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# The Applications of Remote Sensing to Corn Blight Detection and Crop Yield Forecasting

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# The Applications of Remote Sensing to Corn Blight Detection and Crop Yield Forecasting

by

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## INTRODUCTION

The invasion of southern corn leaf blight throughout Indiana captured the attention of LARS researchers in mid-August. By the end of the 1970 crop year, 64 counties had been declared disastor areas by the U. S. Department of Agriculture. While early estimates forecasted corn production losses of a few percent, November 1 statistics showed a production decline of 20% in the state of Indiana. Similarly, nationwide forecasts for the corn crop went from a few percent in August to reductions of 15% by November.

During the week of August 17, a research project was initiated by Purdue University's Laboratory for Applications of Remote Sensing (LARS) in cooperation with NASA to investigate the feasibility of identifying various stages of the southern corn leaf blight using remotely sensed measurements. LARS and NASA were assisted during various phases of the project by industry, a U. S. Air Force research group at the Rome Air Force Development Center, Rome, New York and the Cooperative Extension groups at Purdue. Credit should be given to the various personnel who assisted LARS to rapidly organize and execute this timely research.

Much has been said and written about the applicability of remote sensing technology to outbreaks of disease in important agricultural crops. The primary motivation for this particular research was to take advantage of a naturally occurring situation to further explore the possibilities afforded by our existing capabilities in remote sensing.

The information which existed at the beginning of the project concerning the blight, such as its epidemiological characteristics and its affects over time on corn plants and yield, was relatively meager. Certainly, the electromagnetic radiation characteristics of infected plants were little known. While southern corn leaf blight has proven to be one of the most serious, if not the most serious, infections to strike corn, the situation is believed to be generally typical of outbreaks of diseases that routinely strike cultural crops. It has become an occasion for the remote sensing community to test its present capabilities and to establish current deficiencies, thus providing guidelines for future program development.

## BACKGROUND

### PATHOLOGY

The southern corn leaf blight disease is caused by the fungus pathogen, Helminthosporium maydis. Evidentally this species is composed of two physiologic races, which are morphologically similar, if not identical, in that the size, shape, number of crosswalls and color of the spores are the same in both races. A distinguishing feature of these two races is the unusually high virulence of one of them on corn containing "Texas Male-Sterile" cytoplasm. Additionally, the spores of this new race are rather large in size ranging from 75 to 80 microns in length. This new race, designated the "T" race is only mildly pathogenic on normal cytoplasm; usually so benign as to cause only small, hardly recognizable lesions.

The old race, designated the "O" race, has existed coincidentally with corn culture down through the centuries. This race attacks both "Texas Male-Sterile" corn and that bearing normal cytoplasm with equal facility but rarely causes any serious problems.

Both races are favored by warm, wet weather. Heavy dews are especially conducive to rapid multiplication of both races. The "T" race appears to be a prolific spore producer. In other words, the "T" race reproduces an abundance of innoculin in a warm, wet environment. The time between penetration of a leaf to production of spores on the dead tissue of the lesion can be as little as seven days under ideal conditions. It is though, exceedingly productive on corn containing "Texas Male-Sterile" cytoplasm.

The symptoms incited by the race are characterized by tan-to-brown eliptical lesions that are generally spindle-shaped and range in size up to about 1 X 1/2 inches. Usually these lesions appear first on the lower leaves. Eventually, more lesions are produced from successive infection of the upper leaves. Lesions are also formed on the husks, and from there the fungus penetrates through the successive shucks in the ear and on and within the kernels. Figure 1 is a photograph of leaves at six different stages of the infection. Stages range from healthy to a severely blighted condition. The leaves shown are representative of the following stages:

0. No infection - no lesions present
1. Very mild - a few scattered lesions which appear mostly on the lower leaves with less than 10% of the lower leaf surface affected.
2. Mild - many lesions appearing on the lower leaves and a few scattered lesions on the upper half of the plant; 10-30% of the lower leaf surfaces and less than 10% of the upper leaf surfaces affected.
3. Moderately severe - lesions on the lower leaves to the extent that large areas of the leaves are non-functional with scattered lesions on upper leaves; 30-60% of the lower and 10-30% of the upper leaf surfaces affected.
4. Severe - lower leaves mostly killed with the upper leaves beginning to die; 60-90% of lower and 60-90% of upper leaves affected.
5. Very severe - nearly all leaves have become non-functional; more than 90% of total leaf surfaces affected.

Healthy corn plants are shown in Figure 2a. Figure 2b shows moderately infected plants and Figure 2c is a photograph of a field of severely infected plants.

The reduction of functional leaves from the disease predisposes the corn plant to stalk rot not only by Helminthosporium maydis, but also by other fungi of less aggressive capabilities. Figure 3 is a photograph of the effects of stalk rot on corn plants suffering from the blight. Such secondary invaders can also grow on or within kernels infected with Helminthosporium maydis. Corn ears suffering from such rotting are shown in Figure 4.

The disease appeared initially in southern Florida in 1970 where seedsmen were growing a winter crop of foundation stocks. From there, it spread to Alabama and Mississippi. The disease fanned out in a northerly direction and week by week progressed to the Corn Belt. Since then it has been recognized from Texas eastward to the Atlantic Coast and northward through Iowa, Ohio, Minnesota, Wisconsin, Michigan and southern Ontario in Canada. Figure 5 illustrates the counties in Indiana where severe blight damage occurred. Spores were evidently windborne and the northerly progression was in a stepwise manner. The pathogen can also be seedborne; seed treatment probably has little or no affect for control of the disease, since the fungus can be within the seed as well as on the surface.

Three major factors are of cardinal importance in the development of any plant disease, and these must act coordinately to bring about disease establishment. These factors are:

- virulent pathogen;
- a favorable environment for reproduction of the pathogen; and
- a susceptible host.

These three requisites have been operative in the production of the southern corn leaf blight in 1970 in that a new virulent race of the pathogen was wide spread, weather conditions in the gulf states and on up through the eastern half of the United States were conducive to rapid growth and development of this race of Helminthosporium maydis and, lastly, a very susceptible host with "Texas Male-Sterile" cytoplasm had been widely planted. It has been reported that some 80% of corn varieties planted in the U. S. in 1970 contained "Texas Male-Sterile" cytoplasm.

## CROP MANAGEMENT - RECOMMENDATIONS AND CONTROL

In 1970, fungicide applications were started too late to be very effective; such treatments should have been started in mid-July and repeated weekly. However, most observers believe that fungicide applications did serve to check the spread of blight and so were justified. Producers were advised to harvest infected fields at as early a date as possible based on the development of ears and moisture content. This early harvest generally required that artificial drying or ensiling be utilized. Not much is known of how well kernels from blighted plants will store. It is generally thought that corn from infected plants can be used as feed without harmful effects to livestock.

While fungicide applications may be effective in 1971, control of this disease can be only satisfactorily accomplished by using hybrid with normal cytoplasm which are quite resistant to the blight. Next year it appears that 20% of the corn crop will be blight resistant, 40% will be blends only half of which are resistant and 40% of the seed will be of varieties which are again susceptible to the blight.

While it appears that Indiana suffered a windborne invasion in 1970, agriculturists say it may overwinter and strike earlier in the growing season next year. If it does overwinter in the north, then its spread earlier in the crop year could lead to more extensive damage to those susceptible varieties. By 1972, sufficient blight resistant varieties should be available for the producer.

## ECONOMIC IMPLICATIONS

The immediate economic consequence of the blight would be an expected drop in production for the 1970 corn crop. The various production loss estimates obviously affected current and future corn prices. Any assessment of this price situation depends upon the accuracy of crop damage estimates, the resultant loss of production and the reduction in the quality of the 1970 crop.

Producers who harvested early and sold early realized prices which reflected estimates of the overall 1970 crop production at that time. A first major price increase attributable to the blight occurred on August 10. Upward pressure of the prices intensified after that date, with future prices on August 21 about 25¢ a bushel above August 1 level. With an expected 4.8 billion bushel corn crop, corn prices seemed destined to settle to a $1 to $1.10 level at harvest. On August 24, the change in crop prospect reflected a $1.35 to $1.40 level. Speculators report that yield reductions on the order of 15% could result in corn prices of $1.60 per bushel. Estimates of expected production for Indiana and the U. S. at various dates are shown in Figure 6.

Blight damage also affects test weight and kernel damage. Price reductions are generally realized by producers when kernels are for any reason graded as distinctly low quality corn. Much of the blighted crop was so affected.

The blight is expected to have major influences on seed corn availability and prices. Corn seed production from the 1970 crop was reduced about in line with the overall crop reduction. Producers will be seeking feed supplies which are resistant to blight. Such seed will being premium prices.

Additionally, the reduced corn crop and resultant higher corn prices boost livestock feed prices and are reflected in increasing prices of livestock.

## RESEARCH OBJECTIVES

On August 17, 1970 a remote sensing research project was initiated in Indiana to investigate the feasibility of identifying the various stages of the disease infestation on a basis of measurements collected with aircraft together with a relatively limited quantity of ground truth. Ancillary studies were already underway by other groups to relate the degree of infestation at a specific stage of plant maturity to yield reduction.

The application objectives for remote sensing in this situation would include:

- finding foci of infection outbreaks and mapping spread to predict and advise (1) spray programs and (2) harvest practices
- determining number of fields infected, the degree of infection for use with current climatological data to predict damage i.e., yield reduction
- determining the epidemiology characteristics of this disease

Investigations were conducted to determine the ability to identify significant levels of infection from photography with different film filter combinations and from spectral measurements made with the University of Michigan and Bendix Croporation airborne spectrometers. Photographic data was to be processed with standard photo-interpretative techniques and digitized multiband photography was to be subjected to computer analysis using pattern recognition techniques. Multispectral measurements were to be analyzed using the same pattern recognition techniques.

These data were to be collected at 7 to 10 day intervals to permit investigations of the temporal characteristics of radiation from blight infected areas.

As a result of the stage of the growing season when this research was instituted, it was only possible to measure tasseled corn. However, measurements of infected plants were collected at different stages of maturity due to the rather wide range of geographic latitude of the flightline from Lake Michigan to the Kentucky-Indiana border at the southernmost tip of Indiana.

## EXPERIMENT DESCRIPTION

Figure 7 illustrates the test site for this research. A flightline following highways U. S. 421, Indiana 43, U. S. 231 and Indiana 57 was established as a representative test site in Indiana. The flightline proceeds from near Michigan City in northern Indiana 260 miles south to near Evansville at the southern end of the state.

Within this site, six intensive study segments were selected. Each segment was 8 to 10 miles long and approximately 1 mile wide. Ground truth information was collected in 30 to 60 corn fields in each segment. These intensive study areas were designated as A, B, C, D, E and F. In addition an area southwest of West Lafayette along the Wabash River was used as a control area.

Table I lists the various dates on which aircraft data over the test sites were collected, the aircraft system used, the geographic portion of the test site covered and the altitude of the aircraft system and the type of data acquired. Data was first acquired on August 19 with the last data being acquired on September 11. By September 11 much of the corn crop was near its final stage of maturity prior to harvest.

Data were to be collected by the University of Michigan aircraft and the NASA RB-57F on three occasions at 7 to 10 day intervals beginning August 24 and ending on September 11. Additional data was acquired by the Purdue University light aircraft photographic system, a Bendix

Aviation Corporation light aircraft system equipped with the Bendix multispectral scanner and an Air Force C-131 aircraft system with a 9 lens 70mm camera system. On September 5 the University of Michigan aircraft flew three 25 mile flightlines in Tippecanoe County in addition to the corn blight test site. Tippecanoe County was also designated for intensive study since much remote sensing data have been collected over the area during the last few years.

Corn fields in each of the intensive study areas were visited near the time of each flight. Area Crop Extension agents and Purdue staff members collected ground truth data on these fields. In addition, they identified crops in all other fields in the intensive study areas. Each corn field was rated as to the degree of blight infestation. Information was collected on the following items: leaf damage, ear and stalk lesions, ear and stalk rot and plant maturity stage. Additional comments on such factors as fertility deficiencies and drought damage were requested.

The specific analysis goals were to evaluate the feasibility of detecting the southern corn leaf blight by each of several remote sensing techniques and further to determine the detectability of various degrees of blight infection with the better of these techniques. The techniques under consideration were:

- standard photo-interpretative techniques applied to various forms of aerial photography;
- automatic pattern recognition techniques applied to digitized multiband aerial photography; and
- automatic pattern recognition applied to multispectral measurements.

Photographic frames were to be digitized using standard television Vidicon systems and drum type microdensitometers. A comparison was also to be made of multichannel black and white photography with spectral data obtained through color separation of three emulsion transparencies.

Pattern recognition techniques to be applied to these data had been incroporated into the LARSYSAA computer software programs by researchers at LARS over the past several years.

## ANALYSIS AND DISCUSSION

Figure 8 and Figure 9 are color and color infrared photographs taken simultaneously from an altitude of 10,000 feet. The fields designated by the letter "A" are relatively healthy corn fields. The fields designated by the letter "B" contain moderately infected corn plants. Fields designated by the letter "C" contain severely infected corn plants. The field designated by the letter "D" is a freshly plowed field. A field of soybeans is designated by the letter "F". Three classifications of corn are clearly discernible in this photography.

The 35mm and 70mm color and color infrared collected by LARS/Purdue has proven useful for distinguishing these three categories of corn: (1) healthy corn, little or no infection; (2) moderately infected corn turning brown due to other influences; and (3) blight-killed corn or early maturing corn. An interpreter sees a mixture of green vegetation and dry, brown vegetation, that is, green corn fields with various levels of brownness. Preliminary analysis of this photography has shown it to be difficult, perhaps impossible, to distinguish brownness due to corn blight from brownness due to other causes, such as natural senescence. However, an interpreter should be able to deduce abnormal senescence if the date of planting and variety are known.

The 9-inch RC-8 camera color and color infrared photography and the 9-inch Zeiss imagery in color infrared taken simultaneously have been given intensive photo-interpretive effort. Intensive study region "D", south of Worthington, Indiana was selected for this concentrated attention because of its diversity of blight infected corn fields and because it coincided with the portion of the scanner data receiving initial attention. Figure 10 is the photograph taken with color infrared film with an RC-8 camera over this area. Figure 11 was taken simultaneously with a second RC-8 camera using conventional color film. Figure 12 was taken simultaneously with the Zeiss camera utilizing color infrared film. An overlay was made for the frames to be analyzed. Each frame covers an area about 10 miles square. Thirty-nine fields for which ground truth was available were located and coded according to field number, leaf damage, maturity stage and estimated yield loss.

It was possible to classify fields into three categories based on the severity of blight infection. Again, these categories correspond to the brownness of the vegetation. Initially, keys in the form of charts were evaluated. Ground cover defined by the keys consisted of soybeans, pasture, hay crops, trees, bare soil and diverted acres. The diverted acres group was considered to be any responses not otherwise defined. Corn fields in area D ranged from the dough stage to the ready-to-harvest maturity stage. Blight levels ranged from mild to very severe (1 to 5). Preliminary results with these keys provided accuracies that ranged from as low as 60 to as high as 99% accuracy. Photographic keys are now being developed to replace the chart. It is believed that the photographic key will produce considerable more accuracy since they will be based primarily on relative color. Copies of photographic data received at LARS generally vary in density and image quality from mission to mission, but appear to be suitable for the present research.

Figures 10, 11 and 12 are photographs taken simultaneously from approximately 60,000 feet with the two RC-8 cameras and the Zeiss camera utilizing color infrared, color and color infrared respectively. The photographs are of area D and were collected on August 24. The following features are called to the readers attention: The area designated as "1" is a power station. Fields designated "2" and "3" are soybeans. The area incorrectly classified and designated by the number "4" is a pasture. Field 8 is a field of corn with blight severity level 4 and of maturity stage 7. Field 9 is corn with level 1 blight and maturity stage 8. The field marked 5 is corn with infection level 2 and maturity stage 4. Field 6 is corn with level 3 infection and maturity stage 5. There is also a seed field that has a stripe pattern and is designated by 7. The owner-producer of this seed field reported that "the 6 female rows with T cytoplasm were making 50 bushels per acre while the 6 rows with normal cytoplasm were averaging 100 bushels".

A frame of the Zeiss photography from the RB-57F flight was selected for automatic analysis. The IBM Corporation's Houston Scientific Center at Houston, Texas volunteered their Vidicon camera computer system to color separate a color infrared frame and subsequently digitize the frame. The striped seed field designated by the number 7 in Figure 10 was selected for this initial analysis using the digitized Vidicon data. Figures 13 and 14 are low-altitude photographs using, respectively, color and color infrared film of this field. Figure 15 shows a color-coded computer classification of this Vidicon-converted color infrared photo. The frame was digitized with a 256 X 256 point raster. The initial results of this effort were most gratifying.

On the basis of this success, fields of a large area are to be similarly digitized and analyzed. Small scale 70mm multiband black and white are to be scanned, digitized and overlayed so that a three-band data storage tape is created which represents the photograph in digital form. In addition to the Vidicon digitizing technique, color infrared photographs will be scanned and digitized in two other ways. In one case, color separations are to be formed in a printing process and a scanning reflectometer will then be used to convert and digitize the data. Thirdly, color infrared transparencies will be converted through the use of a conventional color separation scanner.

The Vidicon conversion system has certain desirable characteristics in that it can be easily used in conjunction with a human interpreter. An operator can focus the optics of the Vidicon system on those fields designated as corn and the system can then digitize that area and convert it to a machine-compatible form in near real time. The operator could be provided with a quantitative analysis of the points within that field. Considerable work will be done in the near future with these data. While LARS scientists are optimistic at this point that such automatic data processing techniques will provide useful information with multichannel photographic data in this application, LARS researchers are doubtful that such data will provide the precision data that can be obtained from airborne scanning spectrometers.

Thus far, analysis of the multispectral airborne scanner data has proven most successful. Data collected on August 24, 1970 consisted of two passes over intensive study areas A through F. Due to marginal weather, data from the first pass is unusable. Similar conditions caused the two southernmost segments of the northbound pass to be unusable. Analysis of segments A, B and C were discouraging. The fields for areas were divided into classes according to blight severity levels. Histograms of the resulting classes were clearly unimodal; the statistics were input to the divergence processor to determine the separability of severity classes. It was found that the classes were non-separable, even when 11 channels were used. More significant improvement was obtained using the thermal infrared channels in conjunction with the visible and reflective infrared channels. These data were collected very late in the day - 6:20 p.m. over area A and it is speculated that the low light levels were responsible for the radiation characteristics of these data. Attention was then shifted to area D from the northbound pass. These data were designated "D2". This area contained a reasonable number of fields with ground truth and which were not obscured by cloud cover. The distribution of corn fields between blight severity levels was also quite satisfactory for the initial investigations. Fields for which ground truth data were available were divided into classes according to blight severity levels. The classes proved to be multimodal, and so were divided into subclasses on the basis of comparisons of histograms of the fields. The result was a total of 15 training classes distributed among five blight severity levels. Level 0 was not represented in this area. The divergence processor was used to determine the best 2, 3, 4, 5 and 11 channels out of 12 visible and reflective infrared channels. Results indicated that as few as three channels could be used to obtain separability between blight levels. A classification using all 12 reflective channels produced results which were qualitatively very satisfactory. Quantitative tabular results were not obtained for this classification. The classification map indicates that most corn fields were classified to a very high degree of accuracy. The majority of errors in the classification resulted from "other" cover types being incorrectly classified as corn. The greatest offenders in this respect were pastures which were mixtures of green and brown grasses.

The analysis has been extended to include a total of 17 channels of data including three middle infrared channels over the range of 1 to 2.5 microns and two thermal infrared channels over the range of 4.5 to 14 microns which have been overlayed on the reflective data. Interestingly the thermal infrared channels did not assist in recognizing corn blight. The latter result is somewhat surprising since the thermal characteristics of relatively healthy green vegetation are surely significantly different from the thermal infrared characteristics of dry, diseased vegetation. It may be that the late afternoon hour in which the data were collected affected the observed response substantially. Further investigation along this line is required.

Summarizing, the analysis of the August 24, 1970 mission data was somewhat limited due primarily to problems arising out of marginal weather conditions at the time of the mission. Results obtained appear to indicate that the southern corn leaf blight can be detected in multispectral scanner data. Preliminary indications from these data are that up to five levels of blight severity can be discriminated at this stage of the growing season, although severely blighted corn may be difficult to discriminate from normally mature corn late in the growing season. Data in the .4 to 1.0 micron region are reasonably effective in detecting blighted corn; additional yield can be gotten from the near and middle infrared (1.0-2.5 micrometers). It is not yet clear whether the thermal infrared data (4.5-14.0 microns) is of value.

Data from the September 5 flight over segment D was selected for the next analysis. Data from 3000 foot altitudes was displayed on grayscale computer printouts in the .62 to .66 and .8 to 1.0 micron wavelength bands. Ground truth information on corn blight severity levels and corn crop maturity was added to the listing. For classifications, the 4.5 to 5.5 and 8 to 14 micron bands were included. When all bands were processed with $DIVERG, the best set of four channels included the 8 to 14 micron band. The 4.5 to 5.5 band did not appear to be as valuable as the 8 to 14 band and it was not used in the classification. The spectral bands selected were .55 to .58, 1-1.4, 1.5-1.8 and 8 to 14 microns respectively. When the thermal channels were not included, $DIVERG picked the following spectral bands: .44, .62-.66, 1.0-1.4 and 1.5 - 1.8 microns, respectively. In order to make direct comparisons between classification with or without thermal overlay, the data was restricted to the 40° field of view of the thermal scanner from the University of Michigan system. Clustering techniques were used to derive seven classes of corn. These classes were combined with three classes of soybeans, pasture, bare soil and trees to produce a set of statistics which was used with the $DIVERG and $CLASSIFY programs. Classification of corn and soybeans was improved by clustering the two cover types together. A total of 23 classes were defined with corn and soybeans having several subclasses. Corn blight severity level 2, three classes; corn blight severity level 3, four classes; corn blight severity level 4, five classes; soybeans, six classes; harvested corn, one class; and trees, one class. It was noted that only a slight overall increase of accuracy of the blight levels was obtained using thermal channels. Still LARS researchers do not feel these results are conclusive. Classification accuracy for corn vs. other cover types were 89.6% correct. Accuracy for blight level categories vs. other cover types were as follows: severity level 2 - 90.5% correct, severity level 3 - 81.2% correct, and severity level 4 - 74.5% correct recognition accuracy. Other cover types were close to 100% and heavy categories were classified with 84% recognition accuracies.

At the time of this writing, analysis is being conducted of the data collected over Tippecanoe County on September 5. Preliminary results of these data are equally encouraging.

This analysis together with results of other efforts have indicated that many of the subclasses of categories as seen in the spectral data results from influences of such factors as sun angle, view angle, etc. Currently, LARS researchers are preparing software programs to transform spectral measurements to measures which are more invariant with such conditions. Initially, this transformation is to be comprised of taking the ratios of the energy in each band to the total energy in all bands for each instantaneous measurement. These new data are to be evaluated with data collected in the corn blight research program.

Figure 16 shows a computer printout of the results of classification of the spectral data collected on August 24 over area D on the northbound pass. There was generally good agreement between the ground truth (indicated by large numerals) and the letter C and classification results. Non-corn areas were designated by dashes. Note as an example, the field directly below the power station. It is designated "C3". The ground truth for this field indicated that it was at infection level 3 and was in maturity stage 6 which is the dent stage.

## SUMMARY

Photography collected over the north-south flightline revealed the widespread and variable affects of southern corn leaf blight in Indiana. Three levels of severity of the infection could be discerned from good quality color and color infrared photography. As many as five severity levels appeared to be detectable and classifiable with multispectral scanner data and pattern recognition analysis. These conclusions are preliminary in nature, however, having been obtained from a limited amount of good quality scanner data collected over a small geographic area. The degree to which these results could be generalized to more significant areas remains to be seen. Analysis of these data in subsequent months are pointed towards this objective. Nevertheless, it is already clear that remote sensing technology is applicable to the corn blight situation. Remotely sensed measurements collected from aircraft in conjunction with limited amounts of ground truth can be combined to permit the analysis of a vast amount of measurements collectably from an aircraft system. Not only does the presence of blight appear to be detectable but considerable information as to its severity level is discernible. Certainly the results of these investigations warrant further investigations of the applicability of remote sensing to the corn blight. Already, a considerable amount of knowhow related to applying remote sensing to this real situation is being accumulated. Certain techniques developed in the past are proving to be extremely useful while the deficiencies of other techniques are being demonstrated.

LARS researchers in cooperation with other interested scientists will continue the analysis of the data collected this past summer and their final results are to be reported upon the conclusion of the work.

Table I. 1970 CORN BLIGHT STUDY MISSIONS - AERIAL

| DATE | ORGANIZATION/PLANE | AREA COVERED | DATA TYPE |
|---|---|---|---|
| 8/19 | Purdue Univ. Beechcraft | S. River Road | Photography:<br>35mm color & color IR |
| 8/21 | Purdue Univ. Beechcraft | S. River Road; study areas south of Lafayette | Photography:<br>70mm color; 35mm color and color IR |
| 8/24 | Purdue Univ. Beechcraft | S. River Road; study areas north of Lafayette | Photography:<br>70mm color; 35mm color and color IR |
| | University of Michigan | N/S flight line study areas, 2 passes (3000') | Multispectral scanner;<br>Photography: black and white; color; color IR |
| 8/26 | NASA RB-57 | N/S flight line, 2 passes (60,000') | Photography (RC-8):<br>Color and color IR<br>Photography Zeiss:<br>Color IR<br>Photography (Hasselblads):<br>Various film/filter combs. |
| 8/27 | Air Force C-131 | N/S flight line (20,000') | Photography:<br>9 lenses, 70mm format |
| 8/28 | Bendix Corporation | N/S flight line study areas | Multispectral scanner |
| 9/5 | University of Michigan | N/S flight line study areas (3000', 5000'); flight lines 21,23,24 in Tippecanoe Co. (3000') | Multispectral scanner:<br>Photography; black and white |

Table I. 1970 CORN BLIGHT STUDY MISSIONS - AERIAL (con't.)

| DATE | ORGANIZATION/PLANE | AREA COVERED | DATA TYPE |
|---|---|---|---|
| 9/9 | NASA RB-57F | N/S flight line, 2 passes (50,000') | Same as above (8/26) except longer lens on Hasselblads |
| 9/10 | Air Force C-131 | N/S flight line | Same as above (8/27) |
| 9/11 | Purdue Univ. Beechcraft | N/S flight line study areas (3000' - 9000') | Multispectral scanner; Photography; black and white |

1970 CORN BLIGHT STUDY MISSIONS - GROUND TRUTH

| DATE | ORGANIZATION | AREA COVERED |
|---|---|---|
| 8/26-8/27 | Purdue University | N/S flight line study areas |
| 9/3-9/4 | Purdue University | Study areas D, E and F |
| 9/8-9/9 | Purdue University | Study areas A, B, and C; and flight lines 21, 23, 24 in Tippecanoe County |
| 9/12-9/15 | Purdue University | N/S flight line study areas |

Table II. Ratings and Descriptions for Southern Corn Leaf Blight

Leaf Damage

0. No infection - healthy, no lesions present
1. V. Mild - few scattered lesions, mostly on the lower leaves
2. Mild - lower leaves have many lesions, only a few scattered lesions on upper half of plant.
3. Mod. severe - many lesions to the degree where dead or dry areas appear on leaves of lower half of the plant, scattered lesions on upper half.
4. Severe - lower leaves mostly dead, upper leaves are beginning to dry up.
5. V. severe - nearly all leaves are dead (brown) or dry.

Ear & Stalk Lesions

0. None
1. Few - less than 25% of surface affected
2. Many - more than 25% of surface affected

Ear & Stalk Rot

0. None
1. Mild - less than 25% of ears or stalks infected
2. Many - more than 25% of surface infected

Plant Maturity Stage

1. Tasseling
2. Pollenation
3. Blister
4. Milk
5. Dough
6. Dent
7. Mature
8. Ready to harvest

Comment: Reason for drying of plants (if occuring) other than blight:

1. Normal maturity
2. Drought damage
3. Fertility deficiencies
4. Other blights or diseases


Southern Corn Leaf Blight
Healthy
Very Mild
Mild Infection
Moderately Severe
Severe Infection
Very Severe

Figure 1

Figure 2a

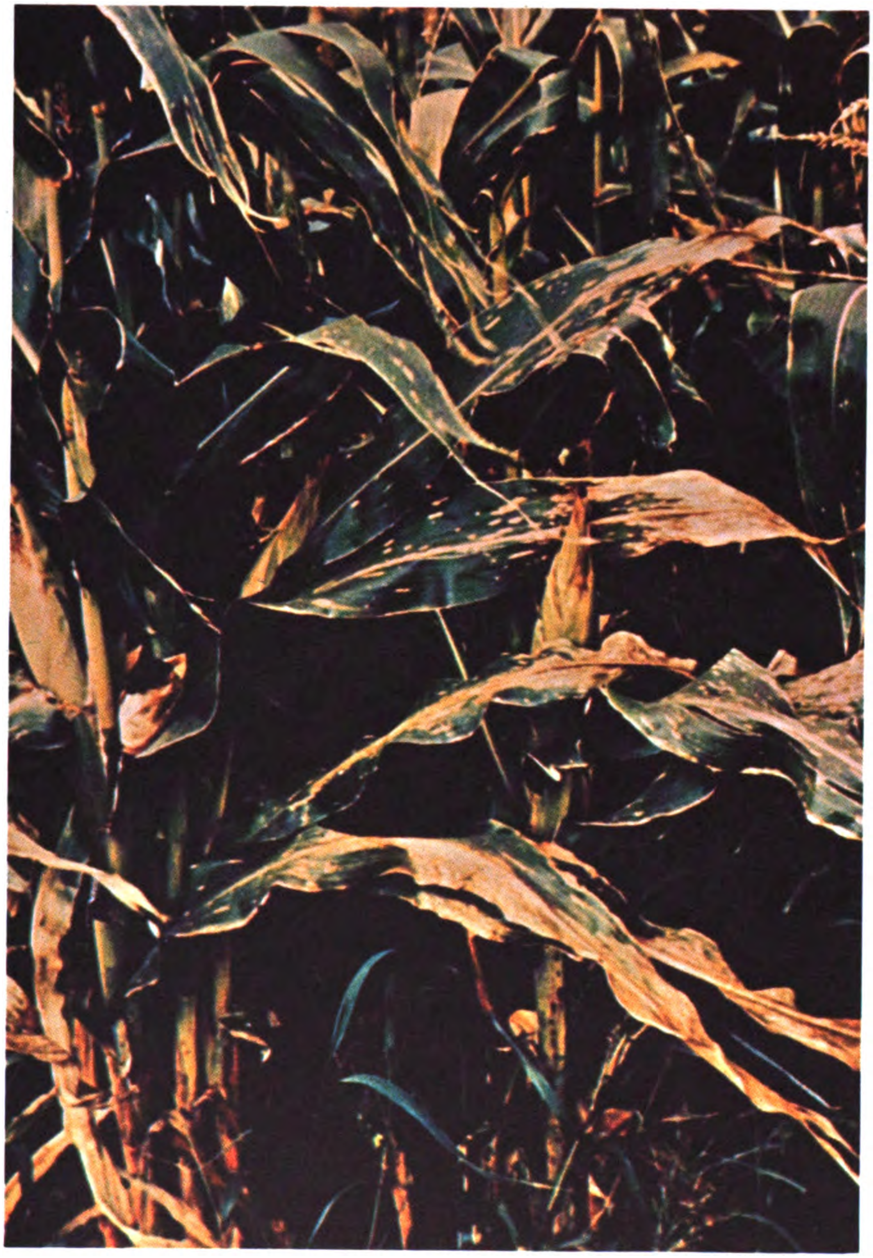

Figure 2b

Figure 2c

Figure 3


Ear Rot Resulting From
Southern Corn Leaf Blight
Severe Infection

Figure 4

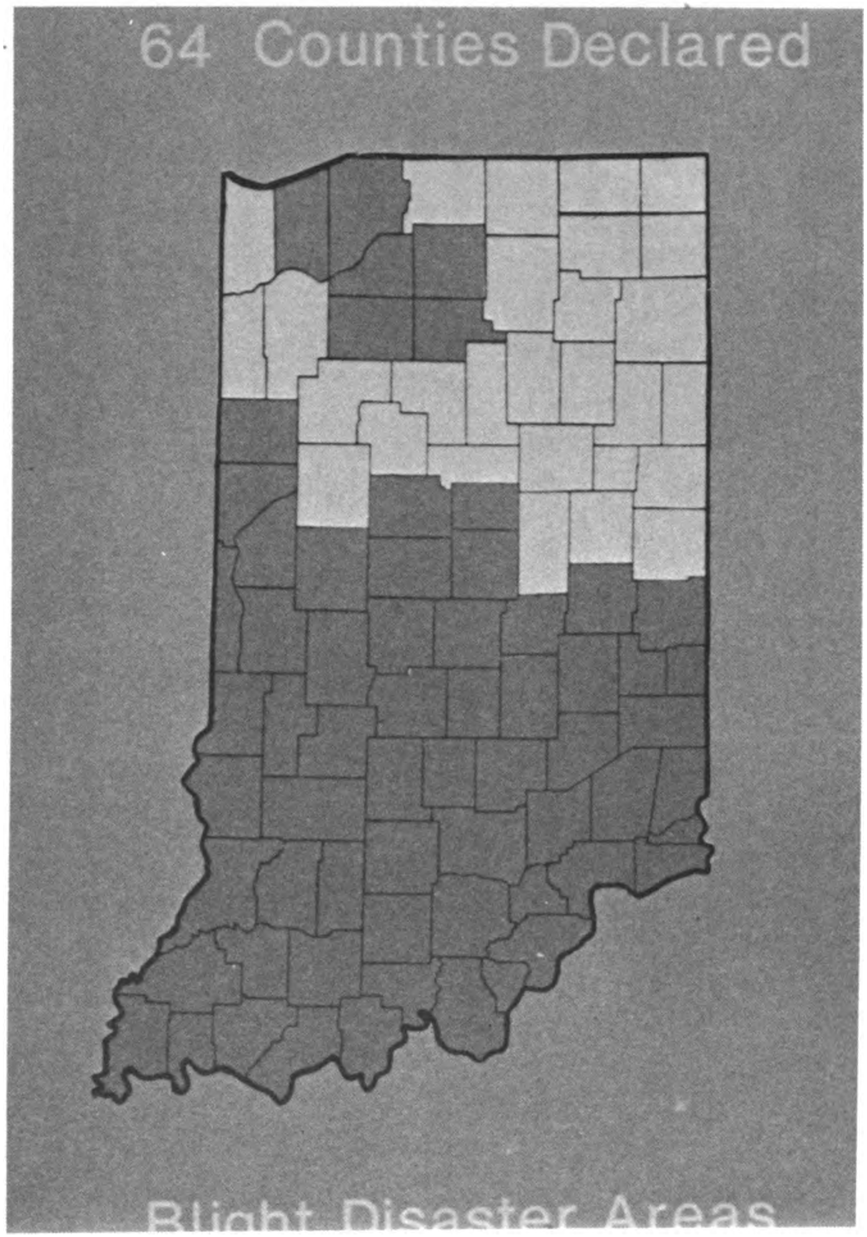


Figure 5

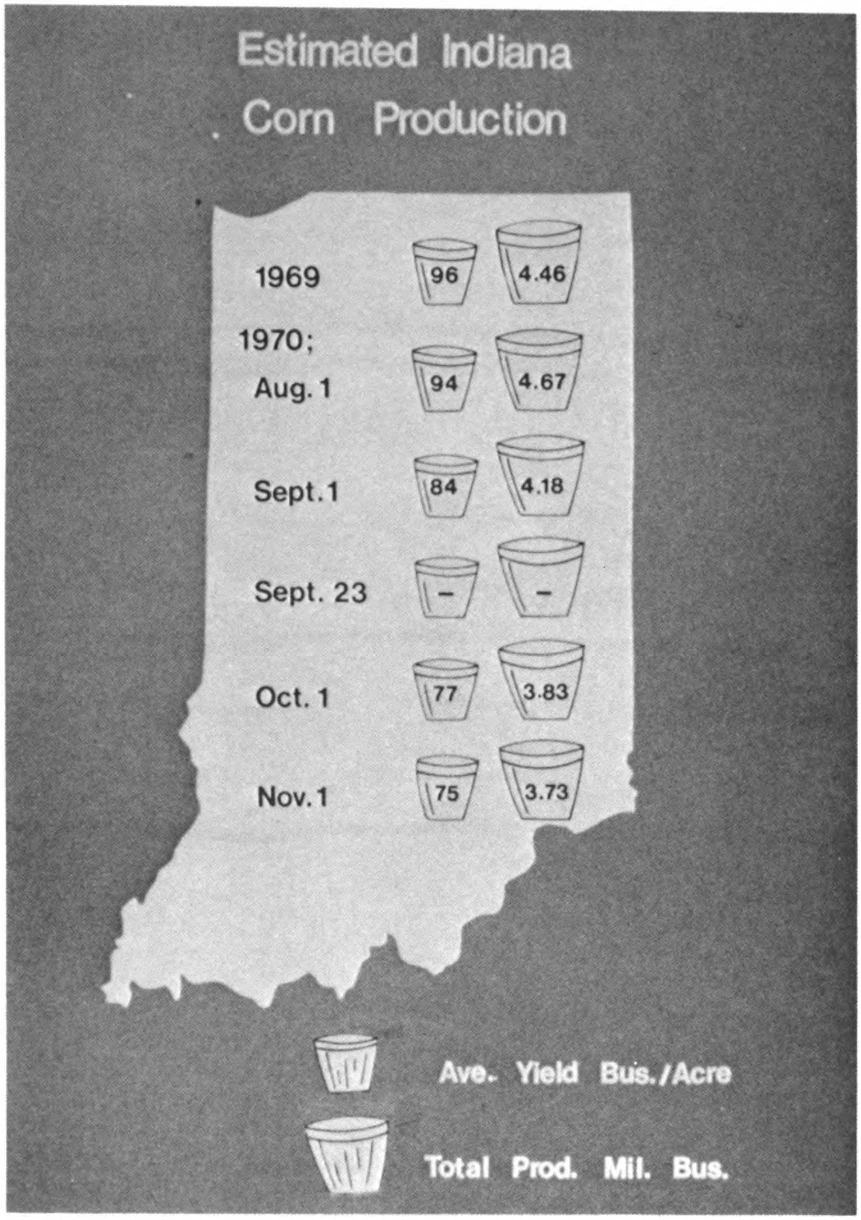
Estimated Indiana
Corn Production
1969
96
4.46
1970;
Aug. 1
94
4.67
Sept. 1
84
4.18
Sept. 23
–
–
Oct. 1
77
3.83
Nov. 1
75
3.73
Ave. Yield Bus./Acre
Total Prod. Mil. Bus.

Figure 6a

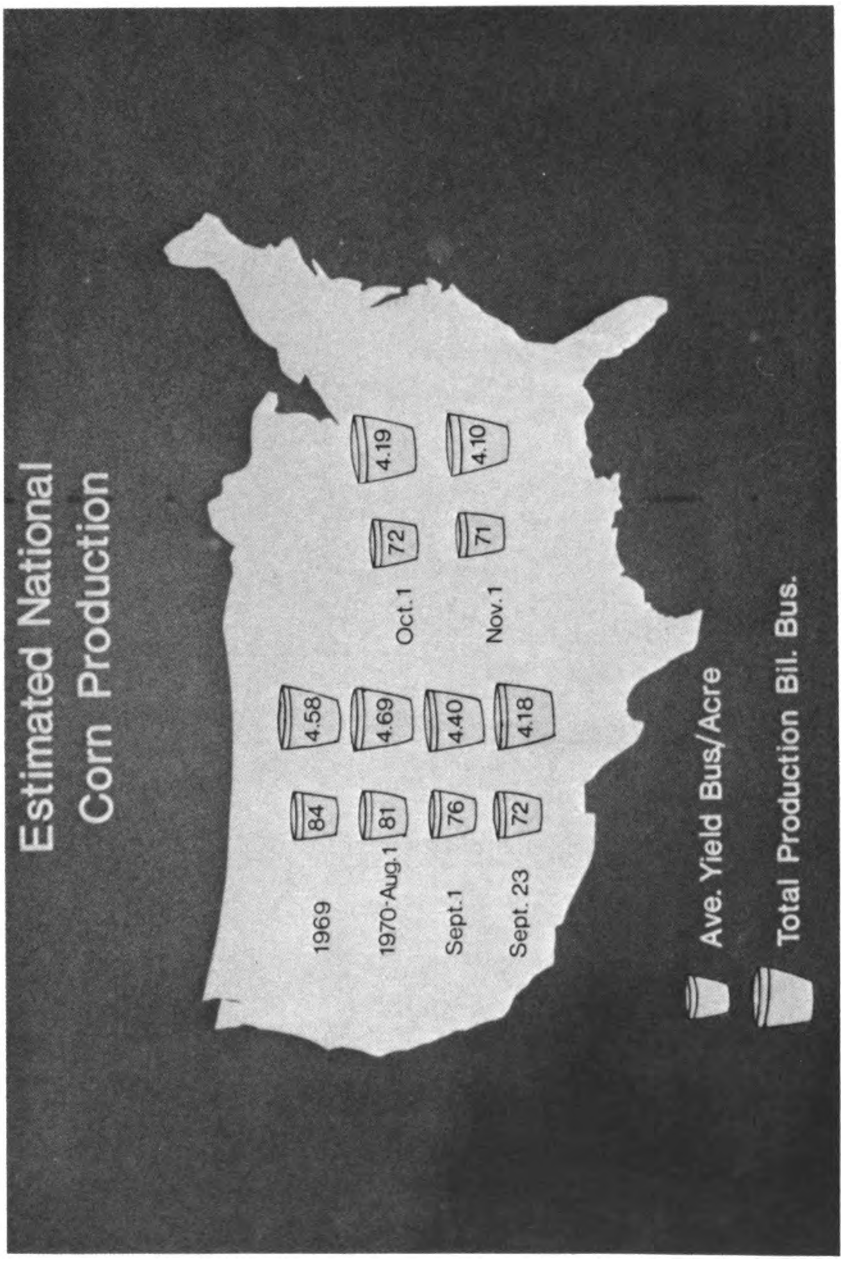
Estimated National
Corn Production
1969
84
4.58
1970-Aug.1
81
4.69
Sept.1
76
4.40
Sept. 23
72
4.18
Oct.1
72
4.19
Nov.1
71
4.10
Ave. Yield Bus/Acre
Total Production Bil. Bus.

Figure 6b


Figure 7

Southern Corn Leaf Blight Flightline in Indiana flown in August, 1970 for the Laboratory for Applications of Remote Sensing (LARS) at Purdue University. Cross-hatched regions are intensive study areas.

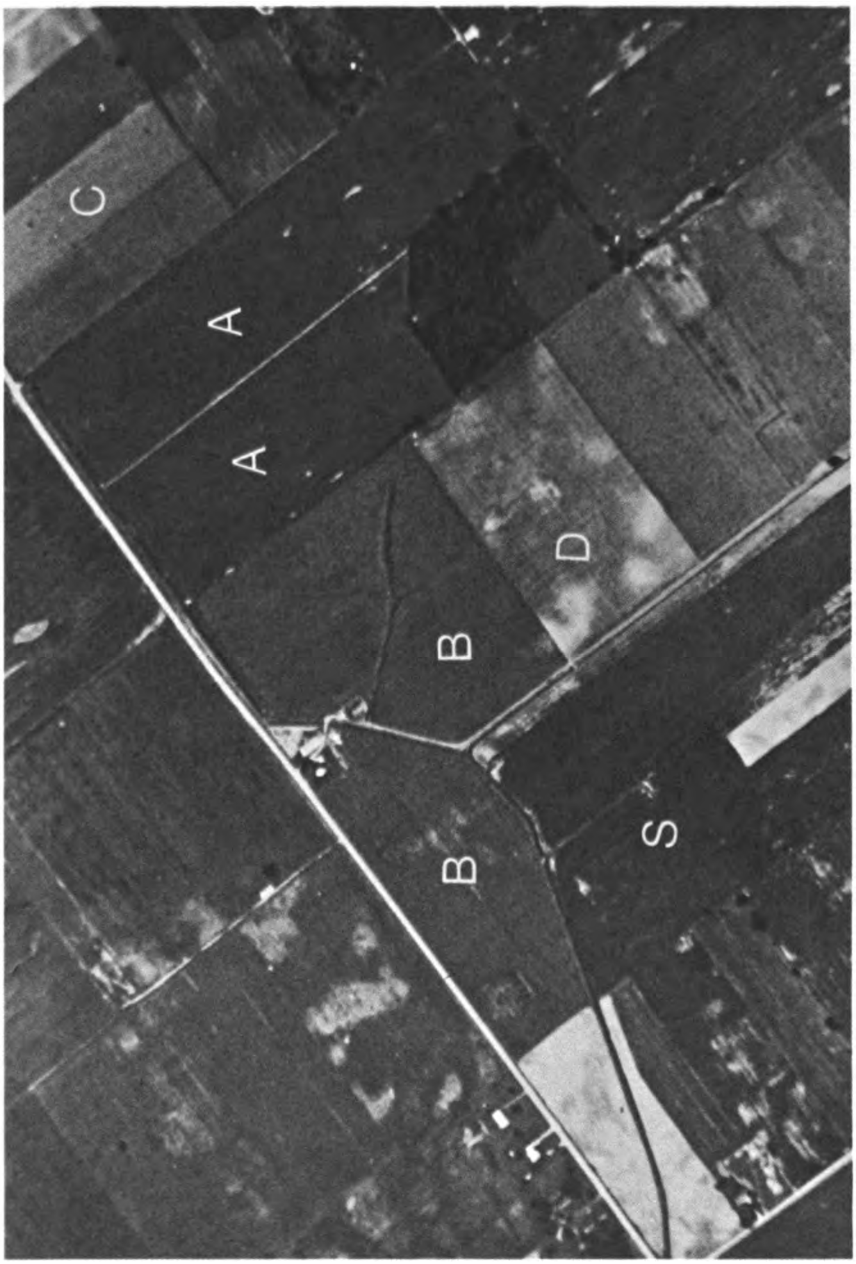


Figure 8

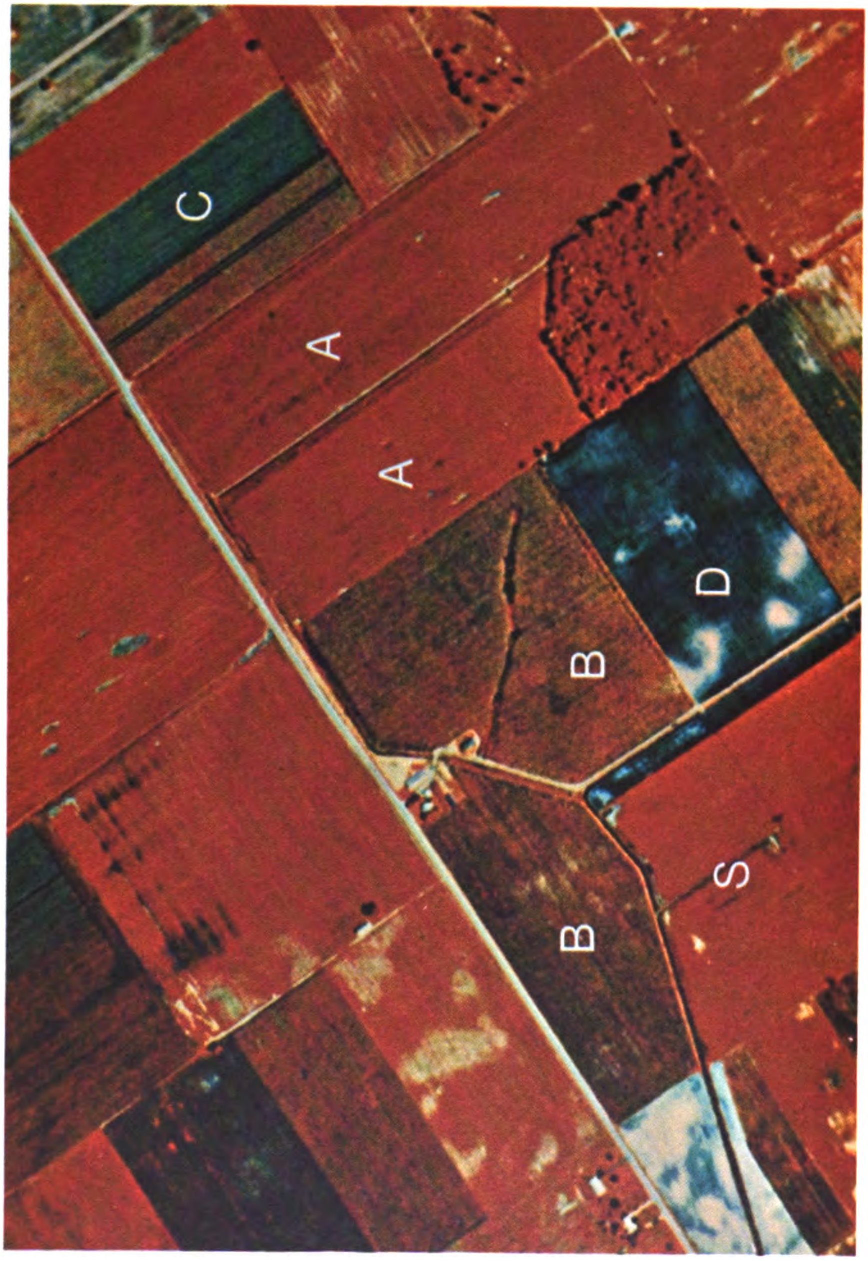


Figure 9

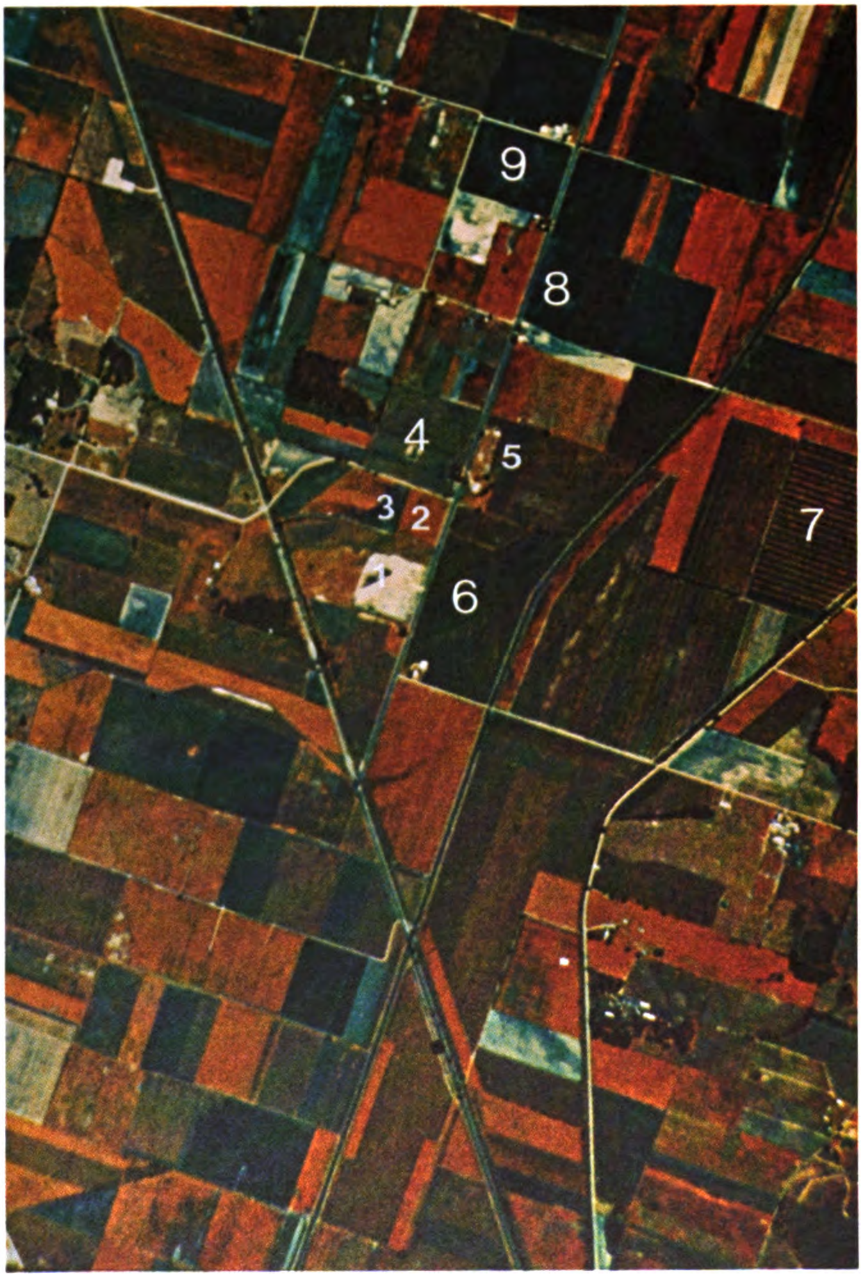


Figure 10

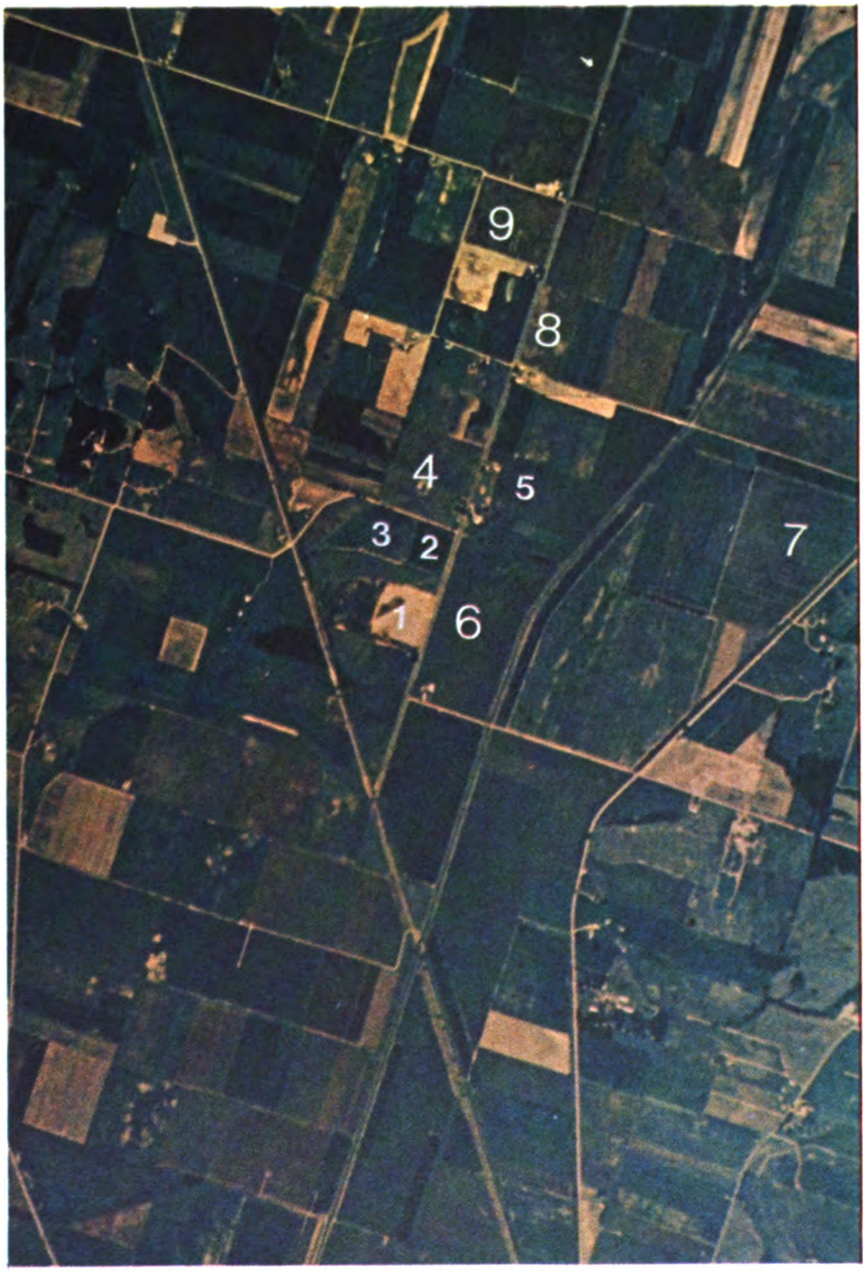


Figure 11

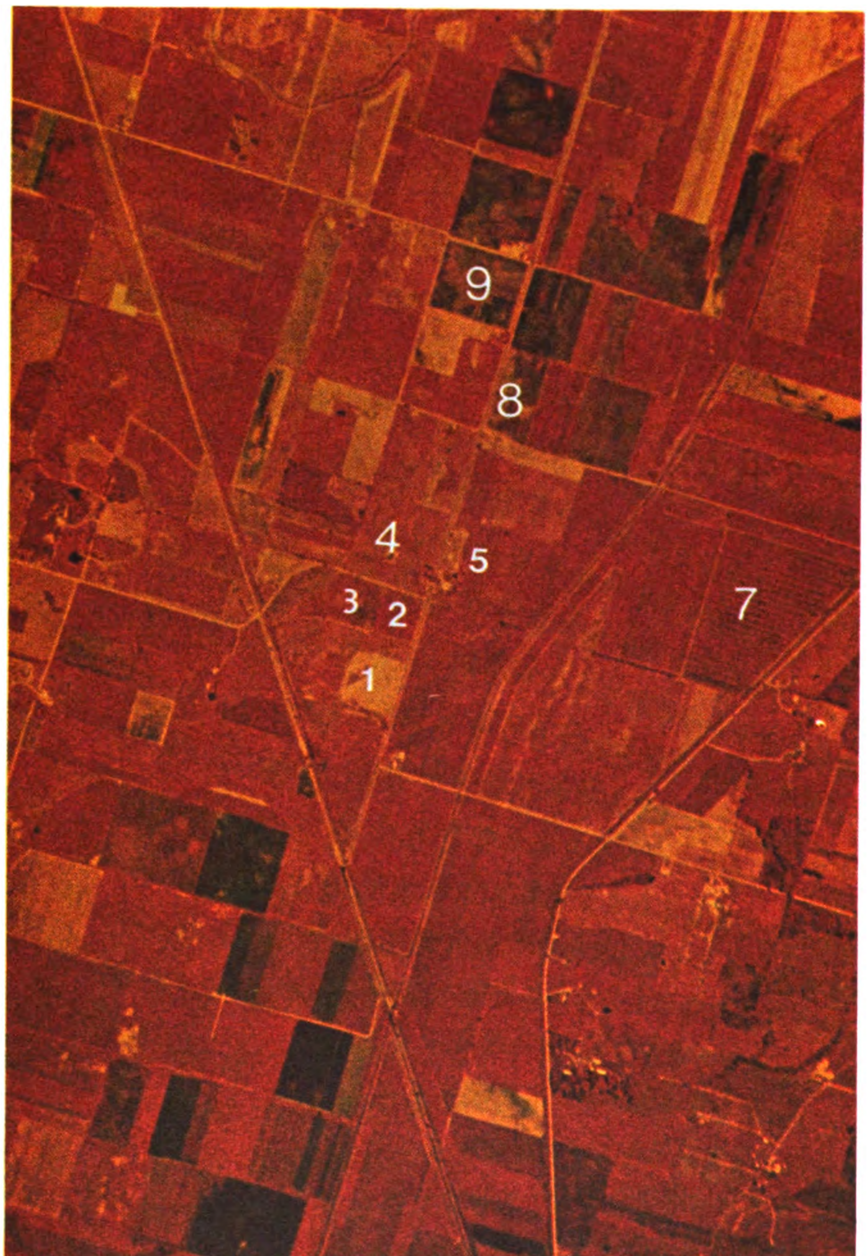


Figure 12


Figure 13

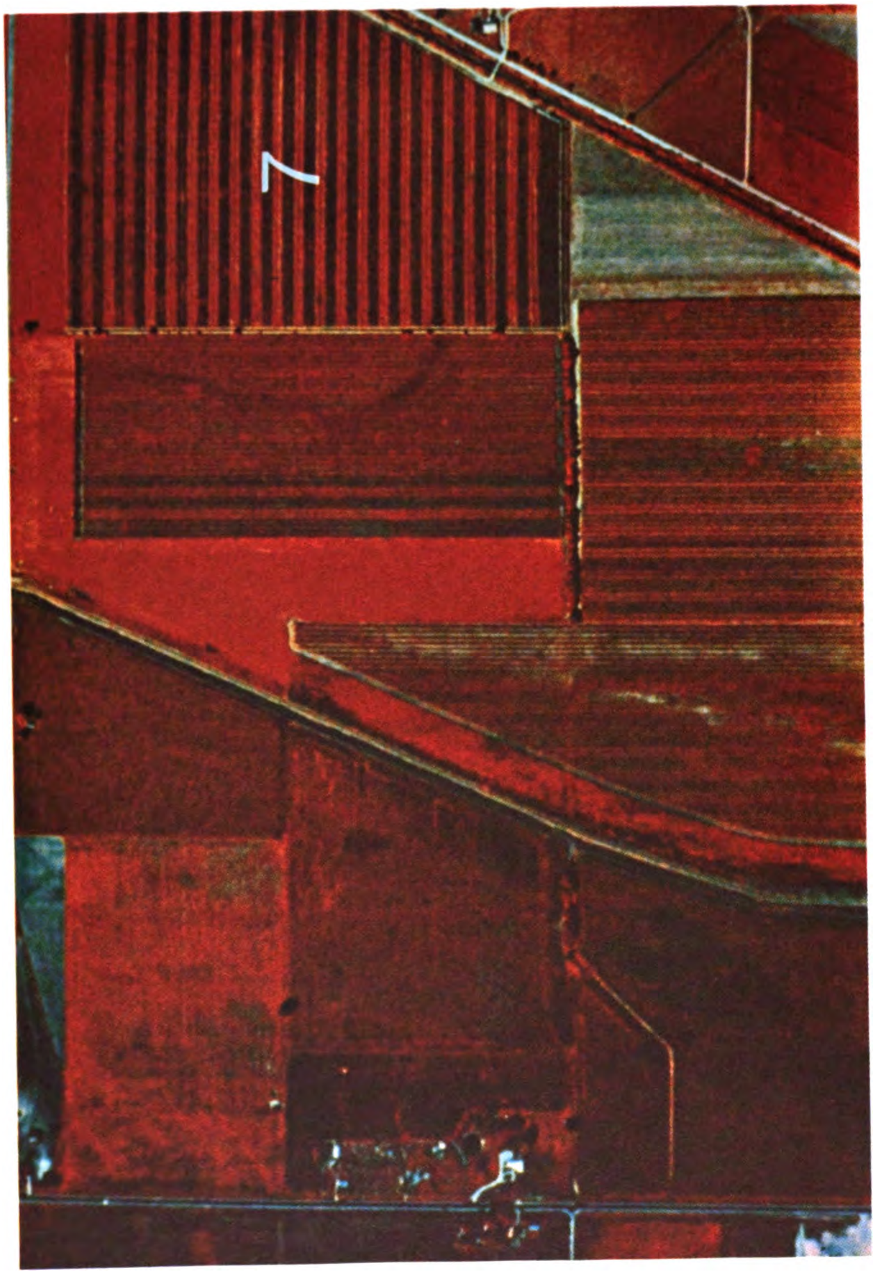


Figure 14

# Computer Analysis of Vidicon Digitized Color IR Film

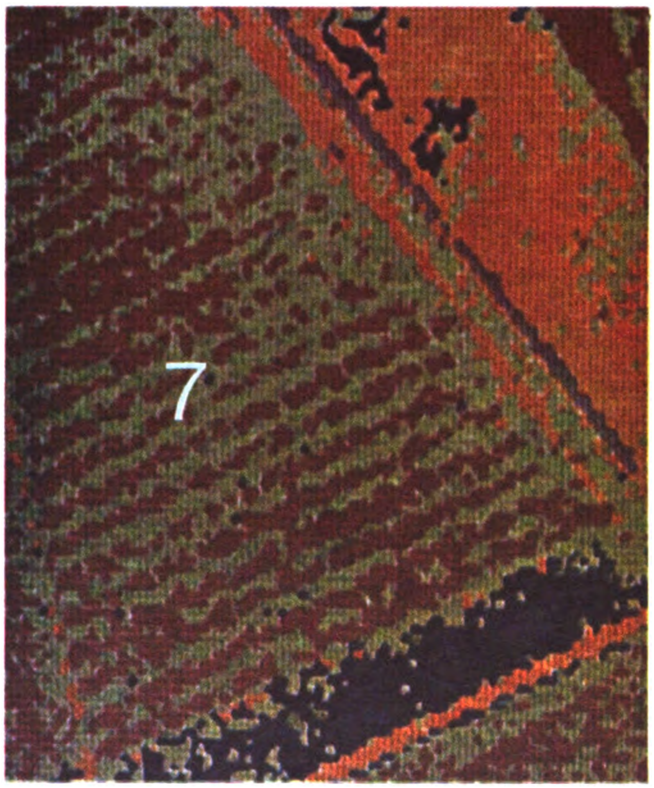


Figure 15

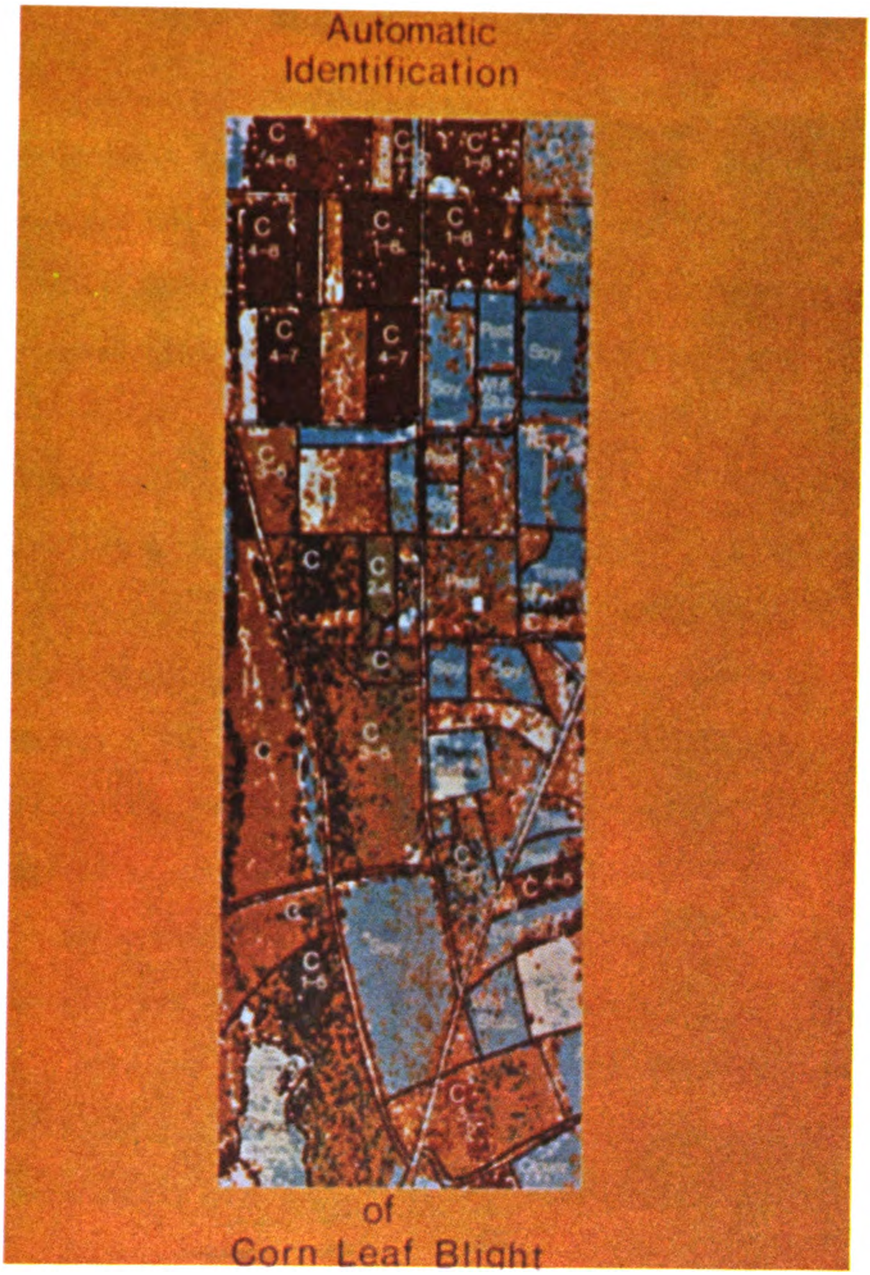


Figure 16