Risk Prediction of Loblolly Pine Decline on Littleleaf Disease Sites in South Carolina

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ABSTRACT

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Three crown health classes in loblolly pine were identified and compared among three different littleleaf risk classes predicted by two methods, a point system and a soil series system. As determined by the point system, incidence of crown symptoms was 15% on high-risk sites, 13% on intermediate-risk sites, and 1% on low-risk sites. As determined by the soil series system, incidence of crown symptoms was higher on intermediate-risk (22%) and high-risk (8%) sites than on low-risk sites (5%).

Decline of forest trees is a general term that describes a reduction in tree vigor usually expressed by a series of symptoms beginning with foliage chlorosis, followed by retarded leaf and twig growth, then by branch dieback and reduced annual increment. The concurrent lack in vigor may result in direct mortality of the trees or increase their susceptibility to attack by disease and insect pests.

Littleleaf disease of shortleaf pine (*Pinus echinata* Mill.), which is prevalent on severely eroded clay soils in the southern Piedmont, shows this type of symptom progression. Trees growing on these sites become stressed and are predisposed to attack by *Phytophthora cinnamomi* Rands and other feeder root pathogens. Ultimately, these low-vigor trees die prematurely or, in the early stages of decline, are at high risk for successful attack by the southern pine beetle.

There are two methods for predicting littleleaf risk in shortleaf pine stands, both using soil characteristics but in differing ways. In the 100-point rating system, on-site evaluations are made by applying a rating scale that assigns point values for the critical soil factors of erosion class, soil consistency, depth to zone of greatly reduced permeability, and amount of subsoil mottling (3). A low numerical rating indicates a high relative risk to disease. Although considered more accurate, the system is labor-intensive and requires on-site soil evaluation.

The soil series rating system utilizes the identified associations of different amounts of littleleaf disease with certain soil series (3). Soil series are placed in one of three risk classes based on the close association between risk and the internal drainage characteristics of that soil series. The obvious advantage of this approach is that it can be applied without costly, labor-intensive fieldwork. Neither risk-rating system for littleleaf disease, however, has been evaluated for other pine species.

Historically, shortleaf pine has predominated on eroded agricultural sites in the Piedmont and has been most severely damaged by the littleleaf complex, but loblolly (*P. taeda* L.) and Virginia pine (*P. virginiana* Mill.) also are attacked. Loblolly pine has been recommended as a management alternative to shortleaf pine on southern Piedmont sites (3,4,9,11) and over the last 30 yr has been used to replace shortleaf pine on many high-risk littleleaf areas where littleleaf disease has been prevalent and particularly severe. Although considered less susceptible (8), loblolly pine has sustained severe damage on high-risk littleleaf sites where the forest product and other resource management objectives require a 50- to 80-yr rotation. Loblolly decline on high-risk littleleaf sites occurs in at least two Piedmont National Forests in the South. Some loblolly pine stands show 10-yr net losses in stand volume because of slowed diameter growth and mortality (H. E. Johnson, Ranger, Tyger Ranger District, Sumter National Forest, SC).

Although a littleleaf-related loblolly decline was obviously present, little was known of its actual incidence or influence on growth and there was no means of predicting incidence. In this research, we surveyed and evaluated decline of loblolly pine stands on littleleaf sites and then compared the two risk-rating procedures developed for littleleaf disease of shortleaf pine.

MATERIALS AND METHODS

Personnel on the Tyger Ranger District, Sumter National Forest, in South Carolina provided a list of compartments known to contain stands of shortleaf or loblolly pine with visible symptoms of littleleaf disease. This district is within an area identified as having abundant littleleaf disease when shortleaf pine was more widely distributed (3). Seventeen stands composed of immature sawtimber-size trees (minimum diameter at breast height, 23 cm [9 in.]) were chosen from these compartments for survey.

The 100-point soil rating system was used to rate littleleaf risk on each site by determining the overall amount of erosion by a visual examination and evaluating the pertinent features in three soil cores removed with a bucket auger (4). The soil series system (7) was evaluated by examining district soil maps. These are 1:24,000 scale and were mapped by the resident soil scientist to conform with Standard Soil Conservation Service County Reports (estimated 80% accuracy).

A 100-tree transect was used within each stand to estimate crown symptom incidence. Each transect was installed so that it lay entirely on soils of the same risk class as identified by the soil series system (7).

Littleleaf crown symptoms were recorded for each dominant and codominant tree. These included: no distinct littleleaf symptoms (healthy), light littleleaf symptoms, and severe littleleaf symptoms (Fig. 1). At the time of this survey (February), the crowns of healthy loblolly pines are normally relatively sparse. Our crown vigor ratings accounted for this by including only trees with marked decline symptoms in the affected categories.

The foliage of lightly affected trees was distinctly yellow, often dwarfed, and confined to branch tips. Severely affected trees had more pronounced foliage

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yellowing and lower density but also had twig or branch dieback not due to suppression; occasionally, an abundant crop of small cones persisted in the crowns. The distribution of crown symptoms by predicted littleleaf risk class by both prediction systems was then compared.

In addition to crown symptoms, two increment cores were collected at 1.4 m for every 10th tree. Annual increments were measured to 0.01 mm. Annual increments were summed for trees within each of the three crown health classes and compared.

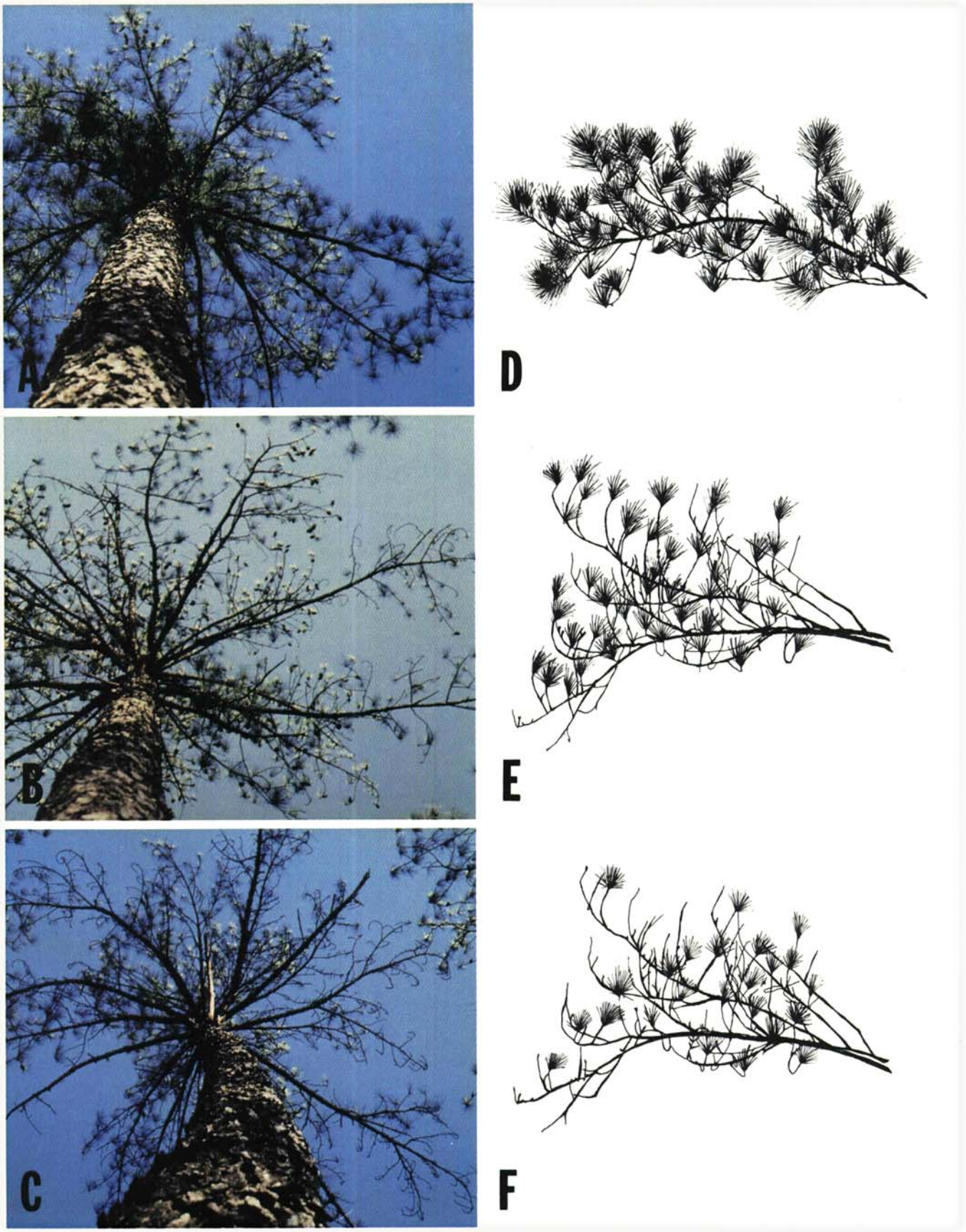

Fig. 1. Loblolly decline symptoms on littleleaf disease sites: **(A)** and **(D)** healthy, **(B)** and **(E)** light decline, and **(C)** and **(F)** severe decline.

After measurement of annual ring widths, the cores were stained with 2-methoxyaniline to determine the sapwood-heartwood boundary by the method of Blanche et al (2). Location of this boundary was recorded in the dendrochronology data set for each tree. As a second measure of tree vigor, sapwood basal area was computed for each of the crown symptom classes.

Although it was soon apparent that affected trees suffered growth loss, a more precise determination of growth loss was needed for use by forest managers. This is done by determining the age at which basal area growth culminates. Mean annual increment and current annual increment were plotted in relation to stand age and their characteristics noted. The age of growth culmination occurs where the two lines cross (1).

RESULTS AND DISCUSSION

The point system determined eight sites to be at high littleleaf risk, seven to be at intermediate risk, and two to be at low risk (Table 1). The soil series risk-rating system assigned six sites to high risk, seven to intermediate risk, and four to low risk (Table 1).

The soil series system was somewhat more conservative than the point system in assignment of risk class, tending to place fewer sites in high risk and more in intermediate and low risk. The soil series system also tended to underestimate lower-risk upland sites. Only two sites—7 and 15—identified as intermediate by the point system were rated as high risk by the soil series system. Four sites—4, 5, 14, and 17—determined to be at high risk by the point system were classified as intermediate by the soil series system, and two sites—2 and 6—were shifted from intermediate to low risk by the soil series system. Risk class change resulting from reclassification by soil series was between adjacent classes in all cases, never skipping completely across a category, such as from high to low or vice versa (Table 1).

With the sites classified by the soil series system, disease incidences in loblolly pine were 8% on high risk sites, 22% on sites of intermediate risk, and 5% on sites of low risk (Table 2). Based on site classifications by the point system, the incidence of littleleaf disease was 15% on high-risk sites, 13% on intermediate-risk sites, and 1% on low-risk sites (Table 3).

Past thinnings may have affected incidence level by removal of trees with symptomatic crowns. The prescription

Table 1. Littleleaf risk of 17 stands as predicted by two systems

Predicted risk class	Stands assigned according to: Point system	Soil series system
High	1	1
	3	3
	4	7[a]
	5	8
	8	15[a]
	14	16
	16	
	17	
Intermediate	2	4[b]
	6	5[b]
	7	9
	9	11
	11	12
	12	14[b]
	15	17[b]
Low	10	2[a]
	13	6[a]
		10
		13

[a] Assigned to intermediate risk by point system.
[b] Assigned to high risk by point system.

Table 2. Distribution of trees by crown symptoms and by littleleaf risk class as predicted by soil series system

Predicted risk	Stand no.	No. of trees	Status of trees: Healthy	Light symptoms	Severe symptoms
High	1	100	96	4	0
	3	100	97	2	1
	7	100	92	4	4
	8	99	87	10	2
	15	100	93	7	0
	16	97	86	9	2
Total	6 trees	596[a]	551	36	9
Intermediate	4	100	89	8	3
	5	100	88	11	1
	9	98	92	5	1
	11	98	74	19	5
	12	100	66	24	10
	14	100	72	26	2
	17	100	64	26	10
Total	7 trees	696[b]	545	119	32
Low	2	99	93	5	1
	6	98	85	10	3
	10	97	95	2	0
	13	98	98	0	0
Total	4 trees	392[c]	371	17	4

[a] Decline symptoms in 8% of trees.
[b] Decline symptoms in 22% of trees.
[c] Decline symptoms in 5% of trees.

Table 3. Distribution of trees by crown symptoms and by littleleaf risk class as predicted by point system

Predicted risk	Stand no.	No. of trees	Status of trees: Healthy	Light symptoms	Severe symptoms
High	1	100	96	4	0
	3	100	97	2	1
	4	100	89	8	3
	5	100	88	11	1
	8	99	87	10	2
	14	100	72	26	2
	16	97	86	9	2
	17	100	64	26	10
Total	8 trees	796[a]	679	96	21
Intermediate	2	99	93	5	1
	6	98	85	10	3
	7	100	92	4	4
	9	98	92	5	1
	11	98	74	14	5
	12	100	66	24	10
	15	100	93	7	0
Total	7 trees	693[b]	595	69	24
Low	10	97	95	2	0
	13	98	98	0	0
Total	2 trees	195[c]	193	2	0

[a] Decline symptoms in 15% of trees.
[b] Decline symptoms in 13% of trees.
[c] Decline symptoms in 1% of trees.

records for seven sites—2, 3, 6, 9, 10, 14, and 16—indicate that thinning was conducted within the stand during the previous 11 yr (Table 4). These stands had an average of 9.9 symptomatic trees per transect. Unthinned stands, conversely, had an average of 14.3 symptomatic trees per transect. Therefore, our observed incidences of littleleaf symptoms in thinned stands are probably conservative, largely representing trees that had developed symptoms since the last thinning. Some unthinned, but declining, trees also may have died before our survey and were likewise not included.

Crown health determinations also were probably conservative. Loblolly pine crowns, even healthy ones, appear in poorer condition at this time of year (February) than at any other time. Thus, a tree was classified as having light or severe decline symptoms only if it was distinctly symptomatic.

Despite these confounding factors, combining high and intermediate risk into a single class results in a clear separation of the two kinds of sites vis-à-vis symptom incidence. This may provide a basis for stand management decision making based on littleleaf risk for loblolly pine.

Examination of growth trends of increments of individual healthy trees indicated that this group was comprised of two major subgroups (Fig. 2A and B). Of 125 trees classed as healthy, 47 (38%) showed what we termed as normal growth, i.e., annual increments declined rapidly to about age 25, after which a steady state was maintained until age 50+ yr. Among the remaining 78 trees (62%), the decline in annual increment continued throughout the chronology length of 60+ yr. This group may include trees that will develop visible crown decline symptoms in the next decade or that had crown symptoms not detected by us with our present evaluation system.

Table 4. Incidence of littleleaf symptoms in each of 17 stands either thinned or unthinned during the previous 11 yr

Stand no.	Incidence of littleleaf symptoms (number of trees/transect)	
	Thinned	Unthinned
1		4
2	6	
3	3	
4		11
5		12
6	13	
7		8
8		12
9	6	
10	2	
11		19
12		34
13		0
14	28	
15		7
16	11	
17		36
Total	69/7	143/10
Av. no./stand	9.9 a[z]	14.3/b

[z]Treatment means followed by different letters are significantly different (99% LOC).

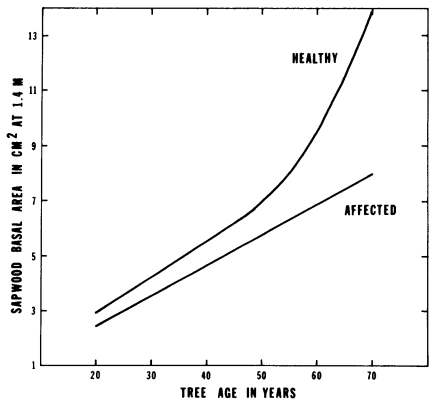

Fig. 3. Sapwood basal area growth of healthy and littleleaf-affected (symptomatic) loblolly pine trees.

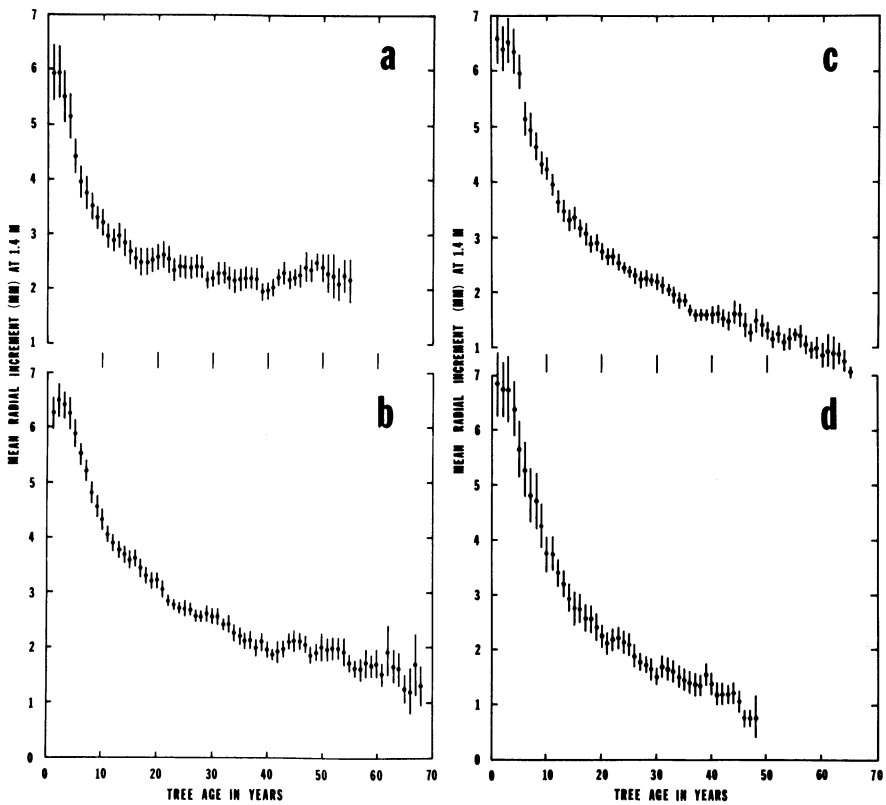

Fig. 2. Raw annual radial increment at 1.4 m of loblolly pine trees with healthy appearing crowns with **(A)** "normal" growth or **(B)** growth decline or with decline symptomatic crowns with **(C)** light or **(D)** severe littleleaf crown symptoms. Vertical bars represent standard errors of the means.

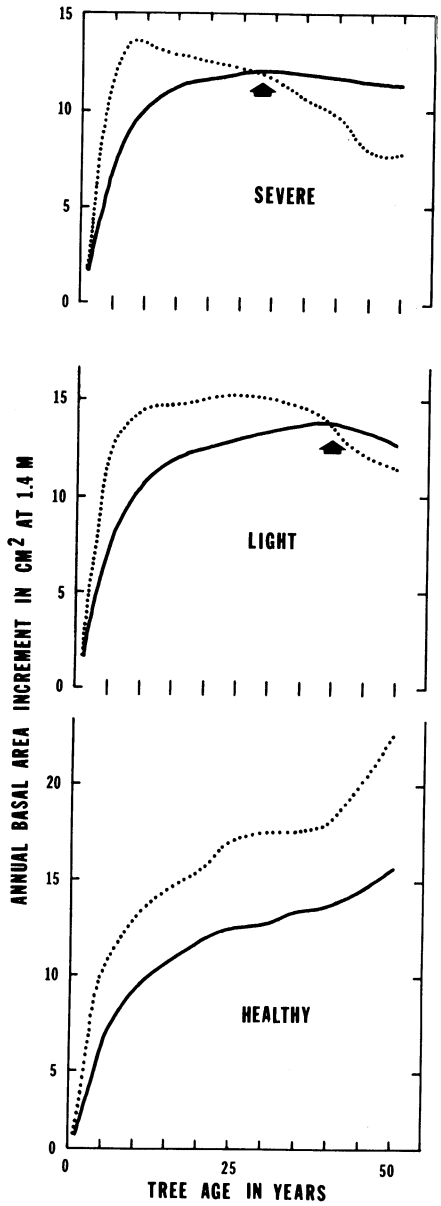

Fig. 4. Current (dashed line) and mean (solid line) annual basal area increment of healthy loblolly pine trees or trees with light or severe littleleaf crown symptoms. Arrows indicate approximate point of growth culmination.

The average age for all trees with healthy crowns was 44 yr.

Growth decline in trees with visible littleleaf crown symptoms was striking (Fig. 2C and D). Growth among all symptomatic trees was identical during the first decade, but an apparent marked divergence between trees with light and severe symptoms appeared after 20 yr of age and continued throughout the chronologies. The slower growth of symptomatic trees compared with healthy trees was generally highly significant after age 20. Average age of trees with severe crown symptoms was 44 yr and of trees with light symptoms, 47 yr.

For many tree species, there is a direct linear correlation between foliage biomass or leaf area and the cross-sectional area of sapwood at 1.4 m aboveground (5,10). Sapwood basal area of all the healthy loblolly trees increased linearly until approximately age 45, after which it continued to increase but in an exponential fashion (Fig. 3). Conversely, sapwood basal area of the trees with visible littleleaf crown symptoms increased only in a linear fashion throughout stand life. Sapwood basal area of symptomatic trees was always less than that of healthy trees, but the differences were not statistically significant (at 95% LOC) until after age 50. Although sapwood basal area was clearly related to overall tree vigor, its predictive value for identifying declining loblolly trees was probably less useful than visual crown symptoms.

The growth culmination point differed between crown symptom classes but did not differ between high-, intermediate-, and low-risk sites. The culmination point was 30 yr for trees with severe crown symptoms and 40 yr for those with light crown symptoms (Fig. 4). For trees with healthy crowns, a culmination point was not evident within the range of the 50-yr age data included on the graph (Fig. 4). The mean annual increment and current annual increment lines more or less paralleled each other, with no tendency to cross.

The soil series system and the 100-point system for littleleaf risk prediction in shortleaf pine are valid for predicting growth decline in loblolly trees only if they are combined with a crown health class rating system. Both systems seemed to work best when high- and intermediate-risk classes are combined, but the soil series system, although underestimating littleleaf incidence, may be preferable because it was much easier and less expensive to use.

Growth culmination point was quite low for symptomatic trees. If all other management considerations, such as stumpage prices, product size limitations, etc., are equal, the culmination point is regarded as the ideal harvesting or rotation age in terms of most efficient volume production (1). Selection of optimum rotation age may be particularly important on these low productivity sites, and the incidence of trees with crown decline symptoms is undoubtedly a key consideration. Annual radial increments of even the healthy trees was at best only several millimeters, and devastating outbreaks of the southern pine beetle are a high risk. Indeed, the southern pine beetle risk rating system most applicable to the Piedmont defines high-risk stands with factors that also identify littleleaf-prone areas (6).

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