Effects of *Heterobasidion annosum* on Radial Growth in Southern Pine Beetle-Infested Loblolly Pine

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This is the second in a series of articles on the interaction of *H. annosum* and the southern pine beetle (*Dendroctonus frontalis*) in loblolly pine stands.

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ABSTRACT

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The association of *Heterobasidion annosum* with reduced radial growth was observed in loblolly pine (*Pinus taeda*) infested with southern pine beetle (SPB) (*Dendroctonus frontalis*). Plots with SPB and controls were established in thinned plantations and natural stands of loblolly pine. Only sites infested with SPB for less than 8 wk were selected for experimental evaluation. A control plot was established 20 m from each SPB plot. Trees infested with SPB produced an average of 6% less radial growth over the last 1–5 yr in the loblolly pine plantations as compared to the noninfested control plots ($P = 0.05$). Mean *H. annosum* colonization of excavated root systems in SPB and control plots in plantations were 23.1 and 10.9% ($P = 0.05$), respectively. Within the plots infested with SPB located in plantations, the SPB-infested trees produced 28% less radial growth for the last 1–5 yr, respectively, as compared to the noninfested trees ($P = 0.01$). Mean *H. annosum* colonization of excavated root systems in SPB-infested and noninfested trees in the SPB plots were 54 and 11% ($P = 0.0001$), respectively. It was concluded that loblolly pines preferred by SPB were being stressed by *H. annosum* prior to SPB attack and that this stress was being expressed through reduced radial growth.

Additional key words: annosum root rot, *Fomes annosus*, radial growth, bark beetle, predisposition.

The association of *Heterobasidion annosum* (Fr.) Bref. (syn. *Fomes annosus* (Fr.) Karst.) with attacks by the southern pine beetle (SPB) (*Dendroctonus frontalis* Zimm.) in loblolly pine (*Pinus taeda* L.) plantations has been reported (3). An initial report of a significant association between *H. annosum* and reduced radial growth in loblolly pine was made by Alexander and Skelly (1). Further reports supported these initial findings (2,4). Effects on slash pine (*P. elliottii* Engelm.) radial growth by *H. annosum* also have been reported (6).

The objectives of this study were to determine if loblolly pines preferred by SPB exhibited greater stress than those loblolly pines not attacked by SPB, and if the stress, due to prolonged colonization by *H. annosum* in the years preceding attack by SPB, was expressed as reduced radial growth.

MATERIALS AND METHODS

Plots infested with SPB and noninfested controls were established in loblolly pine stands located in the coastal plain areas of Virginia (plots 1101–1117, 2101–2117), Texas (plots 1901–1903, 2901–2903) and Georgia (plots 1401 and 2401). All plantations had been thinned once and were located on high-hazard *H. annosum* sites (7). Natural stands had not been thinned and were located on low-hazard *H. annosum* sites. Only sites infested by SPB for less than 8 wk were selected for study to minimize the amount of *H. annosum* colonization occurring after the SPB infestation. Age of the SPB infestation was estimated according to information obtained from forest managers and others, and the condition of the tree; ie, the presence or absence of foliage and its color, and the presence or absence of the bark beetle. A control plot was established 20 m from each SPB plot.

The root systems of all trees in the plots were excavated and the numbers of roots and their lengths were recorded. Roots were inspected and classified for typical symptoms of infection by *H. annosum* (resin-soaked or stringy roots). *H. annosum* colonization was verified through root chip isolation. Rating for *H. annosum* colonization of each tree or plot was a measurement of the degree of root system colonization by the pathogen and usually was expressed as a colonization percentage of the root system affected. Specific information on the location, age, establishment, and measurement of disease incidence and severity was previously reported (3).

A cross-sectional disk was removed at a 1.4 m height from each tree at the time of root excavation. Four growth measurements were made from each disk: one across the most rapidly growing area, one across the least rapidly growing area, and two across adjacent intermediate growth areas. Annual increment measurements were made with a dendrochronograph (Techtron Systems, Little Ferry, NJ 07643). The average annual increment of growth for each tree was obtained by averaging the four measurements per disk.

RESULTS

The average radial growth for the last 1–5 and 6–10 yr for all loblolly pine plantations and natural stands is summarized in Tables 1 and 2. Trees in those plots (except plot 1103, located in a Virginia plantation) had higher radial growth rates in the controls than in those infested with SPB. The reverse was found in plots located in plantations in Georgia and Texas. In the natural stands this association of higher radial growth rates in controls, as compared with plots infested with SPB, was not found.

Mean annual radial growth rates over the last 10 yr for plantation loblolly pines infested with SPB and in control plots were significantly different ($P = 0.01$) (Table 3). Trees in SPB plots for the last 1–5 and 6–10 years had 6 and 7% lower radial growth rates, respectively, than those in the control plots. The mean *H. annosum* colonization in the SPB and control plots was 23.1 and 10.9%, respectively, at $P = 0.05$ (3).

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For individual trees, the mean annual radial growth was 28 (for years 1–5) and 12% (for years 6–10) less in those infested with SPB than in noninfested trees (Table 4). Average percentages of colonization of the root system with *H. annosum* for the SPB-infested and noninfested trees were 54 and 11%, respectively (3). These values were significantly different, $P = 0.001$.

Annual radial growth rates were from 33–39% less in trees colonized by *H. annosum* than in noncolonized trees (Table 5).

DISCUSSION

Two major pests of southern pine are *H. annosum* and the SPB (5). The association of the southern pine beetle with high *H. annosum* colonization percentages in loblolly pine was reported previously (3). *H. annosum* was predisposing loblolly pine to attack by the SPB by placing each tree under stress. How this stress was manifested over time and how it could be measured were questions that required further inquiry. The association of high *H. annosum* colonization levels with reduced radial growth also has been demonstrated (1,2,4,6). It was the general objective of this study to determine if radial growth would reflect the impact of *H. annosum* on loblolly pine and if this would increase the risk of a SPB attack.

All loblolly pine plantations studied were located on high-hazard *H. annosum* sites and had been thinned once. This greatly enhanced the possibility of having trees with high enough levels of *H. annosum* colonization to affect radial growth patterns. This was the case and, therefore, a statistical analysis was possible. However, the natural stands had not been thinned and were located on low-hazard *H. annosum* sites.

Those plots infested with SPB produced 6% less annual growth (Table 3) than the control plots and also had significantly higher infection by *H. annosum*.

Within the plots infested with SPB, infested trees over the last 5 yr produced 28% less radial growth (Table 4) than the noninfested trees. This growth difference was significant, as was the difference in degree of *H. annosum* colonization for these trees. Over the past 5 yr, trees colonized by *H. annosum* produced 39% less radial growth (Table 5) than did trees not colonized by the pathogen.

These data established for the first time that, in thinned loblolly pine plantations, trees colonized by *H. annosum* produced significantly less radial growth than trees not colonized and had a significantly greater probability of infestation by the SPB.

TABLE 1. Mean annual radial growth for plots of loblolly pine infested and noninfested by the southern pine beetle (SPB) in plantations located on sites high hazard for infection by *Heterobasidion annosum* for two 5-yr periods preceding SPB infection

Plots infested with SPB			Plots noninfested with SPB		
	Radial growth (mm)[b]			Radial growth (mm)	
Plot no.[a]	1–5 yr[c]	6–10 yr[d]	Plot no.	1–5 yr	6–10 yr
1101	0.81	0.80	2101	1.05	0.91
1102	0.96	0.74	2102	1.16	0.82
1103	0.97	1.11	2103	0.83	0.88
1104	1.90	2.84	2104	2.09	2.48
1105	1.23	1.53	2105	1.46	1.69
1106	0.77	0.79	2106	0.99	0.84
1401	2.00	2.71	2401	1.86	2.23
1902	3.27	2.31	2902	2.73	2.68
1903	3.02	2.16	2903	2.34	2.03

[a] Plots were located on loblolly pine stands in the coastal areas of Virginia (plots 1101–1106, 2101–2106), Texas (plots 1902–1903, 2902–2903), and Georgia (plots 1401–2401).
[b] Radial growth average of four cross-sectional measurements.
[c] Mean radial growth for the past 5 yr prior to plot establishment.
[d] Mean radial growth for the past 6–10 yr prior to plot establishment.

TABLE 2. Mean annual radial growth for plots of loblolly pine infested and noninfested by the southern pine beetle (SPB) located in natural stands located on sites low hazard for infection by *Heterobasidion annosum* for two 5-yr periods preceding SPB infestation

Plots infested with SPB			Plots noninfested with SPB		
	Radial growth (mm)[b]			Radial growth (mm)	
Plot no.[a]	1–5 yr[c]	6–10[d]	Plot no.	1–5 yr	6–10 yr
1107	0.74	0.87	2107	1.04	1.48
1108	0.87	1.13	2108	0.59	0.75
1109	0.58	0.60	2109	0.70	0.91
1110	...[e]	...[e]	2110	0.58	0.87
1117	0.84	1.17	2117	0.74	0.84
1901	4.22	5.92	2901	2.99	4.25

[a] Plots were located in loblolly pine stands in the coastal areas of Virginia (plots 1107–1117, 2107–2117) and Texas (plots 1901–1903, 2901–2903).
[b] Radial growth average of four cross-sectional measurements.
[c] Mean radial growth for the past 5 yr prior to plot establishment.
[d] Mean radial growth for the past 6–10 yr prior to plot establishment.
[e] No measurements were taken.

TABLE 3. Mean annual radial growth for the past 10 yr for plots of loblolly pine infested and noninfested (control) by the southern pine beetle (SPB) in plantations high hazard for infection by *Heterobasidion annosum*[a]

Year	Radial growth (mm)[b]		Difference (%)
	SPB plots	Control plots	
1	1.71	1.83	−7
2	1.83	1.89	−3
3	1.63	1.68	−3
4	1.63	1.89	−14
5	1.25	1.32	−5
6	1.27	1.35	−6
7	1.55	1.67	−7
8	1.64	1.71	−4
9	1.86	2.00	−7
10	1.88	2.06	−9
Avg 1–5[c]	1.61	1.72	−6
Avg 6–10[d]	1.64	1.76	−7
Avg 1–10[e]	1.63	1.74	−6

[a] Mean *H. annosum* colonizations for plots infested with SPB and not infested (controls) were 23.1 and 10.9%, respectively (3).
[b] Radial growth average of four cross-sectional measurements.
[c] Mean radial growth for the past 5 yr prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.05$.
[d] Mean radial growth for the 6–10 yr period prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.01$.
[e] Mean radial growth for the past 10 yr prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.01$.

TABLE 4. Mean annual radial growth for the past 10 yr for loblolly pine infested and noninfested by the southern pine beetle (SPB) in plantations high hazard for infection by *Heterobasidion annosum*

Year	Radial growth (mm)[a,b]		Difference (%)
	SPB plots	Control plots	
1	1.21	1.87	−35
2	1.34	1.98	−32
3	1.38	1.70	−19
4	1.22	1.75	−30
5	1.04	1.31	−21
6	1.15	1.31	−12
7	1.30	1.63	−20
8	1.47	1.69	−13
9	1.63	1.93	−16
10	1.90	1.87	+2
Avg 1–5[b]	1.24	1.72	−28
Avg 6–10[c]	1.49	1.69	−12
Avg 1–10[d]	1.36	1.70	−20

[a] Radial growth average of four cross-sectional measurements. Based on 22 infested trees and 70 noninfested (control) trees.
[b] Mean radial growth for the past 5 yr prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.01$.
[c] Mean radial growth for the past 6–10 yr period prior to plot establishment. Student's *t*-test indicated no significant difference, $P = 0.05$.
[d] Mean radial growth for the past 10 yr prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.01$.

TABLE 5. Mean annual radial growth for the past 10 yr for loblolly pine colonized and noncolonized with *Heterobasidion annosum* in plantations high hazard for infection by *H. annosum*

Year	Radial growth (mm)[a]		Difference (%)
	Colonized	Noncolonized	
1	1.42	2.25	−37
2	1.48	2.49	−41
3	1.34	2.16	−38
4	1.26	2.31	−45
5	1.10	1.52	−28
6	1.13	1.54	−27
7	1.31	2.01	−35
8	1.43	2.03	−30
9	1.57	2.41	−35
10	1.57	2.45	−36
Avg 1–5[b]	1.32	2.15	−39
Avg 6–10[c]	1.40	2.09	−33
Avg 1–10[d]	1.36	2.12	−36

[a] Radial growth average of four cross-sectional measurements based on 32 colonized trees and 60 noncolonized trees.
[b] Mean radial growth for the past 5 yr prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.001$.
[c] Mean radial growth for the past 6–10 yr period prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.001$.
[d] Mean radial growth for the past 10 yr prior to plot establishment. Student's *t*-test indicated significant difference, $P = 0.001$.

Therefore, we conclude that reduced radial growth accurately reflects the impact of *H. annosum* on loblolly pine and the risk to SPB attack. These *H. annosum*-stressed trees can play a major part in SPB spot proliferation in plantations. In natural stands, however, the effect of *H. annosum* infection on radial growth rates is considerably less than in plantations and, therefore, affected trees in these stands play a much reduced role in SPB infestations.

This interrelationship between pathogen, host, and insect clearly establishes the need for using an integrated pest management approach. By utilizing those management and control measures available for reducing the impact of annosum root rot in thinned loblolly pine plantations, reduced stress will reduce the susceptibility of loblolly pine to attack by the SPB and increased radial growth will occur. An additional benefit would be increased wood and fiber production.

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