Association of *Heterobasidion annosum* and the Southern Pine Beetle on Loblolly Pine

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This is the first of 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* and the southern pine beetle (*Dendroctonus frontalis*) (SPB) was determined in plantations and in natural, undisturbed stands of loblolly pine (*Pinus taeda*). Only sites infested with SPB for less than 8 wk were selected for plot establishment. Average incidences of *H. annosum* in the plantations were 65 and 73%, respectively, for the nine SPB and nine control plots. For the natural stands, average incidences of *H. annosum* were 24 and 13%, respectively, for six SPB and six control plots. Mean severity levels for *H. annosum* in SPB and control plots in plantations were 23.1 and 10.9% ($P = 0.05$), respectively. Mean severity levels for *H. annosum* in SPB and control plots in natural stands were 12.0 and 0.1% ($P = 0.02$), respectively. Average percentages of roots colonized in SPB-infested and noninfested trees in the SPB plots were 54 and 11% ($P = 0.001$), respectively. A significant and consistent association between SPBV-infested loblolly pine and the increased severity of annosum root rot was found on sandy coastal plain soils. Annosum root rot was found to be a major factor in increasing the susceptibility of trees in thinned plantations located on high hazard annosum root rot sites to attack by SPB.

Additional key words: annosum root rot, *Fomes annosus*, bark beetle, predispose.

Annosum root rot which is caused by the fungus *Heterobasidion annosum* (Fr.) Bref. (syn. *Fomes annosus* [Fr.] Karst.), is a major disease of loblolly pine (*Pinus taeda* L.) and other conifers in the southeastern United States. Evidence of high disease incidence and severe effects of *H. annosum* in loblolly pine plantations has been reported over the past few years (1,2,5). The southern pine beetle (*Dendroctonus frontalis* Zimm.) (SPB) is also a major pest of pines in the southeastern United States and over the past decade has caused considerable damage (8). Bark beetles are considered to be secondary insects, because under endemic conditions they prefer less vigorous trees. Trees which have been stressed by such factors as drought, flooding, mechanical injuries, fire, lightning, wind, air pollution, defoliation, root rot, dwarf mistletoe, or needlecast have been shown to be more susceptible to attack by insects (7,9,10,17).

Associations between root rots and bark beetle infestations have been found primarily in the western United States (6,12,13,16,19). *Heterobasidion annosum* has been reported to directly predispose trees to bark beetle infestation (4,19,20). Stark and Cobb (19), in a study at Boggs Mountain State Forest, California, found that at least 60% of the Ponderosa pine (*P. ponderosa* Laws.) trees infested by bark beetles (*D. brevicomis* Lecante and *D. ponderosae* Hopkins) were colonized by *H. annosum*. Another root disease of ponderosa pine, caused by *Verticicladiella wagenerii* Kendrick, also has been found to predispose trees to attack by bark beetles (11). *V. wagenerii* was shown to affect the physiology of the tree by reducing the moisture content, especially in the foliage (19).

The objective of this study was to determine the relationship between colonization of loblolly pine by *H. annosum* and infestation by southern pine beetle.

MATERIALS AND METHODS

SPB-infested and control plots were established in loblolly pine stands located in the coastal plain areas of Virginia, Texas, and Georgia (Table 1). Only sites infested by SPB for less than 8 wk were selected for plot establishment. Plot centers were established 1.5 m due north of the tree initially attacked by SPB. Plots of variable size were established by using a 10-factor basal area prism (BA-10). Each tree determined to be "in" the plot was numbered for later examination.

The presence of *H. annosum* conks was determined for each tree. Crown symptom expression was rated for each tree according to the scale: 0 = dead, 1 = mostly brown with some chlorotic foliage, 2 = thin, chlorotic, 3 = thin and green, and 4 = full and green (asymptomatic) crown. Windthrown trees with stringy roots also were noted.

After collection of aboveground data, the root system of each tree in the plots was excavated with a bulldozer (5,18). The extent of *H. annosum* colonization of the roots was estimated, and for root systems with > 1% colonization, the number and length of all colonized and healthy roots were determined. Root tissue was classified in three symptomatic categories: 1 = healthy, 2 = resin-soaked, and 3 = stringy. Categories 2 and 3 were considered to be symptomatic of infection by *H. annosum*. This was verified by plating root chip samples from roots exhibiting resin-soaked or stringy symptoms onto ortho-phenylphenol selective medium (3). Sporulation of the pathogen occurred after incubation at 23 C for 10–14 days.

To compare the SPB plot with the noninfested area of the loblolly pine stand, a control plot was established 20 m due north of each SPB plot. However, if the control plot differed in either site or stand composition from the SPB plot, a more comparable site was designated 20 m distant in a different direction. The same data were collected for the control plots as for the SPB plots.

During the establishment of the BA-10 plots, five single-tree SPB infestations were observed. To determine if the level of *H. annosum* in these single-tree SPB infestations was comparable with that in the other SPB and control plots, a paired-tree study was conducted. This study consisted of an SPB-infested tree within the SPB plot and an noninfested tree selected within 4.5 m of the infested tree to represent the control plot. These two trees constituted a paired tree plot in which each tree of the pair was approximately the same age, height, diameter at breast height (d.b.h.), and crown class. Paired-tree plots were treated in the same

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TABLE 1. Locations and ages of loblolly pine stands evaluated for the effect of annosum root rot on southern pine beetle (SPB) infestations

In plantations[a]				In natural stands[a]			
Plot nos.				Plot nos.			
SPB-infested	Noninfested	Location	Age (yr)[b]	SPB-infested	Noninfested	Location	Age (yr)[b]
1101	2101	Virginia	33	1107	2107	Virginia	64
1102	2102	Virginia	28	1108	2108	Virginia	45
1103	2103	Virginia	26	1109	2109	Virginia	46
1104	2104	Virginia	25	1110	2110	Virginia	42
1105	2105	Virginia	39	1117	2117	Virginia	41
1106	2106	Virginia	62	1901	2901	Texas	16
1401	2401	Georgia	23				
1902	2902	Texas	19				
1903	2903	Texas	20				

[a] All plots in plantations were in high-hazard annosum root rot sites based on Morris and Frazier's (15) hazard rating system; all plots in natural stands except 1901 and 2901 were in low-hazard sites.
[b] Average age in 1978.

manner as the SPB and control plots, including the measurements taken and the excavation of the root systems.

RESULTS

The locations and ages for the loblolly pine stands used in this report are summarized in Table 1. Average age for the plantations and natural stands were 30 and 42 yr, respectively. With the exception of plots 1901 and 2901, the plantations were located on high hazard annosum root rot sites (15) and the natural stands on low hazard annosum root rot sites. All plantations had been thinned once; the natural stands had not been thinned. The paired-tree study was located in the same plantations as plots 1101, 1102, 1105, 1902, and 1903.

Average crown ratings for SPB and control plot trees were 2.6 and 3.2, respectively. The difference in crown ratings was significant, $P = 0.03$. Conks were found on four of the 335 trees examined (1%). No windthrown trees were found in the plots or adjacent areas.

The percentages of trees colonized by *H. annosum* have been summarized for high-hazard annosum root rot sites in SPB and control plots (Table 2). The average incidence of *H. annosum* in 92 trees located in nine SPB plots was 65%, and in 98 trees located in nine control plots the disease incidence was 73%. The percentages of trees with root systems with > 1% *H. annosum* colonization by length were 41 and 26%, respectively, for SPB and control plots. Average percent *H. annosum* colonizations for the SPB and control plots were determined by measuring the primary and secondary roots of all trees with > 1% of the root system colonized, and by assigning a value of 0.5% colonization for those trees colonized but having < 1% colonization. The average *H. annosum* colonization percentages for the SPB and control plots were 23.1 and 10.9%, respectively, significant at $P = 0.05$.

In Table 3, colonization levels in natural stands are summarized. The incidence of *H. annosum* in 66 trees in six SPB plots was 24% and in 79 trees in six control plots was 13%. For root systems with > 1% colonization, the colonization levels were 18 and 0% for SPB and control plots, respectively. The average percent colonization for SPB and control plots was 12.0 and 0.1%, respectively; the difference was significant, $P = 0.02$. The amount of variation in the natural stands was greater than that in the plantations.

In the plantations, the average total number of roots that were measured per tree and the average number colonized with *H. annosum* for the SPB plots were 32 and 14, and for the control plots 24 and 6, respectively. For SPB and control plots, the average percentages of roots colonized were 44 (range, 0–58%) and 26 (range, 0–48%), respectively; the difference was significant, $P = 0.03$. In natural loblolly pine stands located in the coastal plain, the average percentages of roots colonized were 12.5 and 0.5 for SPB and control plots, respectively.

Total root lengths, both healthy and colonized with *H. annosum*, for SPB-infested and noninfested trees in the SPB plots in plantations were analyzed. Average percentages of the root systems colonized by *H. annosum* in the SPB-infested and noninfested trees were 80 and 14%, respectively, and the difference was significant, $P = 0.001$; that in the secondary roots was significantly different ($P = 0.01$) with 44 and 13%, respectively.

TABLE 2. *Heterobasidion annosum* colonization levels in southern pine beetle (SPB)-infested and noninfested loblolly pine and noninfested plots in plantations established on high hazard *H. annosum* sites

Plot no.	Trees (no.)	Trees colonized (%)	Trees colonized > 1% (%)	Colonization[a] (avg. %)
SPB				
1101	9	100	100	54.9
1102	13	85	31	16.6
1103	14	57	29	14.8
1104	11	18	18	4.7
1105	9	44	0	0.2
1106	8	63	50	33.9
1401	10	100	40	17.2
1902	8	88	88	51.0
1903	10	40	40	13.9
Total	92			
Average		65	41	23.1
Control				
2101	8	88	75	25.4
2102	14	79	0	0.4
2103	13	54	15	5.1
2104	15	100	20	7.7
2105	5	100	80	14.9
2106	4	75	50	26.6
2401	15	100	13	3.4
2902	10	50	30	12.3
2903	14	29	29	2.1
Total	98			
Average		73	26	10.9

[a] Differences between all paired SPB and control plots were significant according to *t*-tests, $P = 0.05$.

The average percentage of *H. annosum* colonization of roots in SPB-infested and noninfested trees within the SPB plots in plantations is summarized in Table 4. The difference between the means of these two groups, 54% colonization for SPB-infested and 11% for noninfested trees, was significant ($P = 0.001$). The data indicate that within the immediate area attacked by the southern pine beetle, *H. annosum* is significantly associated with those trees infested by SPB. The conservative measurement of the level of *H. annosum*-colonized roots is indicated by the increased length of roots measured in trees with reduced levels of colonization. This would indicate more *H. annosum* in the root systems than was measured because severely colonized roots tend to break off and remain in the soil.

The level of *H. annosum* colonization in the SPB-infested and noninfested paired trees is summarized in Table 5. Total number of primary and secondary roots measured for SPB-infested and noninfested loblolly pine was 618 and 694, respectively. A significantly ($P=0.01$) greater number of roots in the SPB-infested trees were colonized with *H. annosum* than in the noninfested paired trees.

DISCUSSION

Heterobasidion annosum and the southern pine beetle are two major pests of southern pine. Interaction between these two pests could have a significant effect on the methods employed for control and management. The objective of this study was to determine if southern pine beetle infestation was consistently and significantly associated with annosum root rot of loblolly pine.

Annosum root rot has been reported to predispose trees to bark beetle attack (4,19,20). The possible association of bark beetles with annosum root rot in southern pines also has been suggested (14). In order for this association to be of any importance, high disease incidence and severity must be present. Reports over the past few years (1,2,5), indicate that the average percentage of incidence found in thinned loblolly pine plantations located on high-hazard sites to be 85% with approximately 30% of the trees having significant levels of colonization. Since bark beetles tend to attack trees under stress, trees weakened by root rots could present possible points of bark beetle initiation and/or spread.

Two critical points were considered in obtaining the data for this study: establishing the plots in areas which only recently had become infested by the southern pine beetle, and laboratory determination of the pathogen associated with the root symptoms. Only plots which had been infested recently, as determined by history, the presence of needles on the trees or beetles in the trees, were utilized. *Heterobasidion annosum* was isolated from all plots (18 of 20) from which root samples were taken. Therefore, it could be concluded that the level of annosum root rot as determined by symptom expression, accurately reflected the colonization level prior to SPB infestation.

In both the plantations and natural stands used in this study, loblolly pine was the primary, if not the only, pine species present. The plantations were located on high-hazard annosum root rot sites and all had been thinned once. Thinnings significantly enhance the incidence and severity of *H. annosum* in loblolly pine stands. For this reason the BA-10 plots and paired tree plots were established in thinned loblolly pine plantations.

The average percentage of trees with > 1% *H. annosum* was significantly higher in the SPB plots than in the control plots whether they were in plantations or natural stands. Mean percentage of roots colonized by *H. annosum* were 23.1 and 10.9%, respectively, for the SPB and control plots in the plantations. In natural stands the colonization levels also were significantly higher for the SPB plots (12%) than for the control plots (0.1%). The higher amounts of infection by *H. annosum* associated with SPB-infested trees within SPB plots were even more significant than in comparisons between SPB and control plots. The initial SPB-infested tree consistently had a high level of *H. annosum* colonization; an average of 48.6% of roots were colonized. The average SPB plot established in a thinned plantation consisted of 10 trees with the SPB-infested and noninfested trees having an average of 54 and 11%, respectively, of their roots colonized. Similar levels of *H. annosum* colonization were found in the paired-tree study with 46 and 15% colonization for the SPB-infested and noninfested trees, respectively.

The percentage colonization found by measuring root length and root numbers indicates that either approach is acceptable and significant. There also was a significant difference in the crown symptom ratings of the SPB and control plots.

The association of high *H. annosum* colonization levels with SPB infestation on high-hazard annosum root rot sites was clearly significant. This association between annosum root rot and SPB was greatest in thinned loblolly pine plantations regardless of location. On low-hazard annosum root rot sites, however, this association was considerably weaker and *H. annosum* appeared to have a much reduced effect on SPB activity.

The data presented establishes a significant and consistent association between southern pine beetle-infestation in loblolly pine in the coastal plain of the southern United States and increased levels of annosum root rot. Although annosum root rot is certainly not the primary causal factor in all instances, it is probably the major factor on sites classified as high hazard for *H. annosum* (15), especially during drought conditions or when the stand has been thinned. This association between annosum root rot and the southern pine beetle could be of far-reaching importance for forest managers in their selection of pest management methods.

TABLE 3. *Heterobasidion annosum* colonization levels in SPB infested and noninfested plots established in natural undisturbed stands of loblolly pine

Plot no.	Trees (no.)	Trees colonized (%)	Trees colonized > 1% (%)	Colonization[a] (avg. %)
SPB				
1107	4	0	0	0.0
1108	14	14	14	3.6
1109	13	23	15	13.1
1110	13	...[b]	0	...
1117	12	42	33	29.2
1901	10	60	40	14.2
Total	66			
Average		24	18	12.0
Control				
2107	8	0	0	0.0
2108	18	11	0	0.1
2109	12	25	0	0.1
2110	8	0	0	0.0
2117	13	23	0	0.1
2901	20	10	0	0.1
Total	79			
Average		13	0	0.1

[a]Differences between all paired SPB and control plots were significant according to *t*-tests, $P=0.02$.
[b]No trees were excavated in plot 1110.

TABLE 4. Average percentage of *Heterobasidion annosum* colonization of roots of southern pine beetle (SPB)-infested and noninfested trees in SPB plots in plantations of loblolly pine

Plot no.	Trees (no.)	Average colonization (%)[a]	
		Infested	Noninfested
1101	9	76	38
1102	13	32	12
1103	14	44	7
1104	11	0	5
1105	9	0	0
1106	8	100	12
1401	10	42	1
1902	8	94	37
1903	10	96	5
Average	10	54	11

[a]Differences between infested and noninfested trees were significant according to *t*-tests, $P=0.001$.

TABLE 5. *Heterobasidion annosum* colonization of primary and secondary roots of southern pine beetle-infested and noninfested loblolly pine trees[a]

Root class	Infested	Noninfested
Primary Roots		
Total no.	162	198
Colonized (%)	53	11
Secondary Roots		
Total no.	456	496
Colonized (%)	44	17
Colonization average (%)[a]	46	15

[a]Differences between colonization of five paired (infested and noninfested) sets of trees were significant according to *t*-tests, $P=0.01$.

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