The Lack of a Long-Term Growth Effect of Annosus Control in Southeastern United States[1]

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Abstract: An evaluation of basal area increment was made in 1988 of six pine plantations located across the southeastern United States. These plantations had been thinned in 1969-1970 and stumps treated with borax to measure long-term efficacy of annosus root rot control. In the present study, no long-term growth effects were identified. There were neither negative growth effects of residual infection in surviving trees nor were there positive growth effects in trees which were released as a result of tree mortality. These results suggest that effects of inoculation and control treatments may have been limited only to those trees which died as a result of infection center development following thinning.

Annosus root rot, which is caused by Heterobasidion annosum (Fr.) Bref., is potentially destructive on southern pines growing on high-risk sites. Root contacts and grafts are abundant among closely spaced plantation trees. When these trees are thinned, stumps are colonized by H. annosum, which continues to colonize the root systems of the thinned trees and eventually the roots of adjacent living trees. Affected trees may either be killed after several years or suffer growth loss (Alexander and others, 1981).

An important control measure recommended for plantations on high risk sites at the first thinning is to treat the freshly cut stump surfaces with borax. The boron ion is toxic to germinating spores of many fungi, including H. annosum. As the toxic effects of the boron gradually leach away, soil-borne saprophytic fungi quickly invade the stump and H. annosum is unable to compete. The beneficial effects of borax in southern pine plantations were first observed by Driver (1963) and subsequently shown by Hodges (1970) to reduce stump colonization by H. annosum up to 18 months after treatment.

In 1969, a southwide pilot project was begun to compare the effectiveness of four promising treatments to prevent annosus root rot in thinned southern pine plantations (Phelps and others, 1970). Stump treatments included application of borax, sodium nitrite, Peniophora gigantea, summer thinning, and a check. In addition, the effects of heavy disease pressure were explored by artificially inoculating H. annosum on some plots. The project was a cooperative effort among state forestry agencies, private landowners, and the USDA Forest Service Southeastern Forest Experiment Station, and Southeastern Area Forest Insect and Disease Management.

A summary of results obtained for the period 1969 through 1977 indicated that, although positive effects were not always evident at some locations, borax provided the most effective and consistent protection against stump surface colonization, residual tree infection, and tree mortality (Weiss and others, 1978). No attempt was made at that time to translate residual tree infection and mortality into growth or volume losses.

In 1988, we reevaluated the study and discussed the possibility of taking a final look at the plots before they were lost. Several plots had already been lost, either to natural calamities or to harvesting, and the remainder were approaching final harvest age. Owing to limited survey resources, we decided to examine only the effects of borax treatments in combination with inoculations of H. annosum, which were basically the worst case and best case scenarios. Our objective was to determine if radial growth patterns showed that root disease depressed growth in surviving trees, and if borax stump treatment ameliorated these possible negative growth effects.

MATERIALS AND METHODS

Plots were reexamined at six locations (fig. 1). Plot locations and tree species were: Del Rio, Tenn., and Marion, Va., eastern white pine (Pinus strobus L.); Shelby, N.C., Mineral Springs, Ark., and Lexington, Tenn., loblolly pine (P. taeda L.); and Jasper, Tex., slash pine (P. elliottii Engelm.). The treatments compared were:

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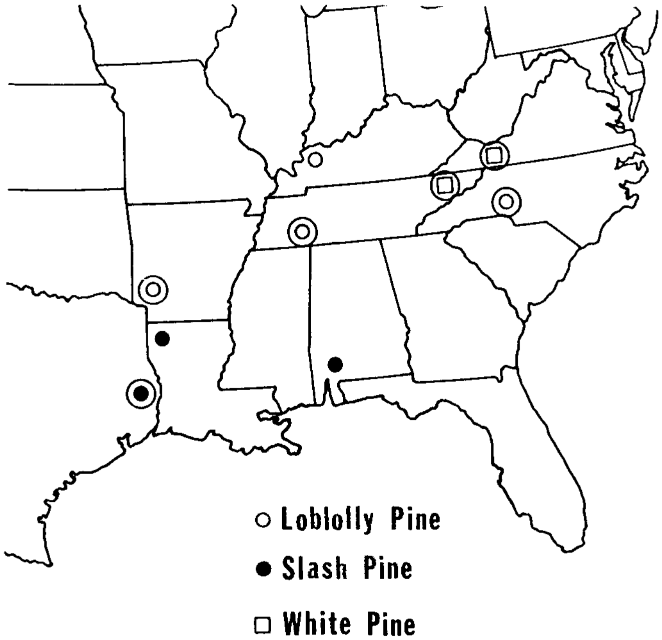

Figure 1--Location of plantations used in the annosus root rot stump treatment pilot project. Circled locations were selected for the present study.

Code Designation	Treatment
A-U	Borax, not inoculated with H. annosum
A-I	Borax, inoculated with H. annosum
E-U	Check, not inoculated with H. annosum
E-I	Check, inoculated with H. annosum

The two available replicate plots for each treatment for each location were sampled. When originally established in 1969-1970, plots were 93.4 ft (28.5 m) square with a 15-ft (4.6-m) wide buffer on each side. Steel rods marked the corners of the buffer zones. Maps were made of each plot, showing the compass bearings of the sides, and plot trees were identified with aluminum tags fixed with aluminum nails about 8.2 ft (2.5 m) above ground. Each plot center was reestablished 87 ft (26.5 m) from a corner rod on a bearing that bisected the corner angle. If rods could not be located, the plot center was estimated by measuring 66 ft (20.1 m) on the same bearing from the tagged tree closest to the true corner location.

All pines and hardwoods with diameter at breast height (DBH) 2 5 in (12.7 cm) and within a 33-ft (10.1-m) radius of plot center were counted to determine the number of trees per acre. This radius ensured that all plot trees were within the original plot without encroaching on the buffer zone. About 40 percent of the original plot area was used to calculate volume and stocking. Basal area was calculated by measuring the stem diameters of those trees. Heights were measured for all pines within the 33-ft (10.1-m) radius and were to be used in volume calculations.

The 10 pines closest to the plot center and within a 40-ft (12.2-m) radius of the plot center were sampled for radial growth analyses. In cases in which a road went through a plot, trees with crowns bordering the road were not sampled. If fewer than 10 eligible trees were found inside the 40-ft (12.2-m) radius, extra trees were sampled on the treatment plot's replicate. For example, if only 6 trees could be sampled on plot E-I-1, then at least 14 trees were sampled on plot E-I-2.

Increment cores to the pith were removed at 4.5 ft (1.4 m) from ground level on the north and south faces of each of the 10 sampled trees. After being dried, the cores were glued into grooves in wood blocks, and a flat surface was sanded on each to prepare a transverse face suitable for measurement of annual ring widths. After cores were cross-dated, width of each annual ring was measured to 0.01 mm with a Bannister increment-measuring machine. The raw annual increment data were then converted to annual basal area increments (BAI) for each tree which were then averaged for each plot for the pretreatment period (prior to 1969) and the posttreatment period (1970-1979). These plot averages were then analyzed by using analysis of variance, and the means were subjected to Tukey's means separation technique. Contrasts were also constructed in which data from the borax treatment plots were compared to those from the check treatment plots, and data from plots inoculated with H. annosum were compared to those from plots that had not been inoculated. The variables of interest were the average BAI of pretreatment, the average BAI of posttreatment, and the average change in BAI between the pretreatment and posttreatment measurements. Because each location also represented a different tree species and stand age, the analyses were done separately for each location and location data were not combined for a pooled analysis.

RESULTS

Basal area increment curves of each of the six locations are shown in figure 2. Stand establishment was generally in the early- to mid-1950's except for white pine at Va., which was established in the early 1940's. Growth at all locations markedly increased during the first 5 years or so of stand life, then settled into a period of several decades of stable growth with rather wide fluctuations. Growth curves of trees from plots with each of the four treatments at each location tended to be relatively synchronous except for white pine at Va. During the last decade (1980's), BAI growth has declined at all the locations except for slash pine at Tex. Growth at all

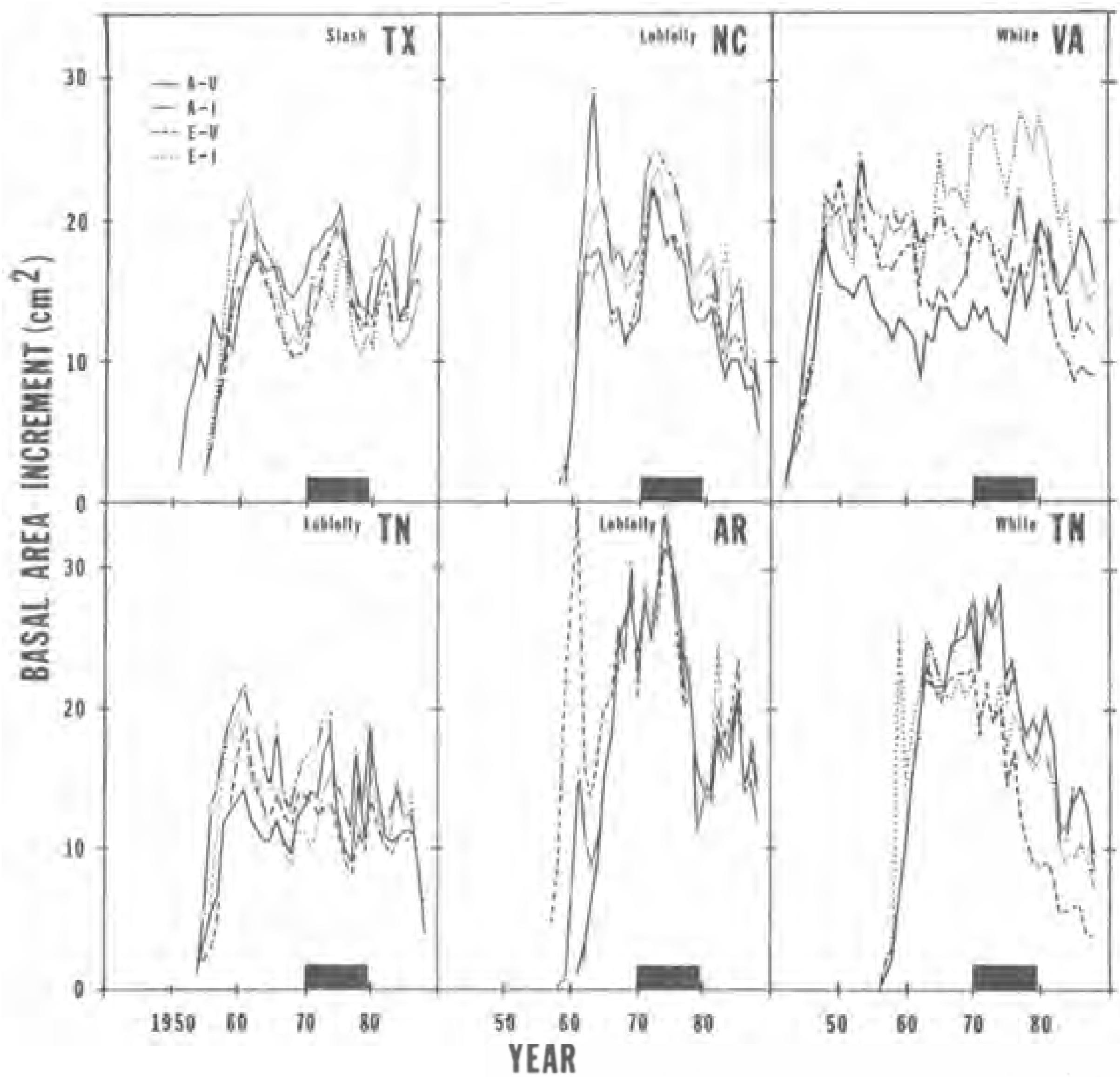

Figure 2--Annual basal area increment growth curves of residual trees, by treatment, for the six locations sampled in the present study. The first thinning and treatments were performed in 1969-70. Growth prior to this period is pre-treatment growth. The broad horizontal bar represents the posttreatment growth period (1970-79) examined for treatment effects. Treatments were: A = Borax; E = Check, not treated with borax; I = Inoculated with H. annosum; and U = Check, not inoculated with H. annosum.

locations except for white pine at Va. exhibited a growth depression just prior to the first thinning in 1969-1970. This was followed by at least some recovery and then a growth decline as the canopy closed.

The first thinning and treatments, performed in 1969-1970, resulted in increased average BAI on most plots at all locations (table 1). Loblolly pine at Ark. showed the greatest positive effect in BAI. Loblolly pine at Tenn. was the only location with a significant effect, with 3 of the treatments having a negative growth in BAI. When pretreatment BAI was subtracted from posttreatment BAI, treatment effects were no longer significant.

Contrast means (table 2) show that borax treatment increased BAI at 4 of 6 locations and that inoculated plots (maximum disease pressure) had lower BAI than uninoculated plots at 4 of 6 locations. These differences, however, are not statistically significant, largely because of the

Table 1--Average pretreatment, posttreatment and change in basal area increment (BAI) (cm^2) for the four treatments and the six location-species combinations. Treatments were: A = Borax; E = Check, not treated with borax; I = Inoculated with <u>H</u>. <u>annosum;</u> and U = Check, not inoculated with <u>H</u>. <u>annosum.</u>

Treatment	Average BAI (cm^2) Pretreatment					
	Slash Tex.	Lob. Tenn.	Lob. N.C.	Lob. Ark.	White Va.	White Tenn.
AI	15.27a[1]	16.51a	17.81a	18.26a	18.43a	18.84a
AU	14.85a	10.84a	13.70a	18.28a	12.93a	18.03a
EI	14.98a	13.20a	16.03a	18.29a	18.08a	19.32a
EU	13.35a	13.09a	12.66a	19.31a	16.33a	17.11a

Treatment	Average BAI (cm^2) Posttreatment					
	Slash Tex.	Lob. Tenn.	Lob. N.C.	Lob. Ark.	White Va.	White Tenn.
AI	16.46a	15.96a	21.58a	26.99a	18.89a	24.28a
AU	17.06a	13.50a	17.83a	27.80a	13.52a	24.18a
EI	13.75a	11.57a	20.80a	28.19a	25.68a	19.82a
EU	15.10a	10.57a	18.39a	25.80a	17.66a	18.55a

Treatment	Change in Average BAI (cm^2) Posttreatment minus Pretreatment					
	Slash Tex.	Lob. Tenn.	Lob. N.C.	Lob. Ark.	White Va.	White Tenn.
AI	1.18a	-0.55a	3.78a	8.68a	0.45a	5.44a
AU	2.21a	2.67a	4.13a	0.60a	0.60a	6.78a
EI	-1.23a	1.63a	4.77a	7.60a	7.60a	0.50a
EU	1.75a.	1.41a	5.73a	1.13a	1.13a	1.44a

[1]Treatment means followed by same lowercase letter in each vertical column of data are not significantly different, P = 0.05, according to Tukey's means separation technique.

large variances present in the data. Although loblolly pine at Tenn. was the only location which showed significant posttreatment growth differences following the A-I treatment (table 1), there were no significant differences between contrasts of borax-treated plots and untreated check plots. There were, likewise, no differences between inoculated plots and uninoculated check plots.

DISCUSSION

From 1969 through 1977, stump surface colonization and subsequent residual tree infection and mortality in loblolly pine plantations were least on borax-treated plots (Weis and others, 1978). In slash pine plantations, stump surface colonization was approximately the same for all treatments, but residual tree infection and mortality were least on artificially inoculated borax plots. In white pine plantations, stump surface colonization was least on borax plots and residual tree mortality did not occur.

The general lack of significant differences in BAI between treatments in the present study suggests that stump colonization and residual mortality effects were limited to trees which died before the 1977 survey and that those happenings had very little effect on growth of surviving trees. Residual trees sampled in 1988 showed no negative growth effects of low-level infection or positive effects from release.

This is, perhaps, not entirely unexpected. Froelich and others (1977) found that slash pine growth was significantly reduced only in trees with more than half of their roots infected by <u>H</u>. <u>annosum</u>. Height growth was reduced by 40 percent and basal area growth by 20 to 32 percent, depending on crown symptoms. A similar result for reduced basal area growth was shown for loblolly pine (Bradford and others, 1978).

Infected trees which did not die within the normal 7-year progression of a disease infection center following thinning (Kuhlman and others,

Table 2--Contrasts in average pretreatment, posttreatment, and change in basal area increment (BAI) (cm^2) for the four treatments and the six location-species combinations.

Contrasts	Average BAI (cm^2) Pretreatment						Average BAI (cm^2) Posttreatment					
	Slash Tex.	Lob. Tenn.	Lob. N.C.	Lob. Ark.	White Va.	White Tenn.	Slash Tex.	Lob. Tenn.	Lob. N.C.	Lob. Ark.	White Va.	White Tenn.
Borax Treated (all A's)	15.06	13.68	15.76	18.27	15.68	18.44	16.76	14.73	19.70	27.37	16.20	24.54
	ns[1]	ns	ns	ns	ns	ns	ns	**	ns	ns	ns	ns
No Borax (all E's)	14.16	13.14	14.34	18.80	17.20	18.22	14.42	11.62	19.60	27.00	21.67	19.18
Inoculated (all I's)	15.12	14.85	16.92	18.28	18.26	19.08	15.10	13.76	21.19	27.56	22.28	22.05
	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Not Inoculated (all U's)	14.10	11.96	13.18	18.80	14.63	16.08	16.08	12.58	18.11	26.80	15.59	21.68

Contrasts	Change in average BAI (cm^2) (Posttreatment minus pretreatment)					
Borax Treated (all A's)	1.70	1.05	3.96	9.10	0.52	6.11
	ns	ns	ns	ns	ns	ns
No Borax (all E's)	0.26	-1.52	5.25	8.20	4.47	0.99
Inoculated (all I's)	-0.02	-1.09	4.28	9.90	4.02	2.97
	ns	ns	ns	ns	ns	ns
Not Inoculated (all U's)	1.98	0.62	4.93	8.00	0.96	4.11

[1]ns = not significant, P = 0.05.

** Significant differences, P = 0.01.

1976) may have suffered a growth loss during that time, but those trees either did not survive or were not included in the present survey. Those trees would have been at high risk to attack by other pests such as the southern pine beetle (*Dendroctonus frontalis* Zimm.) (Alexander and others, 1981). There is little evidence, however, that the surviving trees compensated for this loss by an increase in basal area growth. It is possible that surviving trees, regardless of location and treatment status, may have suffered similar natural low level root infections by *H. annosum* which prevented significant growth response to treatment (Bradford and others, 1978).

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REFERENCES

Alexander, S.A.; Skelly, J.M.; Webb, R.S. 1981. Effects of *Heterobasidion annosum* on radial growth in southern pine beetle-infested loblolly pine. Phytopathology 71: 479-481.

Bradford, B.; Alexander, S.A.; Skelly, J.M. 1978. Determination of growth loss of *Pinus taeda* L. caused by *Heterobasidion annosus* (Fr.) Bref. European Journal of Forest Pathology 8: 129-134.

Driver, C.H. 1963. Effect of certain chemical treatment on colonization of slash pine stumps by *Fomes annosus*. Plant Disease Reporter 47: 569-571.

Froelich, R.C.; Cowling, E.B.; Collicott, L.V.; Dell, T.R. 1977. *Fomes annosus* causes substantial loss in growth of planted slash pine. Forest Science 23: 299-306.

Hodges, C.S. 1970. Evaluation of stump treatment chemicals for control of *Forces annosus*. *In*: C.S. Hodges, J. Rishbeth and A. Yde-Andersen, editors, Proceedings, third international conference on Fomes Annosus. Aarhus, Denmark: 1968. July 29-August 3; unnumbered report. Asheville, NC: Southeastern Experiment Station, U.S. Department of Agriculture, Forest Service; 208 p.

Kuhlman, E.G.; Hodges, C.S.; Froelich, R.C. 1976. Minimizing losses to *Fomes annosus* in the southern United States. U.S. Department of Agriculture, Forest Service, Research Paper SE-151. 16 p.

Phelps, W.R.; Wolfe, R.D.; Laird, P.P. 1970. Evaluation of stump treatments for control of *Fomes annosus:* An interim report of a pilot project. Atlanta, Ga. U.S. Department of Agriculture, Forest Service, SE (unnumbered). 13 p.

Weiss, M.J.; Peacher, P.H.; Knighten, J.L.; Affeltranger, C.E. 1978. Annosa root rot stump treatment: a pilot project. Forestry Report SA-FR1. Atlanta, Ga. U.S. Department of Agriculture, Forest Service; 21 p.