New Technique to Measure Tree Defect Using an Image Analyzer

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ABSTRACT

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A new technique to measure discolored and decayed wood in trees using a video processor image analyzer, commonly used in remote sensing laboratories, is presented. Discolored and decayed wood associated with *Inonotus* (*Poria*) *obliquus* in *Betula papyrifera* and *Phellinus* (*Fomes*) *pini* in *Pinus banksiana* was accurately measured using this simple, rapid technique. The cross-sectional areas of defects were obtained from disks taken at 30.6-cm intervals throughout the main stem of the trees. A highly significant ($r > 0.91$**) correlation was found when this new technique was compared with hand measurements from tracings of the discolored and decayed columns.

Defects in living trees resulting from wood-destroying microorganisms are difficult to quantify. Accurate measurements of discolored and decayed wood are needed to provide a better understanding of the degradation process in forest and urban trees. The patterns of degradation by some of the most important decay-causing fungi on cut transverse surfaces are not uniform, circular zones. Instead, decay can be a patchwork of discolored and decayed wood intermixed throughout the healthy tissue (Fig. 1).

Previous studies to determine decay and volume losses have given only a rough estimate of the defect (3–5,7,9). A photographic method recently proposed by Thies and Harvey (11) using color Polaroid film and an electronic planimeter provided an accurate measure of deterioration in beetle-killed timber. A simple, rapid, accurate, and inexpensive technique is needed to distinguish among sound, discolored, and decayed wood. Instrumentation currently used in remote-sensing laboratories for image interpretation can be adapted for quantifying discoloration and decay.

In this investigation, a video processor image analyzer was used. Discoloration and decay patterns caused by *Inonotus* (*Poria*) *obliquus* (Fr.) Pilát in birch and *Phellinus* (*Fomes*) *pini* (Thore ex Fr.) A. Ames in jack pine were studied.

MATERIALS AND METHODS

Seven birch trees (*Betula papyrifera* Marsh.; all 32–40 yr old), each bearing a sterile conk of *I.* (*Poria*) *obliquus*, were harvested from the Fond du Lac State Forest, Carlton County, MN. Disks 2.5 cm wide were cut with a chain saw at 1-ft (30.6-cm) intervals from ground level to wood that contained no discoloration or decay. The cross-sectional area of discoloration and decay was determined by tracing the defect on acetate sheets superimposed with a square-centimeter grid. This method was used to determine the combined amount of discolored and decayed wood. Because the decay column was not a central core of decayed tissue but a mixture of discolored and decayed wood (Fig. 1A), it was impossible to distinguish between them when tracing.

Disks were also measured using a video processor image analyzer (VP-8 image analyzer; Interpretation Systems, Inc., Lawrence, KS) with capabilities of converting an image into eight gray levels and coding each level into a different color (Fig. 2). The instrument was calibrated using a standard series of known areas. Each disk was placed directly under the lens. Areas of the total disk, discolored wood, and decayed wood were determined. To obtain these areas, the disk was first measured for the amount of discolored wood. The color of the discolored wood was easily detected by the image analyzer. Once this area was determined, a 0.1% aqueous solution of cotton blue was brushed over the defect.

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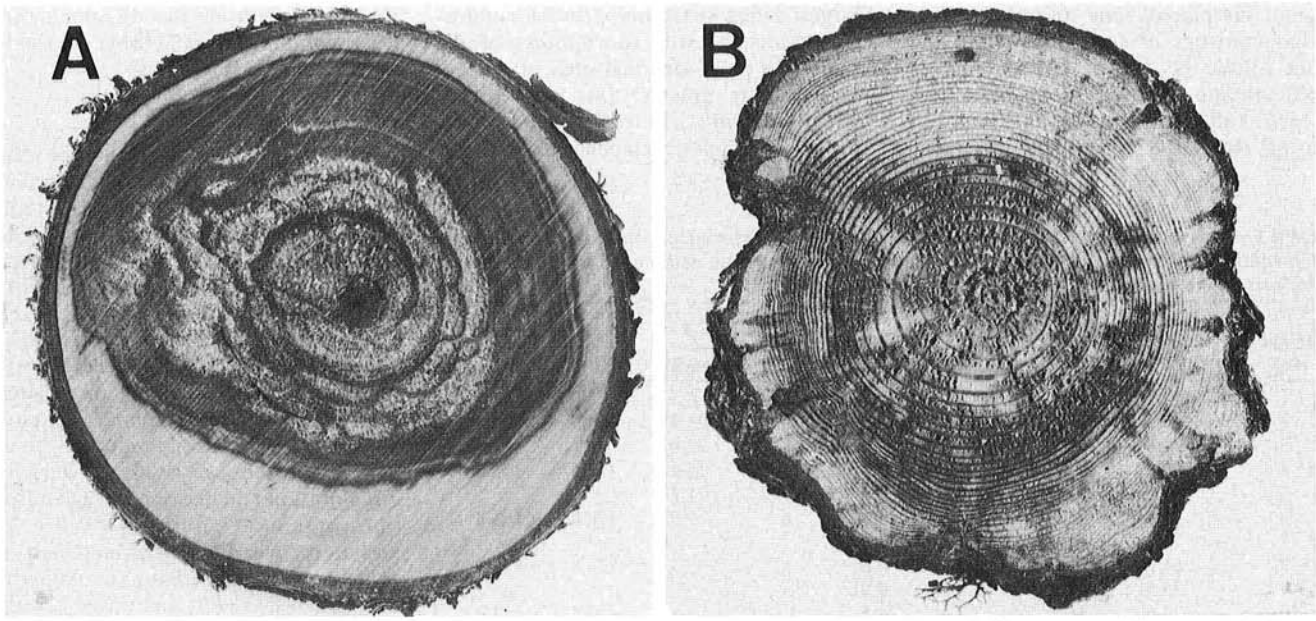

Fig. 1. Cross sections demonstrating the patterns of discoloration and decay in birch **(A)** and jack pine **(B)** degraded by *Inonotus obliquus* and *Phellinus pini*, respectively.

The strain was absorbed by the decayed wood, normally with a white coloration not easily distinguishable from sound wood, and a second reading was taken. The second value represented the area for both discolored and decayed wood. This value was subtracted from the area of discolored wood (first value) to determine the area of decay.

Seven jack pine trees (*Pinus banksiana* Lamb.; four trees 38–42 yr old and three trees 78–81 yr old) with cankers caused by sweetfern rust (*Cronartium comptoniae* Arth.) and sporophores of *P.* (*Fomes*) *pini* at the base of each tree were harvested from the Superior National Forest, Virginia, MN, and the University of Minnesota Cloquet Forestry Center, Cloquet. Disks were cut at 1-ft (30.6-cm) intervals throughout the length of the tree. Tracings were made and areas were calculated as previously described. Disks from the base of the tree contained decay that was well dispersed throughout the sound wood, and only small zones of reddish discoloration surrounded the decay (Fig. 1B). The VP-8 image analyzer gave values that represented the combined area for discoloration and decay. The cotton blue stain was not used on the jack pine samples. In some samples, the red coloration of the bark could not be distinguished from the defect. To facilitate an accurate measurement, the bark was removed from the samples.

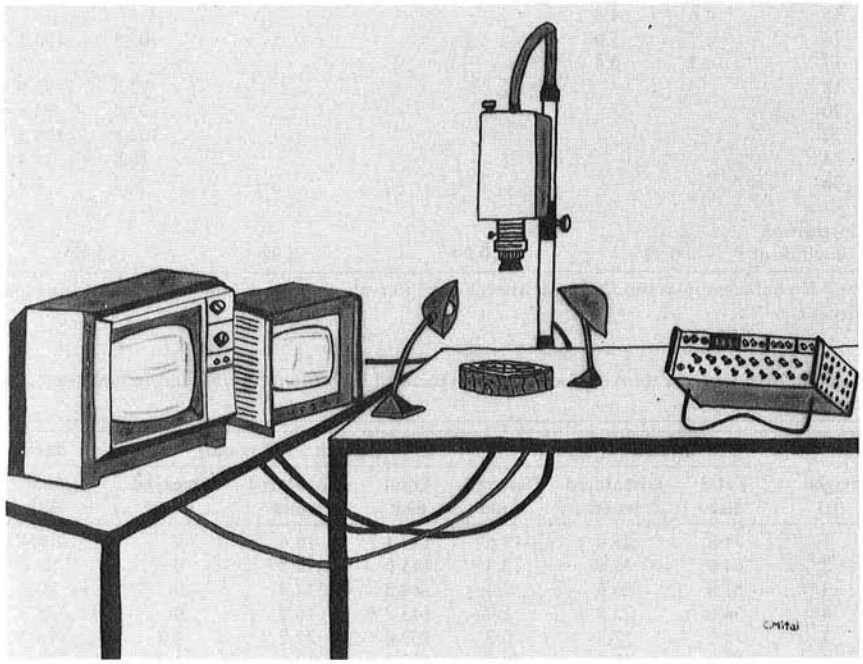

Fig. 2. VP-8 image analyzer: **(Left to right)** Color video display, three-dimensional display, television camera, control unit with digital display.

RESULTS

The VP-8 image analyzer (Fig. 2) accurately measured discoloration and decay associated with *I. obliquus* colonization in birch and *P. pini* in jack pine. A highly significant correlation ($r > 0.91^{**}$) was obtained when areas from tracings were compared with areas calculated by the VP-8 image analyzer (Table 1). Data for four trees, randomly selected from the 14 trees, are presented in Table 1.

Defect columns caused by *I. obliquus* in birch could not be separated into discolored and decayed wood by visual inspection. The VP-8 image analyzer was able to differentiate discolored wood from healthy and decayed wood. It was not possible to distinguish the white-rot decay caused by *I. obliquus*, which has a light color, from unaltered healthy wood without staining with cotton blue. The cotton blue stain was absorbed by the decayed wood and readily detected by the image analyzer. Table 2 presents the cross-sectional areas for two birch trees attacked by *I. obliquus*. The largest area of decay was associated with the location of the sterile conk. The extent of defect above and below the sporophore varied with the height of the conk.

The VP-8 image analyzer readily differentiated the defect from sound wood. It was not possible to separate discolored from decayed wood in cross sections of jack pine infected with *P. pini* either visually or with the VP-8 image analyzer. White-pocket rot decay, typical of *P. pini*, has a reddish discoloration between degraded areas (white pockets) and around the decay columns (1,2). The

small discolored zone and the porous characteristics of coniferous wood did not allow the use of cotton blue to differentiate decayed from discolored wood. Table 2 presents the data obtained using the VP-8 image analyzer. The largest defect was found at the base of the tree associated with sporophores of *P. pini*. The cross-sectional area of defect was usually greatest just above the sweetfern canker. In trees 38–42 yr old, the average defect extended 9.7 ft (2.96 m). The length of the discolored and decay column in trees 78–81 yr old was an average of 18.3 ft (5.57 m).

Table 1. Areas (cm^2) of defect (discolored and decayed wood) associated with *Inonotus obliquus* degradation of birch and *Phellinus pini* degradation of jack pine determined by VP-8 image analyzer and tracings

Height (ft)	Birch 1		Birch 5		Jack pine 3		Jack pine 12	
	VP-8	Tracing	VP-8	Tracing	VP-8	Tracing	VP-8	Tracing
1	40.6	42.4	54.3	56.8	8.5	6.5	55.3	68.9
2	47.3	45.2	44.0	46.9	28.3	25.9	114.5	125.6
3	39.6	42.7	31.3	34.0	22.4	22.8	...[a]	...
4	80.5	83.6	25.8	27.7	17.2	15.2	118.5	175.0
5	117.1	121.8	21.0	23.0	19.5	21.7	...	...
6	73.5	72.9	15.5	16.5	4.3	1.9	128.8	168.8
7	74.1	74.7	11.7	12.2			...	...
8	64.3	65.1	8.2	9.8			126.8	122.1
9	35.5	42.3	5.4	6.9			...	...
10	29.6	36.5	3.1	4.5			123.5	117.6
11	20.3	25.3	0.9	1.6			...	...
12	17.7	13.4	0.25	0.6			105.5	100.3
13	11.7	13.5					...	...
14	7.3	8.9					101.0	105.7
15	4.6	4.6					...	...
16	5.7	5.0					105.5	100.1
17	0.1	0.4					...	...
18							93.5	93.9
20							92.0	93.4
22							103.8	108.5
24							26.8	31.4
26							2.5	1.0
Correlation coefficient	0.99		0.99		0.98		0.92	

[a]... = No data (samples were taken at alternating intervals on large columns of discoloration and decay).

DISCUSSION

This study demonstrates that the VP-8 image analyzer accurately determines areas of defect in deciduous and coniferous trees. The tedious and time-consuming method of tracing disks and calculating the area gave significantly similar results to the rapid, simple method using the VP-8 image analyzer. Because the disks are placed directly under the lens and a reading immediately determined, no photographing is required and costs are drastically reduced.

The VP-8 image analyzer detected discoloration and decay more accurately than tracing techniques (Table 2). Discolored wood in and around decayed zones caused by *I. obliquus* could not be distinguished visually and traced because of gradations from discolored to decayed wood, often within one growth ring (Fig. 1A). The VP-8 detected discolored wood from either sound or decayed wood.

The only difficulty with the use of the VP-8 image analyzer was the separation of zones with similar coloration. The use of cotton blue stain facilitated the differentiation between decayed wood, of the white-rot type, from sound wood. Compounds routinely used to distinguish between white and brown rot fungi (6,10) may also be useful to separate decay from sound wood. The color reactions produced by these compounds when associated with fungal enzymes could

Table 2. Area (cm^2) of total disk and defect associated with *Inonotus obliquus* in birch and *Phellinus pini* in jack pine determined by a VP-8 image analyzer

Height (ft)	Birch 5 (41 yr old)			Birch 6 (38 yr old)			Jack pine 3 (32 yr old)		Jack pine 10 (81 yr old)	
	Total disk	Discolored wood	Decayed wood	Total disk	Discolored wood	Decayed wood	Total disk	Discolored and decayed wood	Total disk	Discolored and decayed wood
1	74.8[a]	43.8	13.6	143.1	10.4	0	114.4[a]	6.5	301.7[a]	69.7
2	64.0	34.6	12.3	145.6	12.3	0	89.2	25.9	255.8	87.5
3	57.8	26.6	7.4	144.0	12.4	0	80.7	22.8	...[b]	...
4	54.6	25.8	1.9	143.7	16.2	0	78.3	15.2	243.6	78.5
5	53.2	22.3	0.7	169.0	22.2	1.7	75.3	21.7	...	...
6	50.0	16.0	0.5	122.3	10.6	1.7	80.2	1.9	236.4	77.7
7	48.4	11.8	0.4	137.1	15.6	0			...	...
8	46.2	9.8	0	119.7	12.2	2.5			245.3	91.6
9	43.9	6.5	0	127.8	14.9	11.1			...	...
10	43.9	4.5	0	134.6	27.5	10.8			240.0	87.4
11	42.9	1.6	0	148.2	39.6	4.6			...	...
12	40.3	0.6	0	191.5[a]	58.4	9.0			231.0	76.7
13				113.6	20.1	7.2			...	...
14				105.8	12.1	4.4			215.3	61.3
15				97.0	9.5	2.4			...	...
16				95.1	10.0	0.5			205.3	70.2
17				95.7	3.2	0			...	...
18				86.0	1.8	0			208.6	66.2
19									...	...
20									195.8	60.4
21									...	...
22									188.6	20.7
23									...	...
24									181.2	10.1
25									...	...
26									179.2	2.2

[a] Location of sporophore.
[b]... = No data (samples were taken at alternating intervals on large columns of discoloration and decay).

help differentiate many types of decay from discolored and sound wood when using image analyzers.

Data obtained from image analyzers can be used to map the defects associated with living trees. In a recent study (8), tracings of discoloration and decay columns were made and coordinates entered into a computer to create a three-dimensional perspective of the defect. Image analyzers could provide a more accurate representation of the defect, and the resulting three-dimensional maps would better represent the true nature of the discolored and decayed columns.

Results based on the two decay fungi used in this study clearly demonstrate that discolored and decayed wood in living trees may not be a centrally located, cylindric defect. This technique will help to develop a more precise measure of defects associated with urban and forest trees and also provide important information regarding the patterns of degradation by wood-destroying fungi.

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