottii*) and loblolly pine (*P. taeda* L.) seedlings to fusiform rust (caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* Burdsall & Snow) is apparently increased by many factors that increase seedling growth (Rowan 1977, 1978; Rowan and Steinbeck 1977). Susceptibility of pine seedlings to the disease may be directly correlated with the size of the infection court (Rowan 1978; Rowan and Steinbeck 1977) and with the physiological condition of host tissues. Resistance, however, must depend on more than the infection court size because two genetically distinct families of pine seedlings may grow at equal rates and produce infection courts of equal size but differ markedly in susceptibility (Rowan 1977). The effect of fertilization with calcium (Ca), magnesium (Mg), or aluminum-iron (Al-Fe) on growth and susceptibility of loblolly pine seedlings to infection by C. *quercuum* f. sp. *fusiforme* has not been reported. Significant effects of any one of these nutrients would require control of its rate of supply to seedlings tested for susceptibility to the disease (Matthews and Rowan 1972; Powers 1974). This Note reports the effects of such fertilization on the susceptibility of loblolly pine seedlings in greenhouse sand culture.

METHODS

Seeds collected from open-pollinated loblolly pines were stratified 30 days and planted in flats of common builder's sand. The seeds, collected in Georgia, were supplied by the Georgia Forestry Commission. Seedlings emerging during a 4-day period were transplanted to plastic flats (33. x 13 x 11 cm) at the rate of 20 per flat. Each flat was filled with builder's sand which had been washed repeatedly with tapwater before washing with pH 2.0 deionized water. The washed sand contained 99.6 percent sand; 0.4 percent silt, trace clay; 6.0 $\mu g/g$ NO_3-N; 0.1 $\mu g/g$ PO_4-P; 2.9 $\mu g/g$ Mg; 14.0 $\mu g/g$ Ca; 0.05 $\mu g/g$ Mn; 0.1 $\mu g/g$ Cu; 1.0 $\mu g/g$ Fe; and nondetectable levels of K, Mo, B, Zn, and organic matter.

Calcium, magnesium, and aluminum-iron were applied at three levels in a randomized complete-block design with 10 replications (flats). The three nutrients were supplied at 0, 80, and 160 $\mu g/ml$ Ca as $CaCl_2$; 0, 25, and 75 $\mu g/ml$ Mg as $MgSO_4$; and 0, 100, and 200 $\mu g/ml$ Al as $Al_2(SO_4)_3$

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mixed respectively with 0, 5.5, and 55.0 μg/ml Fe as $FeCl_3$. All flats received 0.001 μg/ml Mo as Na_2MoO_4, 0.006 μg/ml Cu as $CuSO_4$, 0.090 μg/ml B as H_3BO_3, 0.100 μg/ml Zn as $ZnSO_4$, 0.700 μg/ml Mn as $MnCl_2$, 100.0 μg/ml N as NH_4NO_3, 75.0 μg/ml P as Na_2HPO_4, and 100.00 μg/ml K as KCl. All flats receiving Ca treatments also received 25.0 μg/ml Mg as $MgSO_4$ and 5.5 μg/ml Fe as chelated sodium ferric diethylenetriamine pentaacetate. All flats receiving Mg treatments also received 80.0 μg/ml Ca as $CaCl_2$ and 5.5 μg/ml Fe from the source just mentioned. The chelated iron was not used to test the effects of iron as a nutrient because of the desire to provide a form of iron that would quickly ionize and reach equilibrium with aluminum. All flats receiving the Al-Fe treatments also received 80.0 μg/ml Ca as $CaCl_2$ and 25 μg/ml Mg as $MgSO_4$. All nutrient solutions were prepared and the pH adjusted to 5.5 the day of application. For 12 consecutive weeks, beginning the first week after emergence, 400 ml of nutrient solution were applied weekly to each flat. Similar amounts were applied 14, 16, 20, 24, 32, and 40 weeks after emergence. Seedlings did not require additional irrigation during the first 12 weeks, but tapwater was applied as needed after the 12th week.

Aeciospores (source G-3) were collected from a single loblolly pine gall in Clarke County, Georgia. Thus, a Georgia spore source was used to inoculate a Georgia loblolly seed source. Northern red oak (*Quercus rubra* L.) seedlings were inoculated with these spores, and basidiospores were collected from the oak leaves. Suspensions containing 75,000 basidiospores per ml were used to inoculate the 8-week-old pine seedlings (Matthews and Rowan 1972; Powers 1974). Basidiospore viability on 1.5 percent water agar was 84 percent at time of inoculation.

Seedling heights to the terminal needle tips were recorded at inoculation, and numbers of seedlings infected were recorded 12 months after inoculation. An index of rust susceptibility was calculated as the ratio of number of galls in each flat to the total height of all seedlings in each flat at time of inoculation multiplied by 100. The index, therefore, is a measure of the number of galls per unit of seedling height present at the time of inoculation.

RESULTS AND DISCUSSION

Neither growth nor the percentage of loblolly pine seedlings infected with fusiform rust was significantly affected by fertilization with Ca, Mg, or Al-Fe (table 1). Therefore, variations in the quantities of these elements that were supplied pine seedling progenies should not affect susceptibility tests for fusiform rust. Fertilization with 100 or 200 μg/ml Al and 5.5 or 55.0 μg/ml Fe significantly reduced seedling height at inoculation, but this reduction in height was not accompanied by a reduction in percentage of seedlings infected with fusiform rust (table 1). The number of galls per unit of seedling height was increased by Al-Fe fertilization, indicating that rust suscep-

Table l.-Effects of calcium (Ca), magnesium (Mg), and aluminum-iron (Al-Fe) supply upon susceptibility to fusiform rust and height growth at inoculation in loblolly pine seedlings

Nutrient	Concentration in solution	Seedlings infected	Seedling height at inoculation	Rust susceptibility index[1]
	g/ml	*Percent*	*mm*	
Ca	0	[2]45.5a	118.7cd	7.7ab
Ca	80	40.8a	118.8cd	6.9a
Ca	160	54.6a	113.2c	9.7bc
Mg	0	45.0a	119.7cd	7.0a
Mg	25	53.5a	118.8cd	9.0abc
Mg	75	42. la	120.7cd	7.0a
Al-Fe	o - o	46.8a	126. Id	7.5a
Al-Fe	100-5.5	49.4a	97.0b	10.2c
Al-Fe	200-55.5	49.4a	81.1a	12.2d

[1]Rust susceptibility index = (galls per flat/total height at time of inoculation of all seedlings in each flat) × 100.
[2]Means followed by a common letter are not significantly different (P = 0.01) according to Duncan's multiple range test.

tibility was increased by these treatments.

It was not surprising that Al-Fe reduced seedling growth because these elements interact to affect the availability of P in the soil (Hesse 1971). The lack of correlation between seedling growth rate and susceptibility to rust was a surprise. In genetically similar seedlings, rust incidence increases with the amount of susceptible tissue (shoot length above cotyledons in young seedlings) exposed to infection (Rowan and Steinbeck 1977). A lack of correlation between rust incidence and seedling growth has been reported in field studies (Dinus and Schmidtling 197 1) and in a greenhouse study in which several pine families were included (Rowan 1977). The highest level of Al-Fe applied reduced seedling height 36 percent and caused a 64 percent increase in number of galls per unit of seedling height. If the infection court size is proportional to seedling height at inoculation, then fertilization with Al-Fe increases susceptibility to fusiform rust without increasing the amount of susceptible tissue.

Additional studies are planned to determine more fully the effects of Al and Fe on growth and susceptibility of loblolly pine seedlings to fusiform rust. At present aluminum is not supplied in fertilizer supplements to seedlings in the Fusiform Rust Testing Center, nor do I recommend that it be supplied. An adequate supply of Fe should be maintained in fertilizer supplements to seedlings in the testing center to promote growth and prevent chlorosis.

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