AERIAL PHOTOGRAPHY AS A SURVEY TECHNIQUE FOR THE ASSESSMENT OF BACTERIAL BLIGHT OF FIELD BEANS[1]

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Abstract

Aerial infrared false-color photographs were used to assess the incidence of seed-borne bacterial blight caused by Xanthomonas phaseoli in 34 bean (Phaseolus vulgaris) fields in southwestern Ontario in 1968. The percentage of the crop area affected by blight was determined from the photographs by a scanning technique. Techniques for separating the colors in the 3-layer emulsion and reproducing them as separate black and white positives are discussed and illustrated. In some fields up to twice the number of infected plants were detected by infrared photography as were found by ground surveys carried out the same day. The incidence of blight was correlated with the pedigree of the seed used in planting the fields, ranging from zero in many fields of Breeder seed to more than 50% in some fields of Commercial seed.

Introduction

The detection of plant diseases by aerial photography has been attempted by a number of investigators and shows promise as a technique for surveys and for studies on epiphytology (1,2,3,4,5). Most of this work has involveu the photography of experimental field plots in an attempt to correlate photographic patterns of disease with ground truth observations.

Conventional ground surveys for plant diseases, as part of a national crop disease loss program, are carried out under the limitations of the manpower available, and they provide estimates subject primarily to the expertise of the individual and the methods used in sampling the crop and assessing the disease. Aerial photography would solve an important problem by providing a survey technique that could cover vast areas in a short time and visibly portray affected areas.

In Canada, approximately 98% of the white bean (Phaseolus vulgaris L.) crop is grown in southwestern Ontario. Breeder seed for this crop is usually grown in California and Idaho, where arid conditions should assure freedom from bacterial blight caused by Xanthomonas phaseoli (E.F. Sm.) Dows. Breeder seed is distributed by the Canadian Seed Growers Association to approximately 25 growers who produce approximately 1 to 2 acres each of Select beans. This crop is inspected twice during the growing season by officers of the CDA Plant Products Division and the plot is given Select status if it is free from bacterial blight. Select seed is then used to produce approximately 1,000 acres of Foundation, followed by approximately 5,000 acres of Certified seed. Despite stringent regulations and inspections, bacterial blight is often present in Breeder seed and the levels usually increase during production of the other seed grades; in most years commercial crops, which are produced from Certified seed, are infected to varying degrees.

Because the disease produces small foci of infection that orginate from infected seed, bacterial blight of field bean was selected as a model for studies on the feasibility of using aerial photography for plant disease detection. Another important consideration in choosing the white bean crop is that at the time of inspection the plants provide a complete canopy of foliage with no visible ground showing on the photographs to interfere with disease interpretation.

The optimum time for photography occurs within a 3 to 5 day period when the plants nave reached maximum growth and chlorophyll content. For white beans in southwestern Ontario this is usually between August 12 and 17 in the Hensall area and slightly later in the Chatham area. At this time o year chlorophyll content reaches a maximum and a sharp contrast between healthy and diseased tissues can be noted. Soon afterward senescence of the crop begins and differentiation of blight symptoms becomes difficult. Because little secondary spread of the pathogen occurs before August 12, initial seed-borne infections can be located and the disease condition of the original seed determined.

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Materials and methods

Kodak Ektachrome Infrared Aero Film 8443 was used in conjunction with a yellow (Zeiss B) filter and processed as a positive from which reversal prints were made. A Zeiss camera having a 12 inch focal length lens was used throughout the study and exposure was f. 5.6 at 1/300 second. The altitudes of flight were 4,350 feet and 9,150 feet to produce scales of 1:3600 and 1:8400 respectively (6). In the flight area a total of 803.93 acres, including 34 bean fields ranging in size from 2.4 to 80.52 acres, were photographed.

To derive the percentage infection in each field after disease interpretations had been made from the photographs, we used a drum scanner method (7) which measures, depending on the photographic scale, areas of the film corresponding to field areas of from 1.4 to 7.8 sq ft. The areas of diseased and healthy foliage in each field were then recorded on magnetic tape and the percentage area affected by blight calculated. The IR photos were taken August 12, 1968, and ground surveys of the fields photographed were made during the period July 28 to August 19.

Results and discussion

The area of study near the town of Hensall, Ontario, is illustrated in Figure 1 (see map, inside back cover). In this 7 sq mile area tile chief agricultural crops are white beans, cereals, and corn. In Figure 1, the map (left) shows the location and acreage of the bean fields examined and includes the percentage of plants affected by bacterial blight in each field as determined from the infrared (IR) photographs; on the right is a black and white translation reduced from the original false color photographs of the area taken at a scale of 1/8400. These photographs nave been assembled and matched for "best fit" and are a pictorial representation only of the terrain; measurements should not be taken from them. Of the 34 fields in the flight path, 26 were infected. The highest infection in any field was 52.10%. The total area affected was 33.5 acres or 4.1% of the crop.

The black and white translations referred to should not be compared with monochrome copies from "normal" color prints or transparencies because the color values are not represented by gray levels to which we are accustomed. Furthermore this should not, be confused with original panchromatic aerial photography. The value of false color images lies in the fact that reflected infrared radiation is recorded by a layer in the emulsion sensitized to wavelengths between 0.7 and 0.9μ. To incorporate the IR-sensitive layer and maintain a three-layer system, the blue wavelengths, which can be image-degrading, are eliminated by filtration during the original exposure. Therefore green, red, and infrared radiation is reproduced as blue, green, and red, respectively, hence the term "false color", and it is not really significant that high IR reflection is reproduced as "red" image. Normal color emulsions reproduce a scene containing blue, green, and red in the same colors that produced them during exposure. Although a black and white reproduction represents blue, green, and red in a false color original, the silver densities in the copy should not be evaluated in the same way as copies from normal color because the colors in the IR film used are not true to those in the original scene. However, the color separation procedure uses filters to isolate those colors contained in the three layers of the emulsion and reproduces them as separate black and white negatives (Figures 2 and 3). Blue, green, and red in false color transparencies and prints are produced by yellow, magenta, and cyan dye-layers which are formed during processing.

In any positive color material, the yellow dye absorbs blue from white light, magenta absorbs green, and cyan absorbs red. This system produces the color red in those areas of high IR reflection because the density of the cyan layer is inversely proportional to the exposure that produced it. In other words, high infrared reflection results in a low dye concentration in that sensitivity layer. For example, when the transparency is viewed, the yellow and magenta dyes in the green and red sensitivity layers absorb blue and green, allowing the remaining component of white light - red - to be seen. Red is absorbed by cyan but because it is of low concentration its filtering or absorbing capability is reduced.

To separate the dye layers, the transmitted light from transparencies is recorded separately on continuous-tone black and white emulsions through blue, green, and red filters, thus producing silver densities that can be related to the original color and its position in each of the three sensitivity layers.

At this stage in development of the technique, it is necessary to conduct extensive ground truth studies to identify certain characteristics on the photographs. However, we have found it necessary in many cases to return and reassess fields after seeing the photographs because the photography showed more disease foci than were originally noted visually in the field. In one field (Figure 2), only about 50% of the foci shown by the IR film were detected by ground truth observations made on the day the photographs were taken. Two to three days after the photographs were taken, additional disease foci appeared which correlated with the foci indicated on the photographs. It has been postulated that IR photography detects chlorophyll breakdown in the mesophyll tissues prior to the appearance of visible symptoms of infection (2). In

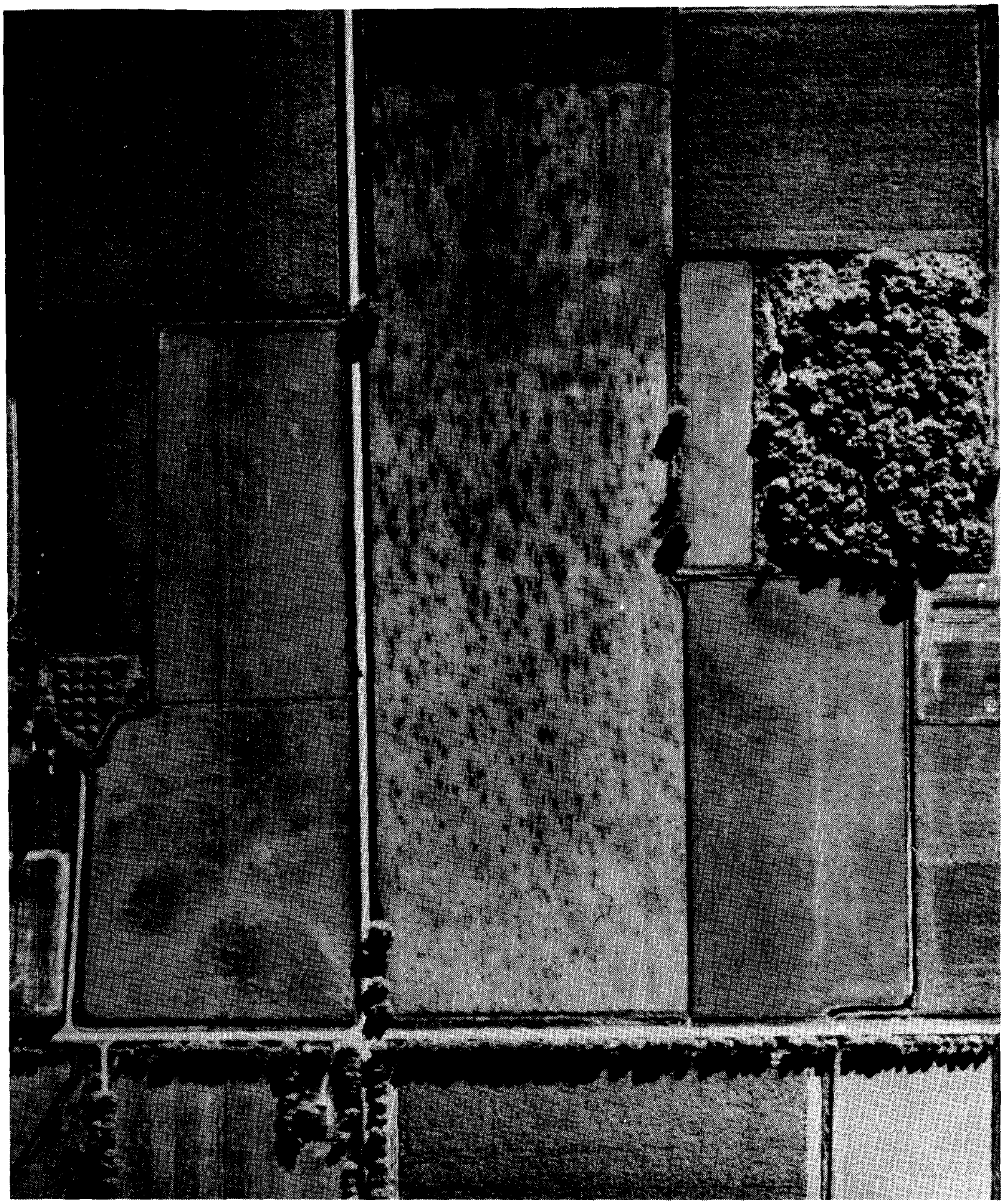

Figure 2. Enlarged black-and-white continuous tone separation from Kodak Ektachrome Infrared Aero film 8443 false color positive print. This reproduction shows only the red filter separation of the cyan dye layer. Dark foci in the center field indicate chlorophyll breakdown in bean plants affected by bacterial blight. Approximate scale: 1/2930.

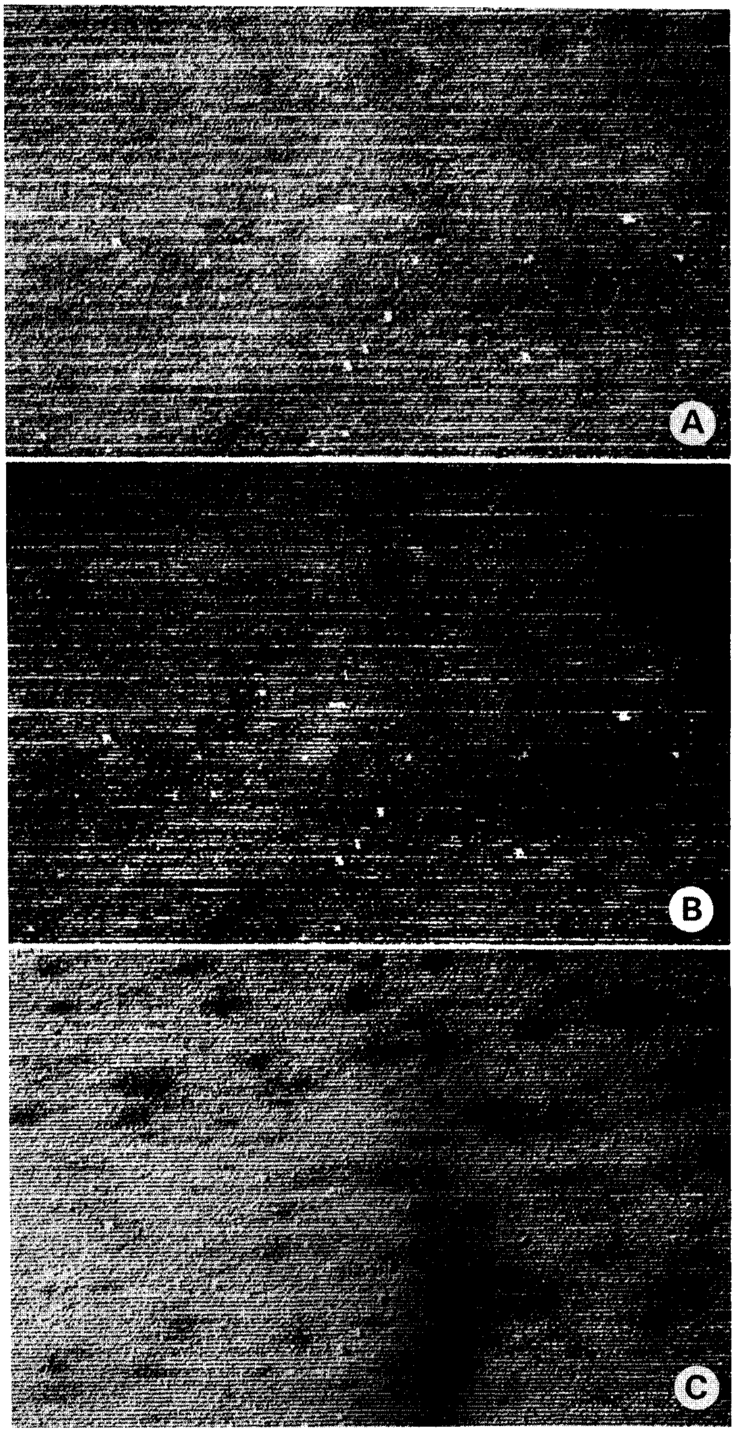

Figure 3. Enlargement of a portion of the same infected field as in Figure 2 but taken from an original camera-exposed false color transparency showing information contained in each sensitivity layer when separated by filters: A) blue, Wratten 47; B) green, Wratten 58; and C) red, Wratten 25. Note at this magnification that individual rows and plants are readily observed. Approximate scale: 1/960.

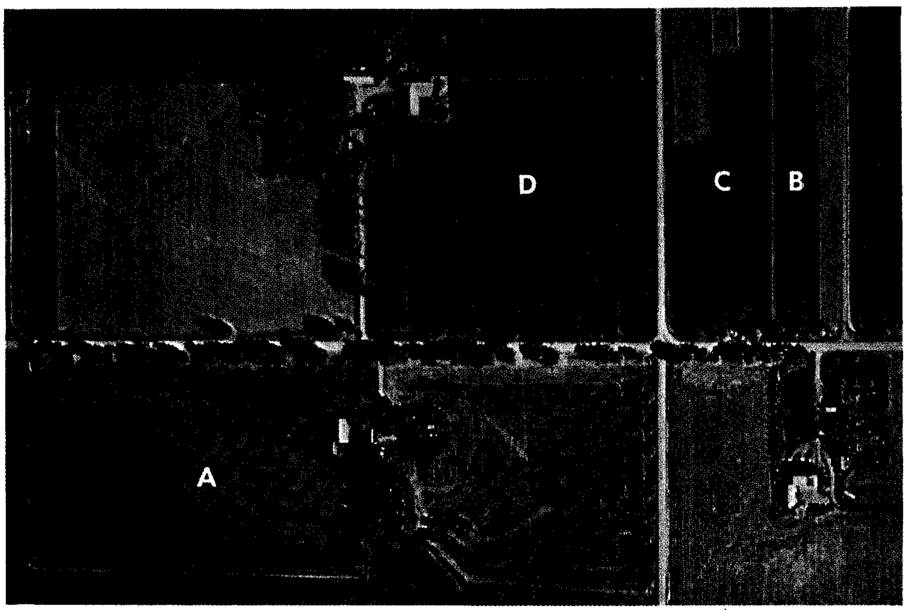

Figure 4. Three-color reproduction from Kodak Ektachrome Infrored Aero film 8443 false color, photographed at an original scale of 1/8400. The photograph depicts four bean fields originating from seed of different pedigree: A) non-pedigreed seed; B) Breeder seed; C) and D) Select seed. The numerous dark areas in A) represent foci of bacterial blight. Approximate scale: 1/7635.

this particular field, it was noted (Figure 2) that fewer foci were present in the area near the crossroads. This area is 2 to 4 ft higher than other areas of the field. Morning dews and fog dissipate earlier in this area and conditions ark not as favorable for development of bacterial blight as in other areas of the field.

In this survey by aerial photography, it was possible to ascertain on a single day the amount of infection arising from seed-borne inoculum in the 34 fields. By conventional means the survey would have taken one man at least 2 weeks and the results would have provided only an estimate based upon sampling. By aerial photography the entire crop was visibly displayed.

From the seed growers' standpoint, this technique displays the importance of using disease-free seed. Figure 4 depicts several fields of various seed pedigree: A) a field that was sown with non-pedigreed seed that was heavily infected with bacterial blight; the seed had been multiplied on this farm for 5 years; B) a Select plot, disease-free; C) and D) Foundation fields, also disease-free, produced from the previous year's Select plot.

It is apparent that in order to use IR aerial photography successfully in its present state of development a number of conditions of crop and disease must be present. The crop must form as complete a chlorophyll canopy as possible so any breakdown in chlorophyll can be detected as a lack of IR reflectance. Large or numerous patches of exposed soil in a field tend to interfere with disease interpretation because of a merging of soil and disease patterns. Also the disease must be present on the leaves photographed because diseased leaves that are covered by an upper canopy of healthy green foliage cannot be detected. Craps such as field beans, corn, and potatoes provide the necessary canopy in mid-to-late season.

Acknowledgment

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