Susceptibility of Eight Pine Species to Comandra Blister Rust in Tennessee

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ABSTRACT

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Field studies in Tennessee compared the relative susceptibilities of eight pine species to natural infection by comandra blister rust (*Cronartium comandrae*) over an 8-yr period after planting. Pond, shortleaf, and slash pines were most susceptible. Loblolly and Virginia pines were less susceptible, and eastern white pine, red pine, and Japanese black pine were resistant. Differences in location of comandra rust needle infection were observed among pond, shortleaf, and slash pines. An apparent minimum 2-yr period was needed for developing rust stem cankers to cause tree mortality after natural direct stem infections through attached needles. All rust stem cankers detected during the first 5 yr after planting caused mortality the subsequent year on all susceptible species. Proximity of the alternate host, false toadflax, to infected pines was an apparent requirement, but false toadflax abundance was not correlated with subsequent incidence of rust-caused stem infection and mortality. Loblolly and shortleaf pine plantings should be avoided on sites where false toadflax would be close to the majority of planted pine seedlings.

In the South, comandra blister rust (*Cronartium comandrae* Pk.) has been found in Alabama, Arkansas, Kentucky, Mississippi, Missouri, and Tennessee (3,6,9,15,16). Previously, the disease was reported primarily on ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*P. contorta*) in the West and on jack pine (*P. banksiana*) in the north central states (3).

The fungus also infects Jeffrey pine (*P. jeffreyi*), knobcone pine (*P. attenuata*), pitch pine (*P. rigida*), red pine (*P. resinosa*), Scotch pine (*P. sylvestris*), Swiss mountain pine (*P. mugo*), and Table Mountain pine (*P. pungens*) (3,12). Susceptibility of red pine is questioned (10). Artificial inoculation of Austrian pine (*P. nigra*) with *C. comandrae* has been successful in nursery and greenhouse studies in Minnesota (2).

Some species of southern pines are hosts for this obligate fungus parasite. Among them, loblolly pine (*P. taeda*) and shortleaf pine (*P. echinata*) are the most commonly affected (3,8). In addition, the rust occurs on naturally infected Virginia pine (*P. virginiana*), pond pine (*P. serotina*), spruce pine (*P. glabra*), and slash pine (*P. elliottii*) in Tennessee (1,4,13).

The alternate host of the comandra rust fungus in eastern North America, false toadflax or comandra (*Comandra umbellata* ssp. *umbellata*), has a widespread natural range that extends east of the Great Plains from Canada southward to upper South Carolina, Georgia, Alabama, Mississippi, and Arkansas (11). On the Cumberland Plateau in Tennessee, false toadflax occurs scattered in localized areas on dry sites in the open or under a thin overstory. This herbaceous perennial is highly intolerant to shade (15).

The objectives of our study were 1) to determine the relative susceptibility of eight species of pines to natural *C. comandrae* infection and subsequent mortality and 2) to examine the relation of these two factors to the abundance and proximity of the alternate host.

MATERIALS AND METHODS

The following species of pines were planted in February and March 1969: loblolly, shortleaf, Virginia, pond, eastern white (*P. strobus*), Japanese black (*P. thunbergiana*), red (*P. resinosa*), and slash. The eastern white and Japanese black pine seedlings were 2 yr old and the red pine was 3 yr old. Seedlings of the other five species were 1 yr old. The pines were planted at The University of Tennessee's Highland Rim Forest near Tullahoma in four replicates in an open hardwood stand. Grass and lower vegetation were removed, and the hardwood overstory was injected with a herbicide before planting. Each replicate contained 25 seedlings per species. Five plots with five seedlings per plot were randomly planted in each replicate at a spacing of 1.8 m within and 2.4 m between rows. The study site encompassed an area slightly less than 0.4 ha.

Data were collected anually during the season of maximum *C. comandrae* aecial fruiting, which ranged from the last week of April to the first week of May, from 1970 through 1974 and in 1977. Rust symptoms consisted of either a spindle-shaped swelling on the branches or stem of seedlings or a sunken canker on large stems. Aecial fruiting was also frequently associated with these symptoms.

Five 4-m^2 subplots were established randomly in the first replicate to determine the annual abundance and distribution of false toadflax plants. Each subplot contained one pine seedling as well as false toadflax plants at the time of establishment. The false toadflax locations were stem-mapped on gridded paper during the study examinations each spring from 1969 through 1977.

RESULTS

The relative susceptibility of the eight species of pines to *C. comandrae* branch and stem infections and subsequent rust mortality are summarized in Table 1. Survival of all eight species averaged 80 of 100 trees after the first year, with no evidence of comandra rust branch or stem infections or associated mortality. Pond pine had the best survival (95 trees), and red pine had the worst survival (36 trees).

Despite the lack of any detectable aecial fruiting or stem swellings in 1970, both comandra rust stem infections and subsequent mortality were observed on shortleaf, pond, and slash pines in 1971. The initial *C. comandrae* aecial fruiting was detected in 1972 on all five susceptible species. All stem cankers detected in 1972 and 1973 resulted in mortality the next year. The only rust-caused mortality on Virginia pine was observed in 1974. Neither *C. comandrae* infection nor mortality was detected on any of the eastern white, red, or Japanese black pines. Basal stem sprouting after stem mortality was observed on one rust-killed shortleaf pine, two rust-killed pond pines, and two pond pines killed by other causes. Multiple *C. comandrae* branch infections were observed on two shortleaf pines. A total of 33 *C. comandrae* stem infections were observed from 1970 through 1974; this varied significantly among years ($P = 0.05$, chi-square test). The total rust-caused mortality for the 8-yr period was 36 pines, representing 7% of the 500 pines of the five susceptible species planted.

The *C. comandrae* needle infection location differences observed among these species of pines are important in determining the rate of disease progression. Stem needles were the most apparent origin of all *C. comandrae*

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infections observed on all species of susceptible pines through 1971. This trend continued on all slash pine initial rust infections and 80% of all pond pine initial rust infections through 1974. Beginning in 1973, however, needles attached to branches were the primary source of comandra rust infections on shortleaf pine. On this species, 57% of all initial rust infections apparently originated through branch needles.

C. umbellata was observed in significant numbers in only the first replicate of seedlings, encompassing a 24 × 36 m area. Consequently, 81% of all observed *C. comandrae* infections and 86% of all observed rust-caused mortality occurred in this replicate. Rust-caused infections in replicates two, three, and four represented only 11, 8, and 0% of the total infection, respectively.

False toadflax populations were observed and summarized annually on five 4-m^2 plots between 1969 and 1977 (Table 2). The largest population occurred in 1970, with an average of 76 plants per 4 m^2. Primarily as a result of increasing shade from the developing pine overstory along with increasing herbaceous and woody plant competition, the presence of the alternate host decreased through 1977 (23 plants per 4 m^2) after yearly population fluctuations.

Table 1. *Cronartium comandrae* branch and stem infections and subsequent rust mortality on pine species in Tennessee

Pine species / Tree condition	Year						Totals
	1970	1971	1972	1973	1974	1977	
Eastern white							
Living[a]	89	84	83	81	76	70	70
Japanese black							
Living[a]	69	67	65	64	55	43	43
Loblolly							
Branch infections	0	0	0	1	0	0	1
Stem infections	0	0	2	0	1	1	3
Mortality	0	0	0	2	0	0	2
Living[b]	89	87	87	84	84	84	84
Pond							
Branch infections	0	0	0	2	1	0	3
Stem infections	3[c]	1	5	2	1	0	12
Mortality	0	3	1	5	3	1	13
Living	95	92	89	81	79	79	79
Red							
Living[a]	36	30	25	24	19	18	18
Shortleaf							
Branch infections	0	0	1	4	3	0	8
Stem infections	3[c]	0	2	1	3	0	9
Mortality	0	3	0	3	1	5	12
Living[d]	86	80	77	75	73	68	68
Slash							
Branch infections	0	0	0	0	0	0	0
Stem infections	5[c]	1	1	0	0	0	7
Mortality	0	5	1	1	0	1	8
Living	82	72	67	61	59	52	52
Virginia							
Branch infections	0	0	1	0	0	0	1
Stem infections	0	0	0	1	1	2	3
Mortality	0	0	0	0	1	0	1
Living[d]	91	91	90	84	81	78	78
Totals							
Branch infections	0	0	2	7	4	0	13
Stem infections	11[e]	2	10	4	6	3	34
Mortality	0	11	2	11	5	7[f]	36
Living	637	603	583	554	526	492	492

[a]No infections.
[b]Includes infected pines.
[c]Infection not detected in late April but assumed present in 1970 because of mortality in 1971.
[d]Only 98 shortleaf and 99 Virginia pines planted.
[e]Stem infections varied significantly ($P = 0.05$) among years (chi-square test).
[f]Includes 1975, 1976, and 1977 mortality.

Table 2. Number of *Comandra umbellata* ssp. *umbellata* stems on five 4-m^2 plots in Tennessee

Plot number	Year									Mean
	1969	1970	1971	1972	1973	1974	1975	1976	1977	
1	28	32	50	52	31	8	19	25	38	31
2	37	115	48	40	41	4	26	7	14	37
3	50	147	41	79	44	4	27	29	47	52
4	8	13	7	5	7	3	6	3	1	6
5	23	74	79	64	38	17	16	13	17	39
Mean	29	76	45	48	32	7	19	15	23	

DISCUSSION

Pond and shortleaf pines were the most susceptible to *C. comandrae*; both rust infections and mortality were highest on these two species. Similar data were obtained in shortleaf pine plantations on the Ozark and Ouachita National Forests in northern Arkansas, where infection ranged from a trace to 68% and mortality ranged from 1 to 40% (16).

C. comandrae infections and mortality on loblolly pine, previously reported as a highly susceptible species (8,15), were surprisingly low. The data in our study, however, are in line with the 7% infection level on 3-yr-old field plantings of loblolly pine reported in an earlier study (14). In addition, the relatively low rust infection and mortality were comparable to the infection (6%) and the mortality (2%) previously observed in 30 loblolly pine plantations in four Tennessee counties on the Cumberland Plateau (5).

A relatively low susceptibility of Virginia pine to *C. comandrae* infection and subsequent mortality is also suggested by the results of our study. These results agree with those previously reported by Powers (14), where less than 1% of Virginia pine seedlings developed natural *C. comandrae* infections in field plots on the Cumberland Plateau. The lack of comandra rust infections on Japanese black pine has also been reported (7).

Infection trends observed on all species of pines showed that only two of nine *C. comandrae* branch cankers observed through 1973 resulted in tree mortality the following year, whereas five of the remaining seven branch cankers formed stem cankers. Disease symptom expression apparently did not progress sufficiently to permit detection of rust stem cankers during the spring of 1970, so that both stem cankers and mortality were observed in 1971. Consequently, an apparent minimum 2-yr period is needed for developing rust stem cankers to cause tree mortality after natural direct stem infections through attached needles.

Whenever rust stem cankers were detected during any year from 1971 through 1974, mortality was detected the subsequent year. This infection and mortality pattern, which accounted for 96% of the variation in rust-caused mortality ($r = 0.98$), would most likely be evident during the first 5 yr of the rotation length of the pine plantation but may have less correlation thereafter because of the larger stem diameters.

The apparent reduction of long-distance spread of *C. comandrae* infection from the false toadflax in the first replicate to pines in the other three

replicates emphasized the requirement of the alternate host to be in proximity to pines for rust infection to occur. In surveys in Arkansas and Tennessee, *C. umbellata* was always found near comandra rust infections on shortleaf and loblolly pines, respectively (15,16). No apparent correlation was observed, however, between the false toadflax population and the incidence of *C. comandrae* infection the following year. This is evidenced by the fact that only two pine seedlings were infected by *C. comandrae* in 1971 and subsequently rust-killed in 1972 despite the high population of the alternate host observed in 1970. This could have resulted from a reduced *C. comandrae* spore inoculum production or unsuitable infection conditions on either host in 1970.

Eastern white pine, Virginia pine, or pitch × loblolly pine hybrid seedlings could be used in plantings in Tennessee regardless of the comandra rust hazard owing to the presence of *C. umbellata* (14). *C. comandrae* rust infection on shortleaf pine seedlings, however, has run as high as 38% (14), and infection of loblolly pine plantations has reached 19% (average infection, 6%) (5). For this reason, loblolly and shortleaf pine plantings should be avoided on sites where false toadflax would be close to the majority of planted pine seedlings.

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