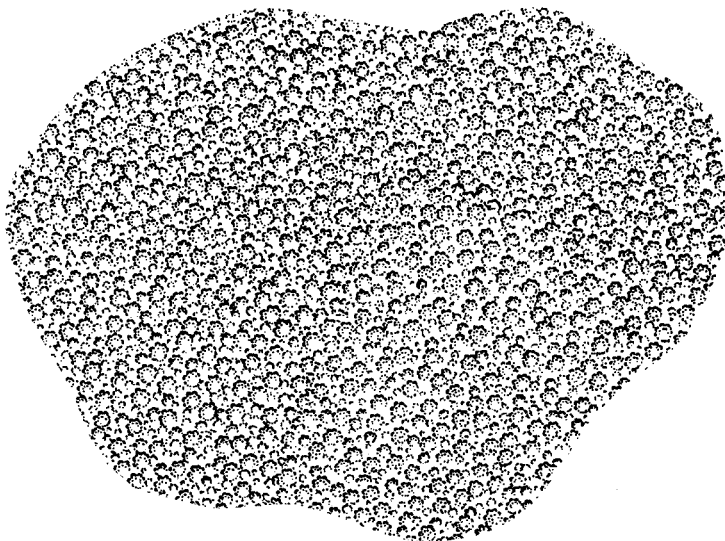


by David R. Houston

The use of large-scale aerial
COLOR PHOTOGRAPHY for
assessing **FOREST TREE DISEASES**

I. Basal Canker of White Pine: A Case Study



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INTRODUCTION

OVER THE PAST decade, the use of aerial color photography as a tool for assessing damage to forest trees by insects and diseases has received increasing attention (Ciesla *et al.* 1967, Heller *et al.* 1967, Meyer and French 1967, Murtha and Kippen 1969, Murtha and Harris 1970). Improvements in infrared color aerial film offered the possibility of extending visibility of tree foliage to wave lengths beyond those sensed by eye and gave added impetus to investigations on color photography for this purpose. Murtha (1969) has published an extensive bibliography on the subject.

In 1966, we began a study to determine the efficacy of using color infrared and true color aerial photography to assess the progressive development of basal canker of white pine. The symptomatology of this disease and the biotic and environmental factors contributing to its etiology and to patterns of its development were presented earlier (Houston 1969).

Briefly, basal canker develops when bark-cankering fungi invade the lower stems of young pines through either lesions made by ants or wounds caused by snow and ice. Presence of the disease is associated with ant mounds and with topographic features that influence their occurrence or that contribute to the accumulation of snow and ice. Such features include depressions and swales, hedgerows, roadways, and rock piles.

This paper discusses the use of aerial color photography to discern symptoms of the disease as it developed over time, the factors contributing to disease development, and the patterns of disease development.

METHODS AND MATERIALS

Eight 0.2-acre plots (66 feet x 132 feet) established and mapped in 1965 or 1966 in 5- to 14-year-old plantations of white pine growing on the Tug Hill Plateau in north central New York were used in this photographic study. The plots, affected by basal

canker, were selected to include diseased trees, ant mounds, and such topographic features as hedgerows, swales, and rock piles that were shown earlier to contribute to canker initiation (Houston 1969).

The disease condition of each tree in these plots was noted annually and whenever the plots were photographed. The plot corners, and sometimes the plot centers, were marked with 6-foot lengths of white water-repellent paper. These markers delineated plots and provided a scale reference. Orange-colored plasticized fabric bags tied to poles that were attached to tree crowns helped to locate plots from the air and indicated direction of the flight line.

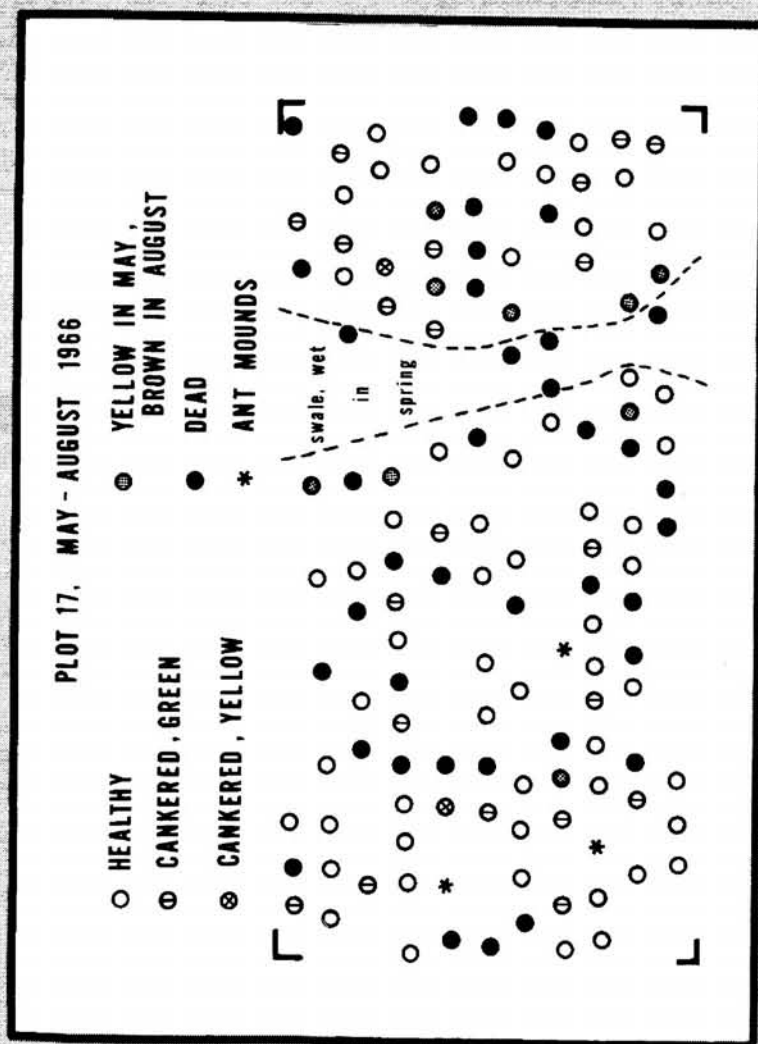
A Hulcher 70-mm. camera equipped with a 150-mm. focal-length lens was used to obtain stereo-sequenced photographs at scales of 1:792 (1 inch = 66 feet) to 1:1,584 (1 inch = 132 feet). True-color film (Kodak SO-282) was exposed at ASA 100 in May and August 1968, and Kodak 2442 was exposed in August 1970. Infrared color film—Kodak 8443 in May and August 1966 and 1968, and Kodak 2443 in August 1970—was exposed through a minus-blue filter (Wratten #12) at ASA 100. "Unaged" film was exposed also through an infrared attenuating filter (Corning #3966 X 0.5). Films were processed with a Morse rewind system, and the positive transparencies were examined stereoscopically. Tree conditions determined visually on films were compared with actual tree conditions on the ground.

RESULTS

Detection of Symptoms

Representative photography of two plots and ground-truth maps of them are presented in figures 1 to 8. Visible symptoms such as chlorotic or brown foliage, thin crowns, or bare branches could be seen readily at any of the scales used on both true-color (TC) and infrared (IR) films. Diseased trees sometimes appeared more striking on IR than on TC, but this usually was because of the unusual color combinations of IR film.

Figure 1.—Map of Plot 17, showing tree disease conditions in May and August 1966 and the locations of ant mounds and wet swale.



Figures 2 to 4.—Stereo-photography of Plot 17 taken at different times and with different films and filters.

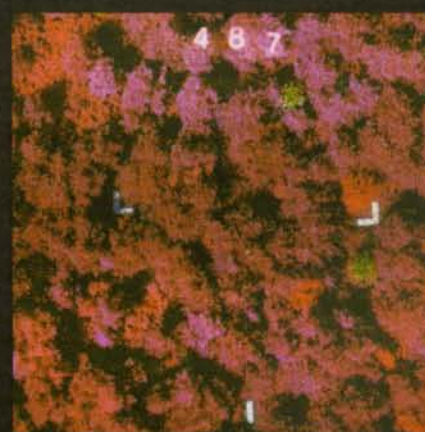
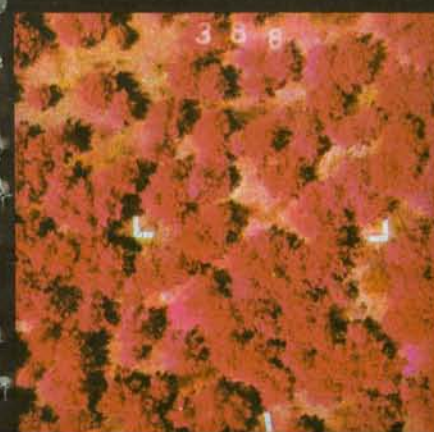
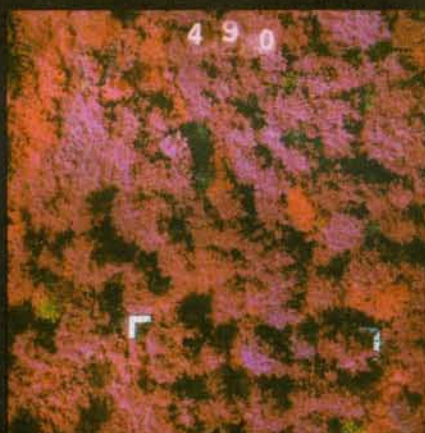
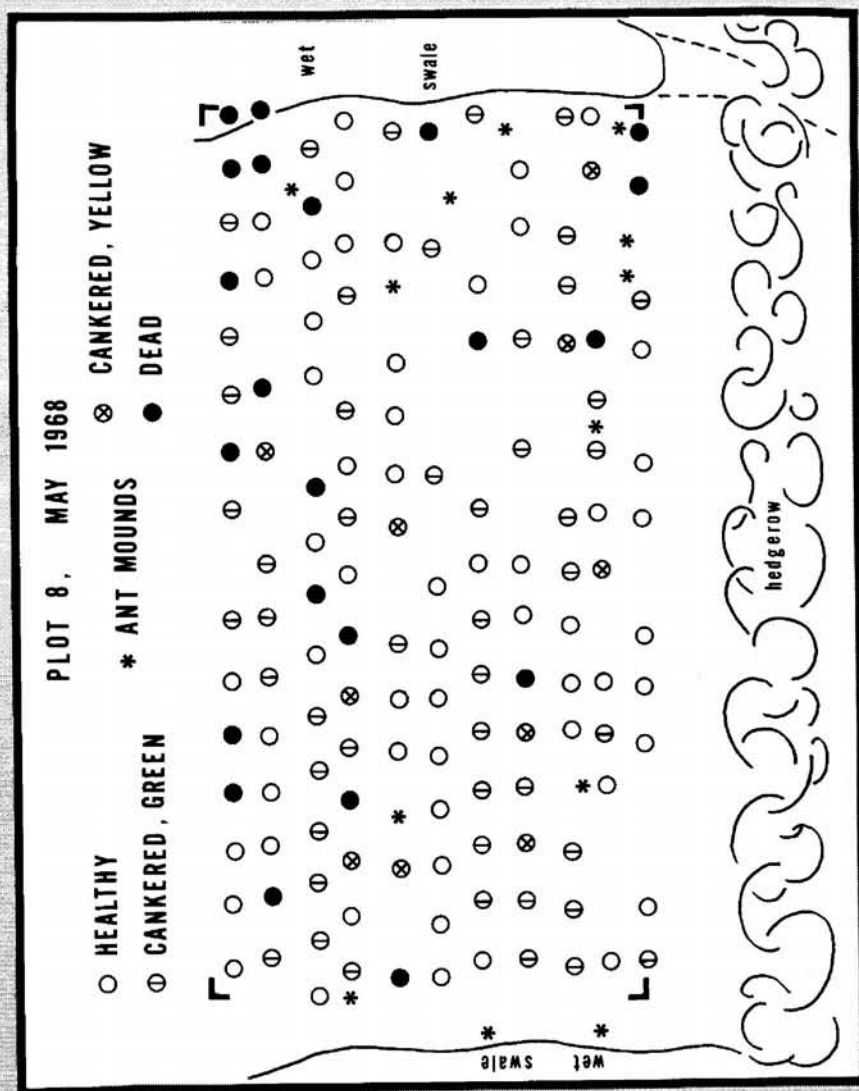


Figure 2.—IR, May 1966.

Figure 3.—IR, August 1966.

Figure 5.—Map of Plot 8, showing tree disease conditions in May 1968 and the locations of ant mounds, wet swales, and hedgerow.



Figures 6 to 8.—Stereo-photography of Plot 8 taken in 1968.

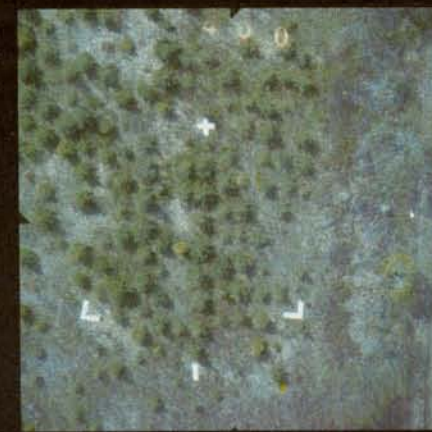
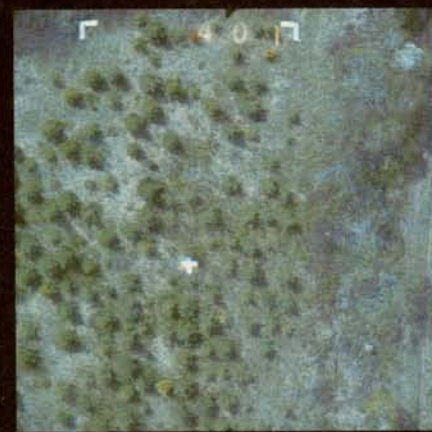
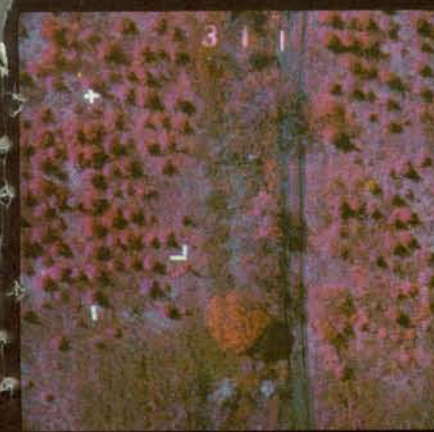
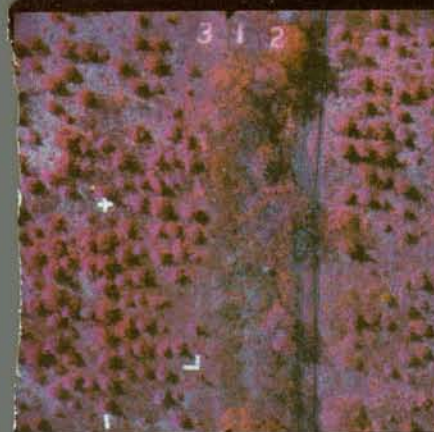
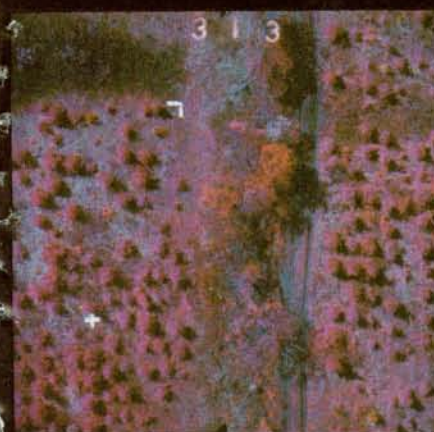
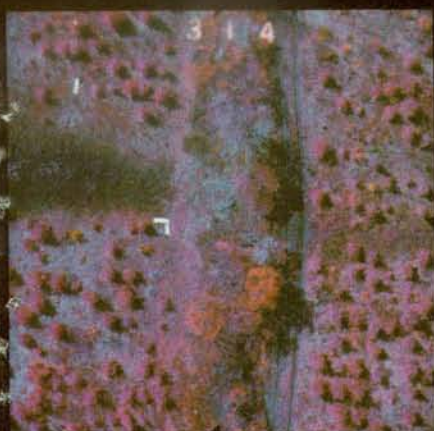


Figure 6.—IR, May.

Figure 7.—TC, May.

Figure 8.—TC, August.

Table 1.—Comparison between ground- and photo-determined tree disease condition of 57 trees (IR, August 1966, Plot 17).

Item	Number of trees determined as—			
	Healthy	Green-cankered	Yellow-cankered	Brown
Ground	34	15	7	1
Film	29	20	7	1

There was no indication that previsible symptoms were revealed by IR photography. Indeed, it was difficult to distinguish accurately between healthy and "green-cankered" trees on the film (table 1). This difficulty is greater than shown by the figures in table 1: 13 of the 20 trees classed as green-cankered on the film actually were healthy, and 8 of 15 green trees with cankers were determined from the film to be healthy.

In general, as trees became progressively more diseased, they underwent foliar color changes from green (healthy) to yellow-green, to yellow, and finally to red-brown (figs. 4, 7, 8). On IR film, these changes were reflected as changes from shades of magenta (healthy) to mauve, pink, or light purple to gray-pink, and finally to yellow and yellow-green, respectively (figs. 2, 3, 6).

Although diseased trees sometimes were more obvious on photos taken in August than in May, most visible foliar symptoms were apparent on films exposed at either time. The IR photography (fig. 2) of May 1966 was fresh film (unaged); that of August 1966 (fig. 3) was the same but was exposed through an IR attenuating filter; and that of May 1968 (fig. 6) was the same film but was aged for 90 days at room temperature and was not exposed through the attenuating filter. Subtle differences in the amount of infrared reflectance from foliage, expressed as a variety of shades of magenta-mauve, were most apparent on the filtered or aged films.

Although foliar symptoms were readily visible on both spring and summer photography, other features were more apparent in the spring. Dead bare trees, standing or down, could be seen best prior to growth of grass and herbaceous weeds (figs. 2, 4, 6, 7). Some other features related to disease initiation and development also were most visible on spring photography.

Detection of Factors Related to Etiology and Disease Distribution

Large ant mounds of *Formica fusca* L. were most evident on TC and on IR photos taken in May before herbaceous growth occurred. Some ant mounds were distinguished by grass that had renewed its growth on the warmer, drier mounds sooner than on adjacent surrounding areas (figs. 6, 7). Tree damage around the ant mounds was visible as openings where trees had died and as dead and dying trees.

Hedgerows, rock piles, depressions, swales, and in many cases, openings devoid of trees, and dead and dying trees associated with such features, were readily detected by most of the photography. Permanently wet swales supporting marsh grasses or alders and willows were easily distinguished in May by dark-colored dead grass on both TC and IR films (figs. 6, 7). But in August, swales were more evident on IR film because of greater color contrasts between the foliage of conifers, hardwoods, and herbaceous plants.

Assessment of Disease Development over Time

Time-sequenced photography of specific plots or areas provided an accurate means of determining the rate of disease development within individual trees from the time their foliage turned color till they died. But photography did not reveal when trees became cankered initially nor the time that they remained cankered and green.

Repeated photography also revealed the patterns of disease development (more accurately, mortality) over time. These patterns varied between plots in different plantations and could be related to the presence of ant mounds and topographic features mentioned

earlier. In figures 2 to 4, disease development and mortality is associated with a slight depression that is wet early in the spring. In figures 6 to 8, tree mortality associated with a swale and with ant mounds can be seen.

DISCUSSIONS AND CONCLUSIONS

Although foliar symptoms were readily apparent on both TC and IR color transparencies, they often were more striking on the latter because of the sharper contrast between yellow and magenta than between red-brown and green. Another advantage of IR film not explored in this study may be the recording of small spectral changes in near infrared reflectance.

In the IR transparencies made from aged film or from fresh film exposed through an infrared attenuating filter, subtle differences were recorded for both healthy and green-cankered trees. Densitometric measurement of the cyan dye layer with a narrow-band-pass red filter might have allowed a more accurate separation of healthy trees and those cankered trees that were still green. Such a technique has shown promise for distinguishing nonsymptomatic red pine trees infected with *Fomes annosus* root rot (Murtha and Kippen 1969).

This study showed the importance of choosing the proper time of year for photography. August photos often had more dead

trees with red-brown foliage than did May photos. This was because most chlorotic trees died and turned brown during the summer. The red-brown dead needles dropped off during the winter. Thus, mid- to late-summer photography would seem best for assessing current mortality.

We gained a general impression that healthy and green-cankered trees photographed in August showed more variation in color and hue than they did when photographed in May. IR reflectance is influenced by needle age, and this may have been a factor. The youngest white pine foliage on Tug Hill is about a year old in May and is about 2 months old in August. Densitometry through narrow-band-pass filters might have verified our impressions.

Photos taken in May, however, were better than those made in August for distinguishing features associated with disease development. Herbaceous vegetation in summer obscured ant mounds, swales, and fallen dead trees that were readily visible in early spring.

Photos also provided an excellent tool for recording disease development. Permanent pictorial records in three-dimensional color permitted accurate reconstruction of tree mortality patterns and rates. Although these patterns and the stand features associated with them were already known for basal canker, the large-scale photographic record obtained in this study would have helped us to determine them more efficiently.

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