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Detection of Diseased Trees

Ektachrome infrared (false-color) film has considerable promise as a means for detecting forest and shade tree diseases.

INTRODUCTION

DETECTION OF PLANT diseases by means of aerial photography is not new, having been used for locating cotton root rot as early as 1929 (Taubenhaus, *et al*). In view of the vast improvement since that time in films, cameras, interpretation equipment and methods, this technique has increasing promise as a practical means of disease detection for control programs, and as a research tool for following disease development. Infrared aerial photography has, for example, been used successfully for detecting certain diseases of citrus crops (Norman and Fritz, 1965), vegetable crops (Brenchley and Dadd, 1962) and cereal crops (Colwell, 1956).

Since 1964, the University of Minnesota, in cooperation with Mark Hurd Aerial Surveys, has studied the use of aerial photographic methods for the detection and assessment of certain tree diseases. Although initial concern was only with the location of forest tree diseases, the study ultimately expanded to include the detection of diseases of residential area shade trees. The change in emphasis to include shade tree diseases was prompted in part by the movement of the Dutch elm disease into Minnesota. The three diseases which have received the greatest attention thus far are dwarfmistletoe of black spruce, Dutch elm disease, and oak wilt.

ABSTRACT: *More effective control programs for Dutch elm disease, oak wilt, and other tree diseases need a detection system which is faster, less expensive, and at least as reliable as ground reconnaissance. A number of areas in Minnesota were photographed using Kodak Ektachrome Infrared (false-color) film at a range of flight elevations, with and without stereoscopic coverage and at different times of the year. Comparisons of photo interpretation results with observations on the ground indicate that there are problems of application, but at the same time suggest this technique can serve as a practical means of disease detection.*

AERIAL PHOTOGRAPHY

AERIAL CAMERA equipment employed in all flights consisted of a Zeiss RMK A 15/23 (6-inch focal length and 9×9-inch format) in a fixed wing aircraft. Kodak Ektachrome Infrared (false-color) film was used for all studies, but Kodak IR Aerographic film with a red filter also was used in a few instances. The latter, however, was of very limited value for tree disease detection and was tested only with the first dwarfmistletoe and Dutch elm disease flights.

ALTITUDES of most initial flights were varied to produce a range of photographic scales from 1:4,500 to 1:25,000 to permit determination of the smallest usable scale. Although flights after 1964 included a variety of photo scales wherever possible, the range of scales has been progressively narrowed to a zone between 1:6,000 and 1:12,000 for most subjects under study.

FILM EXPOSURE AND PROCESSING experience indicates for the most part that manufacturer's recommendations, tempered to

* Published as Paper No. 6229, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul, Minn.

some extent by local conditions, consistently produced the best photography. In one case, on an experimental basis, maximum f-stop and shutter speed were combined with extended time in film chemical processing. The resulting transparencies, however, tended to have a slight brownish tinge and color differentiation was materially reduced.

TIME OF PHOTOGRAPHY in all areas was during July and August on clear days with relatively high horizontal visibility. In a number of instances the sun angle was sufficiently high to produce a hotspot in the area of coverage. For the most part, hotspot effects were quite objectionable because they made stereoscopic examination difficult and tended to abort image color quality in that portion of the photograph. At the other extreme, a very low sun angle seems not only to affect color rendition but also to result in shadows which obscure essential photo detail.

COVERAGE was initially monoscopic rather than stereoscopic. It was soon evident, however, that where forest and shade trees were concerned, the following disadvantages of monoscopic coverage far outweighed its economies: (a) radial displacement tended to obscure infection centers of lesser height than surrounding vegetation; (b) inability to examine a tree crown stereoscopically made identification of both the tree species and the nature of its affliction difficult; and (c) infrared-absorbing surfaces, such as streets, seen through openings in the tree crowns, were often interpreted as dead or diseased portions of the tree—a feature which stereoscopic examination would normally detect.

PHOTO INTERPRETATION

We have become convinced that a major limiting factor in the exploitation of the potential of this film medium is not so much a lack of knowledge of its proper exposure and processing as it is the problems of viewing and photo interpretation. Admittedly, it is difficult to get precisely the same color-level rendition on the photographs even if they are flown over the same area under seemingly similar conditions. Nevertheless, it was found that transparency illumination in viewing could often be adjusted to compensate for many of these inconsistencies in image coloration.

Both the quality and intensity of light need to be controlled to utilize the transparencies fully. In an attempt to meet these needs, a light table was fabricated which incorporated the following features:

- The light is thoroughly diffused through a textureless medium such as opal glass.
- The stereo model is masked to prevent peripheral glare.
- Sheet filters are used to enhance certain color differences and can be inserted into the light table apertures. Dwarfmistletoe, for example, is much more readily detected with a yellow filter.
- Controllable light intensity.

A conventional mirror stereoscope with both 3× and 8× binoculars has been used, but this stereoscope is considered to have two major disadvantages: (a) because of the fixed image viewing distance, the film rolls must be cut for stereoscopic viewing; and (b) a stereoscopic magnification of about 5× (not 8×) seems to be the maximum at which acceptable image rendition on this film, and for these purposes, can be attained. A better solution to viewing, therefore, would be one of the available instruments capable of variable magnification and image viewing distance. Although these are more expensive than conventional fixed/distance instruments, they eliminate the time and expense involved in cutting and handling each individual exposure.

One of the problems involved in using positive transparencies is the difficulty of annotation and use in the field. To delineate detail on the transparencies so as not to mar the film or mark it permanently, .003-inch-thick clear acetate overlays were taped to them and possible infection centers marked with ink. In the absence of a portable light table, transparencies were clipped to a $\frac{1}{8}$-inch-thick sheet of yellow translucent, textureless plastic which was held upward to utilize sky light for illumination in the field. Ground surveys involved persons familiar with each of the diseases and, where in doubt, isolations were made to confirm the cause of tree condition.

COMPARATIVE RESULTS OF AIR PHOTOGRAPHY AND GROUND RECONNAISSANCE

Dwarfmistletoe is a serious disease of black spruce, a valuable species used in the manufacture of paper. Black spruce in Minnesota usually occupies extensive wet sites which, because of their inaccessibility, are not easily observed except by using aerial photography (Anderson, 1949). Centers of infection are visible on conventional minus-blue panchromatic and infrared photography if a sufficient number of trees have been killed to create a noticeable hole in the crown canopy. Calculation of the increase in areas of infection centers and tree-volume losses are possible with the use of sequential aerial photography (Meyer and French, 1966). With conventional photography, however, infected

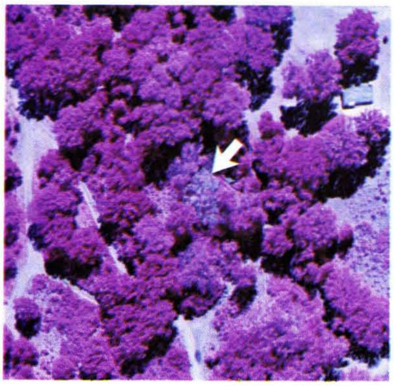

PLATE 1. Elm with Dutch elm disease. Shown 2X original 1:5,000 scale.

PLATE 2. Elm with Dutch elm disease. Shown 2X original 1:5,000 scale.

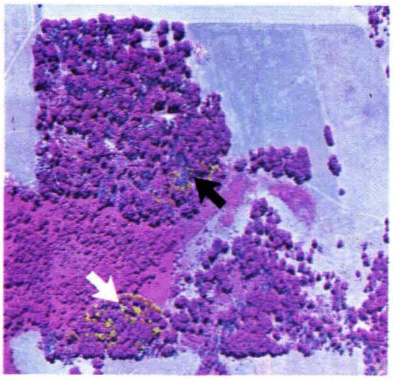

PLATE 3. Stand of oak with oak wilt showing trees in process of wilting (white arrow) and defoliated, previously killed trees (black arrow); 1:6,000 scale.

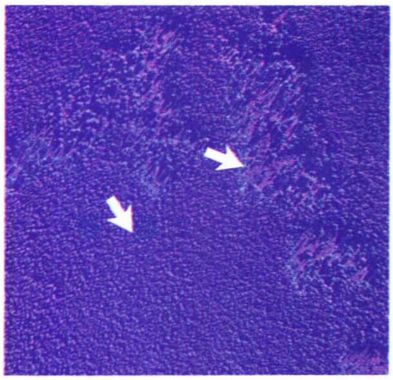

PLATE 4. Black spruce stand with dwarfmistletoe infection center; 1:4,500 scale.

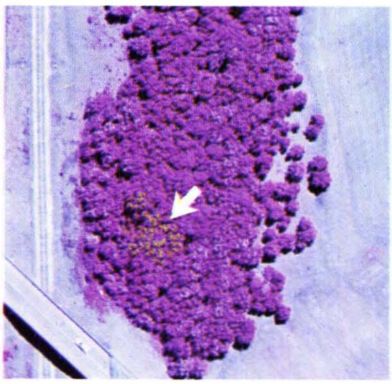

PLATE 5. Wilted crowns of northern pin oak probably due to drought. Shown 2X original 1:5,000 scale.

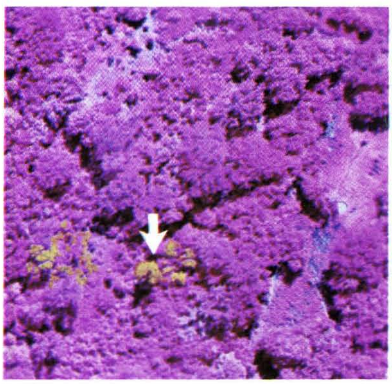

PLATE 6. American elm with insect-damaged foliage. Shown 2X original 1:5,000 scale.

and dying trees which surround these infection centers are not detectable and new infection centers, which are very important in a control program, cannot be detected until several years after establishment.

In an area in north-central Minnesota, black spruce stands were photographed at scales of 1:4,500, 1:13,500 and 1:25,000 with ektachrome infrared in August prior to hardwood autumn coloration. Quite marked differences were evident between healthy trees and those that were dead or dying, as were small newly-developed infection centers without well defined canopy openings (Plate 4). A considerable number of live but infected trees were also evident where suitable lighting, filtering and stereoscopic magnification were used.

The 1:4,500-scale was somewhat too large, as excessive radial displacement sometimes made it difficult to observe crowns stereoscopically. The 1:13,500 scale, on the other hand, was considered too small as color differentiation decreases with increased altitude, and tends to eliminate the necessary subtle color differences. Future flights for the dwarfmistletoe study will specify photo scales in the 1:6,000 to 1:8,000 range.

Dutch elm disease in Minnesota has not caused the extensive losses that have occurred in other states and, thus far, infected trees are relatively uncommon and difficult to locate. Control measures depend on effective surveys for infected and dead trees, now accomplished in some communities primarily by ground surveys. One such survey required one month to cover approximately 65 square miles, and the survey by no means resulted in a 100-per cent detection of infected trees.

Our first attempt in 1964 at detecting Dutch elm diseased trees was in a small community along the Mississippi River, 40 miles northwest of Minneapolis. Ektachrome infrared film was used at scales of 1:5,000, 1:15,840 and 1:25,000. Although other causes of color change in the photography were encountered (including insect infestations, dead branches, and drought) one tree with the Dutch elm disease was detected (Plate 2). Several infected trees were also detected on similar photography taken in 1965, an example of which is shown in Plate 1.

In 1966 three 1×3-mile flight strips, each at scales of 1:6,000 and 1:9,600, were flown of areas in Minneapolis and St. Paul where cases of Dutch elm disease were known to exist. In the St. Paul strip three elms were infected, all of which were detected on the photography. Seven elms with salt injury, and three with native elm wilt, were not detected on the photography. Apparently native elm wilt is not easy to detect on aerial photography unless over 20 per cent of the trees are dead. Until the interpreter developed experience in species recognition, some odd species were selected for ground checking because of off-color appearance (e.g., Russian olive, white poplar).

In one of the Minneapolis areas, 73 trees seemed to be diseased, and 59 of these were elm. Of the 59 elm, 47 were detected on the aerial photography and every one of the additional 12 trees found by ground survey was immediately adjacent to one spotted on the photographs; thus, every potential center was detected from the air. Fourteen of these trees were dead or dying of Dutch elm disease, including one group of three trees one mile away from any known case of the disease. The remaining 36 of the 59 photo-detected elms had small curled leaves, or were dying from unknown causes. In this area, oak wilt was a minor factor and other off-color tree species were not a problem, mainly as a result of greater species identification skill on the part of the interpreter. Throughout, the 1:9,600 scale photography was found to be comparable in detection capability with the 1:6,000 scale.

Oak wilt is a very common disease in southeastern Minnesota and some communities are attempting control by detecting and eradicating infected trees. In July of 1964, monoscopic coverage ektachrome infrared photography at a scale of 1:6,000 was obtained for a portion of a community where oak wilt was common. Despite problems of film color balance, and lighting and viewing of transparencies, many oak wilt infection centers were evident. The same area was photographed in similar fashion in 1965, and infection centers were again quite evident.

In 1966 stereoscopic coverage at a scale of 1:9,600 was obtained of the entire community, and both dead and wilting trees were detected. Defoliated trees (those that had died prior to 1966) appeared as filmy blue-green patches, whereas those in the process of wilting were shades of yellow and yellow-green (Plate 3). Although the ground survey-aerial interpretation results have not been completely coordinated, approximately 60 per cent of the infection centers located by ground reconnaissance were detected by aerial photography.

The 1966 St. Paul test strip, flown primarily for Dutch elm disease detection at

1:9,600 scale, also produced some information with regard to oak wilt. A total of 17 oaks with wilt were detected on the ground, 14 of which had previously been detected on the photographs. The 3 trees missed on the photography were in the understory and all of them had died in 1965. Less experienced personnel on the ground might very well have missed some of these 17 trees.

Also on the ground in this St. Paul community, 23 bur oak were found with wilt, 14 of which had been detected on the aerial photography. Of the 9 trees missed on the aerial photography, the amount of wilt involved no more than 20 per cent of the crown, except for one tree that was partially hidden by buildings. In control programs, however, the bur oak is of minor consequence as compared to red oak.

OTHER TREE CROWN DISCOLORATIONS were also detected with ektachrome infrared film, including yellowing of oak crowns due to drought (Plate 5), and insect attack on elm (Plate 6).

Discussion and Conclusions

Ektachrome infrared aerial photography was very effective in locating trees with Dutch elm disease and oak wilt and, in these studies, resulted in the detection of nearly 100 per cent of the dead and dying elms, and from 60 to 80 per cent of the red oak with oak wilt. The principal apparent advantage of the aerial photography over ground survey is the reduction in time required. Cost figures are not yet available for comparison, but it seems reasonable to assume that, with a trained interpreter properly equipped, the cost of aerial detection should be less than what a ground survey would be for the same area. In one 64 square mile community, one month was required for a complete ground survey of the elms, and the cost was approximately $5,000. We expect that an aerial survey of this area could be completed in half this time and for less money.

This type of aerial photography may not be commercially pratical in locating dwarfmistletoe infection centers of black spruce because of the low value of the crop per acre, and because more advanced infection centers can be located by means of conventional forest aerial photography. However, for the more valuable shade trees, such as elm and oak, it may be economically feasible to use the ektachrome infrared photography and, with further study, it may be possible to locate a high percentage of infected trees in less time and at less cost. The photography may also serve communities in ways other than detecting tree diseases, and these other services would help to reduce further the costs for disease detection.

Acknowledgment

Appreciation is expressed to Edwin G. Tibbils and Norman L. Fritz of Eastman Kodak Company for providing advice and experimental positive color prints for the project. Funds for the dwarfmistletoe aerial photography were provided under provisions of the McIntire-Stennis Law (P.L. 87–788).

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