3-1967

B646: Aerial Photographic Methods of Potato Disease Detection

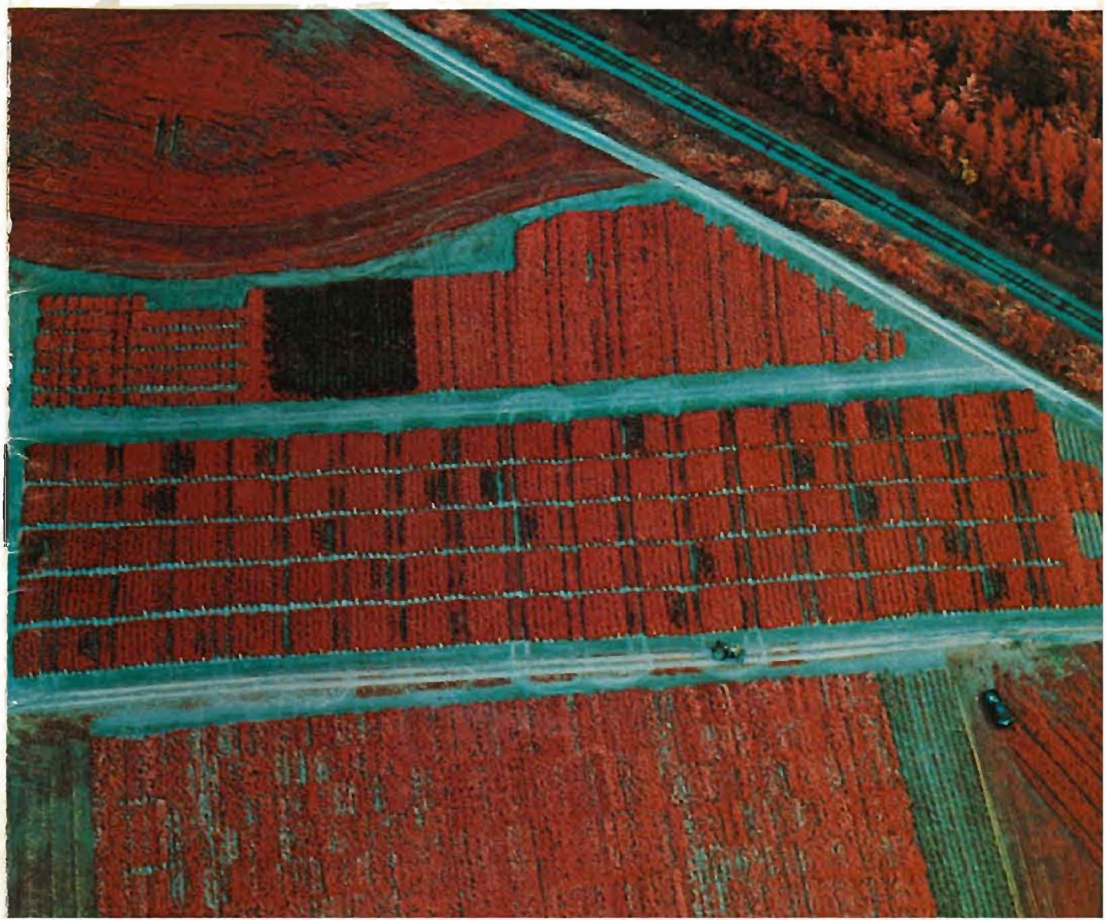
F. E. Manzer

George R. Cooper

BULLETIN 646 MARCH 1967
Maine Agricultural Experiment Station
UNIVERSITY OF MAINE

AERIAL PHOTOGRAPHIC METHODS OF POTATO DISEASE DETCTION

Franklin E. Manzer
George R. Cooper



COVER

In aerial photographs taken with Ektachrome Aero Infrared film healthy potato foliage appears red while foliage damaged by late blight has a dark green appearance. The broad rectangular area in the center is a late blight fungicide experiment containing a total of 180 three-row plots 25 feet long. Some of the individual plots are readily discernible by their dark color, indicative of late blight development. The large dark area above the fungicide experiment is a block of untreated potatoes, artificially inoculated, which served as the primary source of the pathogen in the test plots. Other potato experiments adjacent to this block were protected from infection by fungicide treatments as were those in the foreground. Corners of two clover sod fields are shown in the upper left and lower right of this photograph.

CONTENTS

ACKNOWLEDGMENTS

The authors wish to thank Mr. Norman L. Fritz and Mr. Raife G. Tarkington for their assistance on technical problems and for the films supplied through them by the Eastman Kodak Company. The authors also wish to thank Mr. Rolph M. Augustin, Jr., of the Polaroid Corporation for providing films, equipment and helpful suggestions.

SUMMARY

Aerial photography was shown to be a valuable tool for the detection of late blight and other diseases and disorders of potato. Aero infrared and Ektachrome Aero Infrared films were used to demonstrate that potato foliage, normally highly reflective to near-infrared radiation, loses this property when in an unhealthy condition. The loss in reflectivity seems to vary in proportion to the magnitude of the vine damage. Vine damage resulting from infection by the late blight fungus can be detected on either of the infrared films before visual plant symptoms develop.

Ektachrome Aero and panchromatic films were also used in this study. They were found to be useful in the detection of Verticillium wilt, drought damage and mineral deficencies, but distinctly less effective than the infrareds for the detection of late blight damage.

An inexpensive densitometer was used to estimate relative late blight incidence in experimental plots by measuring the amount of light transmitted through transparencies made from infrared photographs. The method was found to be useful and effective as an adjunct to the usual visual ratings made in the field.

This work will be continued to further expand the usefulness of aerial photography in plant disease work.

AERIAL PHOTOGRAPHIC METHODS OF POTATO DISEASE DETECTION

F. E. Manzer and G. R. Cooper*

INTRODUCTION

Known diseases of the potato are probably more numerous and diverse than those occurring on most any other food crop of the world. Although many of these diseases are of minor economic importance, several can cause substantial losses despite extensive control efforts. Control of late blight, for example, can be both expensive and ineffective unless the applications of fungicides are properly timed. Timing of these applications is dependent upon accurate knowledge of both weather conditions and inoculum potential. Potato dump piles are probably the most important source of primary inoculum in Maine; but when late blight becomes established in fields, its progress there largely determines the inoculum potential. Conventional ground evaluation of disease development in the field has not been satisfactory because it is too slow to be practical as a source of useful current information. Aerial disease survey offers a practical solution to the need for speed, but until recently, no method was available for identifying small foci of infection from aircraft. This new development involves the use of photographic techniques.

Aerial photography dates back to around 1860 (1), and is therefore certainly not new. It was not until 1956 however that Colwell (4) demonstrated its potential usefulness in plant disease work. He showed that panchromatic, color and especially infrared aerial photography could be used to detect rusts and virus diseases of small grains and certain diseases of citrus. Colwell's work stimulated Brenchley and Dadd (2) to study infrared aerial photography of the potato late blight disease in England. In 1962 they reported that infrared was far superior to conventional photography for detection of this disease. The present study, begun prior to the appearance of Brenchley and Dadd's report, was likewise initiated to adapt Colwell's methods to the study of potato late blight. The primary objective was to develop aerial methods of obtaining current field data on late blight incidence. As the work progressed, however, the methods were further adapted as a research tool, and diseases other than potato late blight are currently being investigated. The authors have already presented preliminary reports of progress (7, 9, 10).

---

* Professors of Plant Pathology and Botany, respectively.

MATERIALS AND METHODS

Photographic Films

In the fall of 1961 aerial photographs were taken of the fungicide test plots at Aroostook Farm, Presque Isle, Maine, using Kodachrome film in a standard 35 millimeter camera. These photographs showed only those areas where the potato plants had been severely defoliated by late blight. They did not show the areas in which disease was present but had not caused substantial loss of foliage.

During the summer of 1962 a series of photographs were taken of blighted foliage from the ground to determine optimum film-filter combinations.[1] In addition to various types of conventional color and panchromatic film, a black and white film (Kodak Type 5424) sensitive to visible light and to near-infrared wavelengths of radiation (700 to 900 millimicrons) was used. After a study of the potential of these films when used at ground level, two series of aerial photographs were taken of the fungicide test plots when late blight was developing rapidly.

A fourth type of film known as Ektachrome Aero Infrared or "Camouflage Detection Film" (Kodak Type 8443) was added in 1963. The visible red dye in this film is sensitive to infrared wavelengths in the 700 to 900 millimicron region. Thus healthy foliage being highly reflective to these wavelengths, appears red on this film whereas blighted foliage, having low infrared-reflectance, is not red. Colwell (5, 6) and Gibson et al. (8) present further information on the properties and uses of the film. Norman and Fritz (12) have reported on its use for identifying virus diseases and other disorders of citrus.

All of the above films were reevaluated in 1964 and 1965. In addition to these, a special type of black and white infrared film (Polaroid Type 413), supplied by the Polaroid Corporation was tested. This film can be developed and viewed 15 seconds after exposing, and it is similar to conventional infrared film in spectral sensitivity though of somewhat lower resolution. It was used in both aerial and ground tests.

Film and Print Processing

The precautions normally used in the handling of black and white or color films are inadequate when using infrared films. The loading of the camera must be done in complete darkness as must the unloading. Even a very dimly lighted area results in fogging the film several layers

[1] In these tests Kodak Wratten Nos. 12 (yellow), 25 (light red), and 89B (deep red) filters were used with black and white infrared film. For further information on film properties and filter requirements the reader may consult "Photo-Lab-Index" (3).

FIGURE 1. Ektachrome photographs of a potato fungicide experiment, while better than black and white photographs, fail to define clearly the areas of disease incidence and are of little use in estimating relative disease severity.

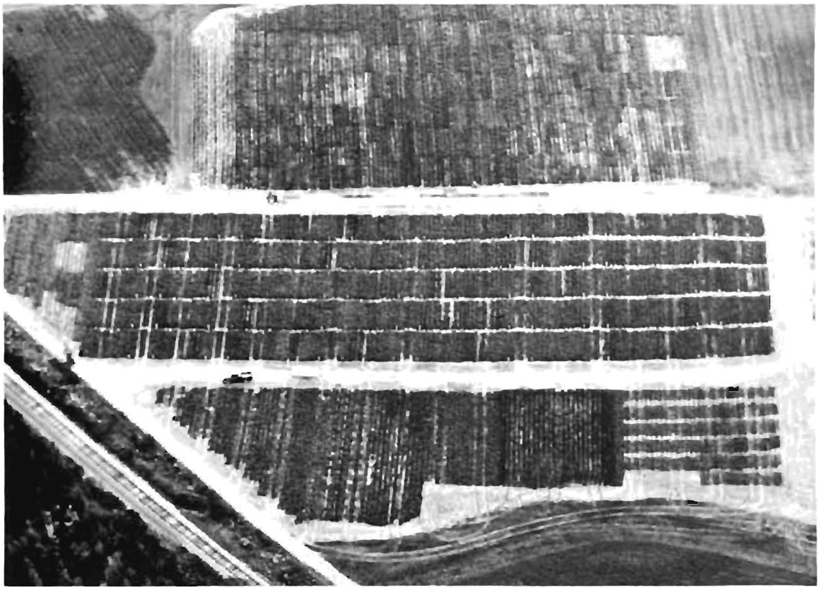


FIGURE 2. Panchromatic photographs of a potato fungicide experiment do not define clearly the areas of disease incidence and have been of little use in the estimation of disease severity.

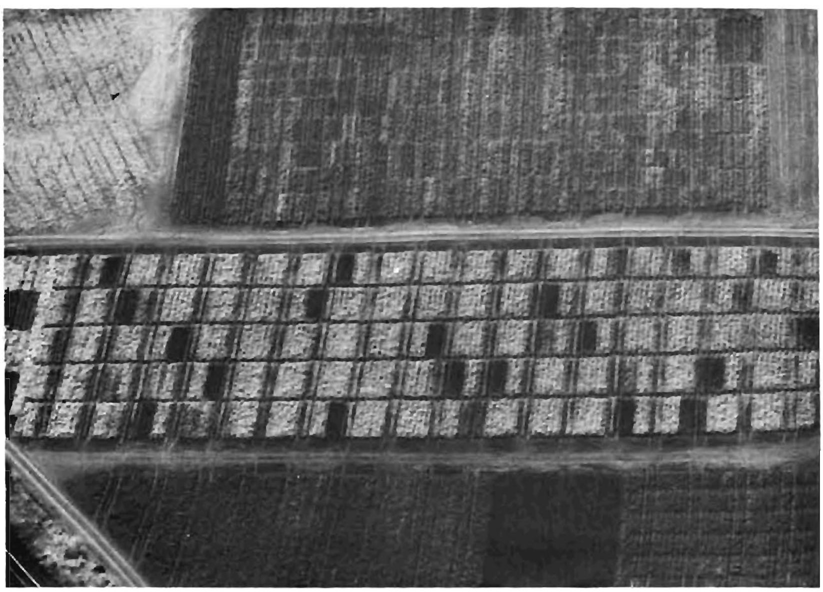


FIGURE 3. The location and relative severity of the potato late blight disease are clearly shown in this infrared photograph of a series of small experimental plots designed to compare the relative efficiencies of disease control fungicides.

FIGURE 4. Individual late blight lesions can be seen as dark areas on white-appearing potato leaves u g black and white infrared-sensitive film (Polaroid Type 413).

FIGURE 5. Polaroid Infrared film (Type 413) was used to obtain this closeup view of healthy and late blight-damaged foliage in fungicide test plots. This film was also used for aerial photographs.

Polaroid-Land camera was used in both the ground and aerial photography.

A Cessna Model 170B was used as the aerial platform for the aerial work except in 1962 when the photography was flown with a Piper model PA-11. In this instance, a Fairchild F-8 aerial camera with a 12-inch lens was employed. In 1965 a few of the aerial photographs were taken from a helicopter.

A sensitive CdS darkroom light meter (S & M Model 960P available from Olden Camera, N.Y.C.) was modified for use as an optical densitometer. This instrument was used to measure the transmission of light from a constant source through positive black and white transparencies made from infrared negatives. Completely infected plots (untreated) and those nearly free of late blight were used to establish the two extremes of the light transmission curve, and intermediate points were established by means of an optical step-wedge. Hence by reading the density of an area on the photograph an estimation of the percentage of defoliation by late blight could be obtained (fig. 11). Further testing of this method has included the use of vertical photographs taken from the ground using a remote-operating camera on a tractor mounted boom (figs. 9 and 10).

RESULTS

Conventional Photography

Aerial color and panchromatic photographs of potato fungicide test plots at Aroostook Farm showed the areas where severe defoliation from the late blight disease had occurred. Areas of only moderate infection, however, could not be discerned in these photographs (figs. 1 and 2).

Infrared-Black and White Photography

The use of infrared-sensitive black and white film with the proper filters demonstrated that, following infection by the late blight fungus, potato plants undergo a marked loss in reflectance to near-infrared radiation. This effect is apparent in photographs even before the plants develop discernible visual evidence of infection (figs. 3, 4, 5, 6 and 7).

As one might expect, the discrepancy between infrared photographs and visual symptom evaluation of apparent foliage damage was greatest during periods of blight-favorable weather.

Ektachrome Aero Infrared Photography

This film has proved to be the most adaptable to aerial disease detection work but it has also been the most difficult to handle. The addition of color greatly extends the film's versatility with suitable filters but light quality, angle of incidence and exposure were found to be critical. The processing of the film also requires special care to obtain reproducible results. Healthy potato foliage, being of high infrared reflectance, photographs as red but as this reflectance is lost the color change will go through magenta, purple and finally dark green depending on the magnitude of the loss. As with black and white infrared film the loss in near-infrared reflectance can be related to the extent of foliage damage due to late blight (figs. 8 and cover).

Photogrammetric Estimation of Foliage Damage

Objective estimates of the degree of foliage damage in late blight fungicide test plots were obtained by measuring the relative amounts of light passing through positive black and white transparencies of these plots. The optical density of these transparencies made from infrared sensitive negatives was low for plots with little foliage damage and high where damage was substantial. In general these measurements were in agreement with visual foliage ratings but some discrepancies were encountered. First, plots with low visual foliage infection were sometimes found to have optical densities higher than expected. This can be accounted for by the findings of earlier work which had shown that blight infections could be detected on infrared film before they were visually evident. Secondly, it was noted that some of the most severely blighted plots were somewhat less dense than expected. Investigations showed that these plots had become infected early in the season and more of the foliage had been destroyed exposing soil beneath. Soil, being more reflective than diseased foliage, will therefore give a lower density reading in the photograph. One further source of error results from the fact that certain agents other than late blight such as, drought, lack of fertilizer, other diseases, etc., can cause a reduction in near-infrared reflectance.

Detection of Other Diseases and Disorders

Aerial photographs of commercial potato fields showed that many agents affecting plant growth resulted in a reduction of the near-infrared reflectance of the foilage. For example, drought damage, nutritional disorders and the Verticillium wilt disease all appear similar in photographs using the film and filter combinations used in this study. It is possible that other film-filter combinations may be found which would permit differentiation of damage from these various causes but this work remains to be done. In addition to infrared films, normal color and panchromatic films were found to be useful in detecting poor vine growth particularly when a change in normal green color was involved (figs. 12 and 13).

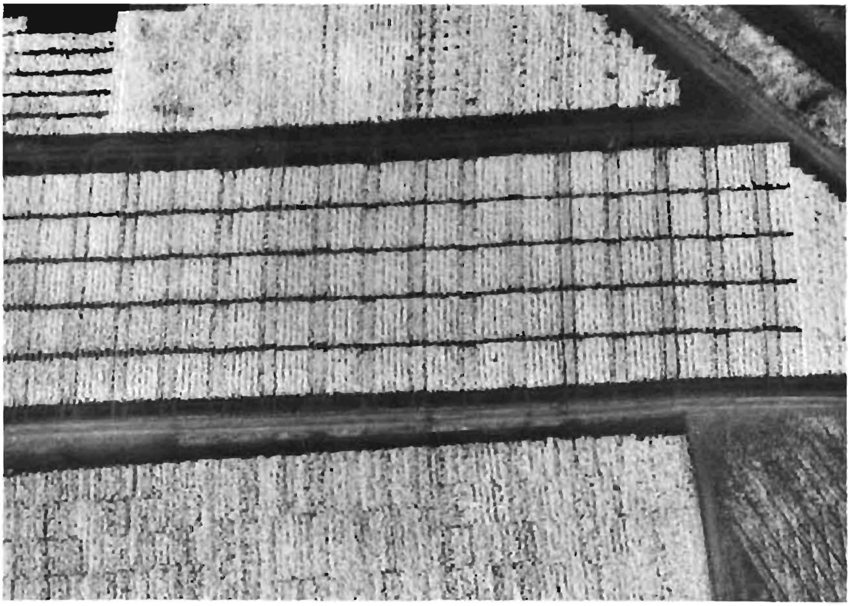


FIGURE 6. The late blight disease can be seen to be largely confined to the wheel rows which were artificially inoculated in the fungicide tests described in the cover photograph caption.

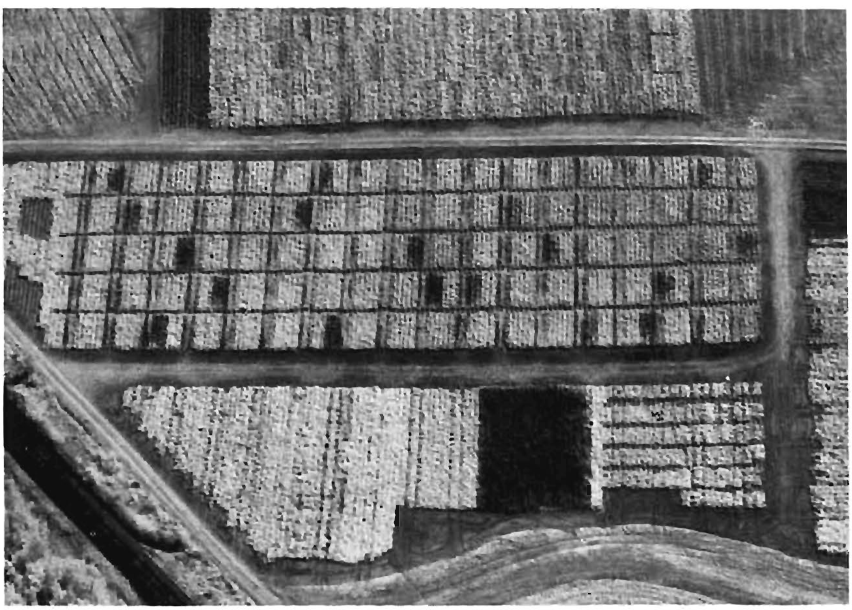


FIGURE 7. This photograph, taken in late August, shows the development of late blight in the fungicide test plots two weeks after the stage shown in figure 6. The almost black square area below the test plots was used as the source of inoculum and can be seen in figure 6 as the disease was becoming well-established.

FIGURE 8. Ektachrome Aero Infrared or "camouflage detection" film shows marked contrast between late blight infected plots, dark areas, and healthy plots, red areas, in a fungicide experiment on potatoes. Note that this photograph, taken 15 days following the one on the cover, shows increased late blight development. Other potato experiments shown here had been sprayed with sodium arsenite and vines are partially dead.

DISCUSSION

The original objective of this research was directed toward developing an acceptable method of estimating the progressive development of potato late blight which is essential for accurate disease forecasting. As advancement was made toward this objective it became evident that aerial photography offered considerable promise as a tool in potato disease research. Realization that the late blight disease could be detected in its incipient stage by use of infrared-sensitive film brought with it both great practical value and confusion. The confusion arose when attempts were made to interpret the photographs and correlate them with visual symptoms. It was also found that other plant disorders could be detected with this film. While this discovery demonstrated a still greater usefulness of the technique, it further complicated the interpretation. The solution to these problems was hindered by the ever-changing nature of living material and by the difficulties encountered in obtaining uniform conditions for photography. The relatively short daily period of suitable lighting (high sun angle) was also a limiting factor as was the requirement of relatively safe and suitable flying conditions. Moreover, most of the photographic data had to be obtained during the period from mid-August to mid-September, when late blight development usually occurs in Aroostook County.

The problem of interpreting photographic evidence of incipient disease development was resolved by making daily visual readings in the field after the photographs were taken. Visual symptoms usually became apparent within one to three days after photographic evidence of disease, depending on the weather for disease development. Weather conditions prior to photographing also helped to establish the validity of interpretation since the likelihood of an infection period at the proper time could be determined. Knowing that infrared film can detect incipient infections made the densitometer estimation of late blight incidence much more useful as an adjunct to visual ratings. This is because fungicide evaluations and certain other types of late blight research require accurate determination of low disease incidence. Visual evaluation is nonetheless important however, to insure against erroneous estimates resulting from both severe late blight damage and damage due to other causes.

Field observations are likewise of prime importance for disease survey work. Since the film was shown to record vine damage due to certain other causes in a manner similar to that for late blight, it became necessary to develop methods for determining the causal agent. In most instances a quick ground check was all that was necessary. The use of normal color film in addition to the infrared was found to be very helpful since such diseases as Verticillium wilt also cause a yellowing of the vines as well as a loss of infrared reflectance. Drought damage and mineral deficiencies can cause vine yellowing but usually an accurate distinction can be made by use of ancillary information such as past weather, knowledge of the soil and crop history in an area, and general topography. To obtain greatest reliability, field observations were found to be desirable for survey work, but the gathering of this "ground truth" could be limited to those fields where the infrared photography indicated non-healthy vine growth, thereby effecting a considerable saving in time and travel.

These studies have demonstrated that aerial photography can be of considerable value both as a tool for basic potato disease research and as a highly practical method for obtaining disease survey information. With the proper film-filter combination late blight can be detected prior to the development of visual symptoms, and an estimate of the damage caused by the disease can be obtained. This capability has an immediate practical usefulness in the control of the disease. For example, periodic survey flights over potato fields sprayed by aircraft can, via infrared photography, show the aerial applicator and the grower when and where added fungicidal protection may be needed. Moreover, the ability to obtain current information on disease incidence over a large area is useful not only in plant protection work but also in the making of reliable estimates of total crop production.

The demonstrated versatility of the Ektachrome Aero Infrared film suggests that it may be useful for differentiating some of the disorders of potato now undistinguishable on black and white infrared film. It may also be possible to identify virus diseases in potato with this film as has been done on citrus. The authors plan to concentrate future efforts on the uses of Ektachrome Aero Infrared film in potato disease work. In addition, more research is needed both to perfect ground methods of obtaining vertical photographs and to improve the reliability of photogrammetric methods of evaluating them. As an adjunct to these studies on potato, preliminary evaluation of the use of these methods on apple, blueberry and other economic crops in Maine have been initiated and will be continued.

The use of infrared photography for aerial plant surveillance has been adapted to many special purposes since Colwell's (4) report in 1956. Norman and Fritz (12) report its usefulness for surveying virus and other disease damage in Florida citrus. Myers et al. (11) are making extensive use of aerial methods of evaluating and mapping soil salinity in Texas. There are still other applications, particularly in forestry (1) and for a thorough discussion of them in terms of worldwide agriculture, the reader is referred to a publication of the National Research Council now in preparation, tentatively titled, "Multispectral Sensing of Agricultural Resources" (Editor-in-Chief, J. Ralph Shay).

LITERATURE CITED

1. American Society of Photogrammetry, Manual of Photographic Interpretation. George Banta Company, Inc., Menasha, Wisconsin, 868 pp. 1960.
2. Brenchley, G. H. and C. V. Dadd. 1962. Potato Blight Recording by Aerial Photography, N.A.A.S. Quarterly Review, London, England 57:21-25.
3. Carroll, John S. (Ed.), 1965. Photo-Lab-Index. Morgan and Morgan, Inc. Hastings on Hudson, N. Y. 24th Edition.
4. Colwell, Robert N. 1956. Determining the Prevalence of Certain Cereal Crop Diseases by Means of Aerial Photography. Hilgardia 26(5):223-286.
5. Colwell, Robert N. 1961. Some Practical Applications of Multiband Spectral Reconnaissance. Am. Sci. 49(1):9-36.
6. Colwell, Robert N. 1964. Aerial Photograph—A Valuable Sensor for the Scientist. Am. Sci. 52(1):16-49.
7. Cooper, G. R. and F. E. Manzer. 1964. Further Development of Aerial Photographic Techniques for Potato Late Blight Detection. Phytopathology 54:127. (Abs.)
8. Gibson, H. Lou, William R. Buckley and Keith E. Whitmore. 1965. New Vistas in In Infrared Photography for Biological Surveys. Jour. Biol. Photo. Assn. 33(1):1-33.
9. Manzer, F. E. and G. R. Cooper. 1963. Infrared Photography of Potato Late Blight. Phytopathology 53:350. (Abs.)
10. Manzer, F. E. and G. R. Cooper. 1965. Photogrammetric Estimation of Potato Late Blight Incidence. Amer. Potato Jour. 42:293-294. (Abs.)
11. Myers, Victor I., David L. Carter and William J. Rippert. 1966. Photogrammetry and Temperature Sensing for Estimating Soil Salinity. Int. Comm. on Irrig. and Drainage 4th Cong. New Delhi, India. Question 19:39-49.
12. Norman, Gerald G. and Norman L. Fritz. 1965. Infrared Photography as an Indicator of Disease and Decline in Citrus Trees. Proc. Fla. State Hort. Soc. 78:59-63.

NOTE: The following literature citation was received too late to be included in the text.

Brenchley, G. H. 1966. The Aerial Photography of Potato Late Blight Epidemics. Jour. Royal Aero. Soc. 70:1082-1085.