L. R. Green
J. K. Olson
Texas A&M University
College Station, TX 77843
W. G. Hart
M. R. Davis
Citrus Insects Research Laboratory, USDA
Weslaco, TX 78596

Aerial Photographic Detection of Imported Fire Ant Mounds*

Color infrared and black-and-white infrared films are superior to regular color film for detecting fire ant mounds.

Abstract: *Studies conducted in the Texas coastal plains from July 1971 through August 1972 demonstrated that mounds of the red imported fire ant,* Solenopsis invicta *Buren, can be detected on color, color infrared (CIR), and black-and-white infrared (BWIR) aerial photographs of ant infested land.*

Analysis of aerial photographs taken with a modified Fairchild K-37 camera† and a Hasselblad camera showed that up to 90 percent of the total imported fire ant mounds present in our research plots could be visually detected on photographs having scales of 1:2000. CIR and BWIR film types appear to be superior to regular color film in terms of our ability to visually detect fire ant mounds on resulting photographs. December proved to be the optimum month for detecting red imported fire ant mounds in Texas with the aerial camera systems used in the study.

Imported fire ants, (IFA) *Solenopsis invicta* Buren and *S. richteri* Forel, are generally considered to be serious pests both in the rural and urban portions of the United States where they are established. Since their introduction into the United States via the Port of Mobile, Alabama (ca. 1918), populations of one or both of these ants have spread into Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas. By 1969 an estimated 126 million acres in the southern United States were infested (Markin, 1970).

Effective IFA control programs are dependent upon accurate survey information regarding the exact location and outward limits of infestations. Present survey procedures are principally ground surveys performed by Federal and State entomologists (Anonymous, 1971). These survey efforts involve plant nursery inspections and general area surveys within known or suspected infestation regions and are augmented by reports from other local officials and landowners. Present surveys are costly and time-consuming and often do not detect all fire ant infestations within a region. More precise, efficient, and less costly methods of detecting and delimiting IFA infestations over large areas are needed.

Remote sensing techniques, particularly those involving aerial infrared photog-

* (Hymenoptera: Formicidae)

† Mention of product names is for the convenience of the reader and does not imply endorsement of or preference for such products over others that might be available.

raphy, have proven effective in the survey of infestations of other pest insect species and offer promise as a means for surveying IFA infestations. Aerial infrared, black-and-white, and color photographic techniques have been effectively employed in the detection of insects attacking forests (Heller *et al.*, 1959), citrus (Hart and Myers, 1968), and pecans (Payne *et al.*, 1972). Hart *et al.* (1971) detected mounds of the harvester ant, *Pogonomyrmex barbatus* (F. Smith), and the Texas leaf cutting ant, *Atta texana* (Buckley), with aerial color infrared (CIR) photography. Driscoll (1971) identified ant mounds on 1:1000 scale CIR photos. These studies along with unpublished work by Hart (1971), where he demonstrated detection of IFA mounds on aerial CIR photographs, gave evidence that aerial photography could be adapted for use in surveys of IFA infestations. Studies reported here compare the capabilities of regular color, color infrared (CIR), and black-and-white infrared (BWIR) film types to record the red imported fire ant, *Solenopsis invicta*, mounds of the coastal plains of Texas.

Methods and Materials

Five aerial photographic missions were flown between July 20, 1971 and August 9, 1972 over research plots in Fort Bend County, Texas. The primary research site in this county was a fire ant-infested pasture typical of the ones located in the coastal plains southwest of Houston near Sugar Land, Texas. Pasturelands in the Texas coastal plains present an ideal situation to study the capabilities of various film types to detect fire ant mounds. Vegetation in heavily grazed areas usually averages 3 to 4 inches in height; thus, mounds are easily seen during most seasons of the year. Eighteen 43-by-50-foot plots were set up in the pasture and were marked at the corners with 9-inch paper plates to facilitate locating the plots on photographs (Fransis, 1970).

Photographs of the study plots were taken from a single-engine aircraft at altitudes ranging from 1000 to 8000 feet*. A modified Fairchild K-37 camera with a 12-inch focal length lens and a Hasselblad camera with a 120-mm focal length lens were used. The K-37 camera has a 9-inch (228.6 mm) format and the Hasselblad camera has a 70-mm format. Flights were conducted at ±2 hours maximum sun angle in order to minimize the effects of shadows that tend to interfere with the reflectance characteristics of surrounding vegetation. The film types used were Kodak Aerographic Film 2448 (natural color film), Kodak Aerochrome Film 2443 (CIR) and Kodak Infrared Aerographic Film 2424 (BWIR). The camera settings and filters used in full sun for each film type were 1/500 at f/5.6, no filter; 1/100 at f/6.3, Kodak Wratten 15 plus 20B; and 1/500 at f/8, Kodak Wratten 89B, respectively. The 9-inch by 9-inch CIR transparencies obtained from the 228.6 mm camera depicted the study plots at scales equal to 1 over the altitude above the target area. Natural color and BWIR transparencies taken with the 70 mm camera were enlarged by the photographer to the same scale as the transparencies taken with the 228.6 mm camera in order that data collected from the two camera systems could be statistically compared.

Mission 1 and 2 were flown on July 20 and December 10, 1971, respectively, using the 228.6 mm camera described above. The camera was loaded with CIR film, and photographs were taken at 2000 and 4500 feet on both missions. Additional photographs were taken at 1000 and 8000 feet in December.

Mission 3 was flown on March 17, 1972. Both the 228.6-mm and 70-mm cameras were used to compare detection results for natural color, CIR, and BWIR film types. Photographs were taken at 1000, 2000, and 4500 feet.

Missions 4 and 5 were flown on June 1 and August 9, 1972, respectively. The 228.6 mm camera was utilized to obtain both CIR and BWIR photographs of the research plots. Photographs were taken at altitudes of 1000, 2000, and 3000 feet during these missions. Additional photographs were taken from 4500 feet in June.

Ground surveys of the plots were completed within five days of each photographic mission. Mound dimensions, a visual estimate of vegetative cover on the mound, the exact location of mounds, and ant activity within individual mounds were recorded for each plot.

A laboratory technician familiar with the characteristic ground appearance of fire ant mounds interpreted all photographic data. Transparencies were viewed on light tables with the aid of a magnifier-

* All altitude readings reflect height above ground level.

illuminator equipped with a 5-inch lens having 3× magnification at 13 inches. Information obtained from the transparencies was compared to the corresponding ground truth data.

Results

Red IFA activity at the primary research site in Fort Bend County was fairly heavy during the period when the photographic missions were flown (Table 1). The maximum average of 108.8 mounds/acre was recorded during ground surveys conducted in December 1971. Ant activity was somewhat lighter during August 1972, and July 1971, when 79.7 and 92.1 mounds/acre were observed, respectively. Mirex was applied to the site on June 20, 1972 by the landowner; however, no obvious changes in mound appearance or numbers were detected during the August photographic mission.

Table 1. Red Imported Fire Ant Activity at Primary Research Site in Fort Bend County, Texas, July 1971-August 1972.

Month	Year	Average Mounds/Acre Active	Inactive	Total
July	1971	79.7	12.4	92.1
December	1971	88.6	20.2	108.8
March	1972	80.9	21.3	102.2
June	1972	62.9	27.0	89.9
August[1]	1972	11.2	68.5	79.7

[1] Mirex applied on June 20, 1972.

The highest percentage of mounds (79.4 percent) detected on any of the photographs taken during this study were photographed with a 228.6 mm camera in December 1971 at a scale of 1:2000 using CIR film (Table 2). This compared favorably with the CIR detection results for March 1972, when 71.4 percent of the mounds in the test plots were detected on photographs taken with the same camera and at the same scale. The numbers of mounds detected on BWIR photographs at the scale of 1:2000 taken in March 1972 were not significantly different from those detected on the CIR photographs taken at the same time and at the same scale. However, the number of mounds detected on regular color photographs at 1:2000 scale taken in March 1972 was 23 percent lower than that detected on CIR photographs. Detection efficiency of the regular color photographs improved when the photography was enlarged to a scale of 1:1000. At this latter scale, the March 1972 detection results for CIR, BWIR, and regular color photographs were all statistically similar (Table 2).

Table 2. Percentages of the Actual Number of Fire Ant Mounds Located on the Primary Research Site in Fort Bend County, Texas, Detected on Photographs Using Aerial Color Infrared, Black-and-White Infrared and Regular Color Film Types.

Photographic Scale	July 1971	December 1971	March 1972	June 1972	August 1972
		Color IR			
G.T.[1]	100.0[a] [2]	100.0[a]	100[a]	100.0[a]	100.0[a]
1:1000[3]	—	69.0[b]	65.9[b]	57.5[b]	57.7[b]
1:2000	27.0[b]	79.4[b]	71.4[b]	58.8[b]	50.7[b]
1:3000	—	—	—	58.8[b]	43.6[bc]
1:4500	0.0[c]	0.0[c]	8.8[d]	20.0[d]	—
1:8000	—	0.0[c]	—	—	—
		Black and White IR			
1:1000	—	—	67.8[b]	—	32.4[bc]
1:2000	—	—	68.1[b]	60.5[b]	18.3[cd]
1:3000	—	—	—	39.5[c]	9.9[d]
1:4500	—	—	0.0[e]	0.0[e]	—
		Regular Color			
1:1000	—	—	66.2[b]	—	—
1:2000	—	—	48.4[c]	—	—
1:4500	—	—	7.7[d]	—	—

[1] Ground truth.

[2] Percentages of mounds detected by the various film types followed by the same letter in a given column are not significantly different from each other at the 5 percent level as determined by Duncan's New Multiple Range Test.

[3] Photographic scale in this instance is expressed as 1:the altitude in feet at which photographs were taken with a 228.6-mm camera having a 12-inch focal length.

Changes in scales appeared to influence the ability to visually detect ant mounds on photographs resulting from each of the three film types used. Detection results for CIR photographs taken at scales ranging from 1:1000 to 1:3000 on the same date were not significantly different (Table 2). At scales of 1:4500 and 1:8000, however, CIR photographic detection efficiency was significantly lower than those detected on this film between 1:1000 and 1:3000. This reduction in mound detection on the photographs with a scale larger than 1:1000 was due to image distortion. Mound detection percentages for BWIR photographs taken at scales of 1:1000 and/or 1:2000 in March 1972 and June 1972 were statistically similar and, as stated previously, compared favorably with the detection percentages for the CIR photographs taken at the same scales on the same dates. However, the number of mounds detected on BWIR photographs taken at scales smaller than 1:2000 were markedly reduced until at 1:4500 no mounds could be detected. Detection results for regular color photographs were significantly reduced with each decrease in scale below 1:1000. Again, image distortion on photographs taken at scales larger than 1:1000 resulted in the detection of a very low percentage of mounds on both BWIR and regular color film.

Seasonal change also appeared to affect the detection of mounds on CIR and BWIR photographs. Mound detection results for BWIR photographs taken at scales ranging from 1:1000 to 1:3000 during August 1972 were significantly lower than they were for BWIR photographs taken at these same scales in March 1972 and June 1972 (Table 2). The effect of seasonal change on detecting mounds on CIR photographs was not as great as it was for BWIR photographs except in the case of the CIR photographs taken in July 1971. In light of these results, detection data for each photographic mission collected from CIR photographs taken at optimum scales ranging from 1:1000 to 1:3000 were combined and subsequently analyzed statistically to determine if the ability to detect fire ant mounds on aerial CIR photographs was significantly affected by the time of year when a given mission was flown. The results of this analysis are summarized in Table 3. December 1971 proved to be the optimum time for detecting fire ant mounds (detection ratio = 0.78) and July 1971 proved to be the least favorable (detection ratio = 0.27). Since the mound numbers within the test plots remained relatively constant throughout the study period (Tables 1 and 3), it can be assumed that the differences in mound detection results for aerial photographs taken on the different dates are due to seasonal changes in the characteristic appearance of the ant mounds.

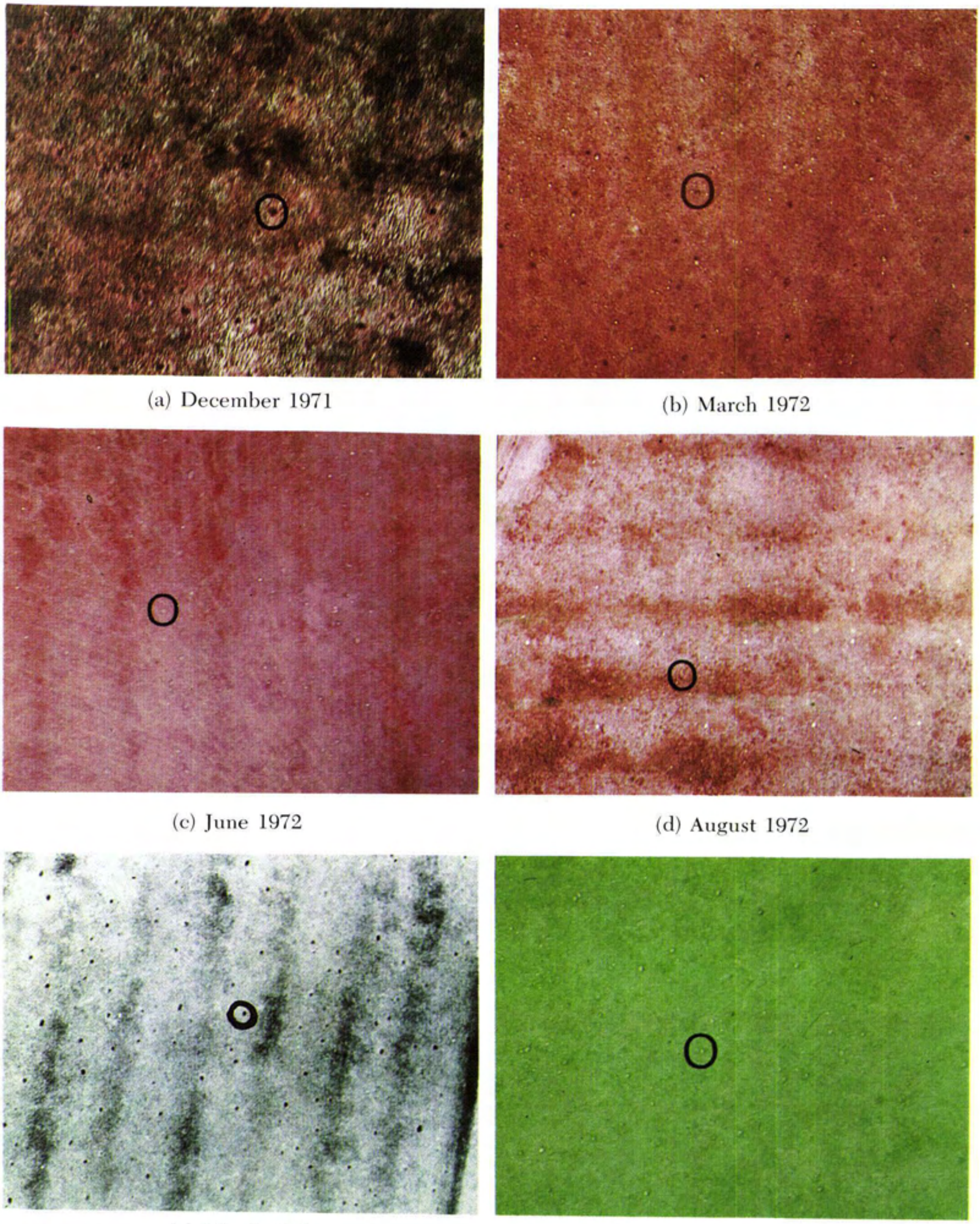
The characteristic appearances or signatures of fire ant mounds in the resulting aerial photographs did vary with the time of the year. Mounds in CIR photographs taken during December 1971 and March 1972 appeared as dark spots surrounded with bright red vegetation (Plate 1a and 1b). Mounds in June 1972 photographs appeared as white spots surrounded by a dull red halo (Plate 1c), whereas in August mounds had a distinct reddish cast due to vegetation growing on their surfaces (Plate 1d). Fire ant mound signatures on BWIR photographs taken during March and June 1972 appeared as black spots surrounded

TABLE 3. EFFECT OF TIME OF YEAR ON THE ABILITY TO DETECT IMPORTED FIRE ANT MOUNDS ON COLOR INFRARED PHOTOGRAPHS TAKEN AT ALTITUDES RANGING BETWEEN 1000 AND 3000 FEET. (PHOTOGRAPHIC SCALES OF 1:1000 AND 1:3000, RESPECTIVELY).

	Date When Photographic Mission was Flown over Plots In Fort Bend County, Texas				
	July 1971	December 1971	March 1972	June 1972	August 1972
Average no. of mounds/plot actually present[1]	4.56	5.39	5.06	4.44	3.94
Average no. of mounds/plot detected on photographs.	1.30	4.22	3.41	2.63	2.06
Detection ratio[2]	0.27	0.78	0.61	0.59	0.52

[1] Based on ground truth data

[2] $\text{Detection ratio} = \frac{\text{Average no. of mounds/plot detected on CIR photographs}}{\text{Average no. of mounds/plot actually present}}$



(a) December 1971

(b) March 1972

(c) June 1972

(d) August 1972

(e) March 1972

(f) March 1972

PLATE 1. Appearances of red imported fire ant mounds on color infrared (a-d), black-and-white infrared (e), and regular color (f) aerial photographs. Characteristic mounds are encircled (o) on each photo.

by a generally gray background (Plate 1e). Mounds on BWIR photographs made in August 1972 were less distinct and were difficult to differentiate from the background shades of the surrounding vegetation. For purposes of comparison, the appearances of fire ant mounds in regular color photographs are shown in Plate 1f.

Discussion

The data presented show that aerial photography is a relatively effective and efficient means for delimiting red IFA infestations. However, a number of influencing factors must be considered when employing this approach. Seasonal development of the mounds and surrounding vegetation are influential factors in selecting the scale and the particular type of film to be used. Photographic missions should be flown at the highest altitude possible that still provides effective detection of ant mounds. Increases in altitude cause a decrease in photographic scale but increase in the area included in each photographic frame. Hence, the number of photographs and associated cost required for area coverage should be reduced by selecting a film type that would provide accurate mound detection information at the highest altitudes possible to record accurately the presence of mounds. Also, the film type chosen should be one whose capability is least affected by seasonal changes. Proper selection of the film, therefore, will provide for temporal flexibility in planning and executing proposed survey programs using aerial camera systems.

Of the three film types used in our study, the CIR film proved to be more suitable for detecting ant mounds under different mound conditions. In terms of photographic scale, the percentage of ant mounds that can be detected on CIR photographs is not seriously affected until the scale becomes smaller than 1:3000, as was determined by our analysis of the data collected in December 1971, and in March-August 1972 (Table 2). In contrast, mound detection accuracy for BWIR and regular color photographs is significantly lowered by scales of less than 1:2000 and 1:1000, respectively. The CIR film type is also the one whose overall mound detection capability appears to be least affected by seasonal changes in the environment (Table 2). However, the signature of the ant mounds on CIR photographs may vary in accordance with the environmental situation at the time when the photographs were taken (Plate 1a to 1d).

Regardless of the film type used, personnel responsible for interpreting aerial photographs should be made aware of the seasonal variability of the fire ant mound signature for the particular area that is being surveyed. The photographic signatures of imported fire ant mounds in Texas coastal plains pasturelands appear to be particularly affected by the degree of surface or mound building activity of the ants and by the type, amount, height, and developmental stage of the vegetation located on and around the mounds. The intensity and location of ant activity and vegetative conditions are functions of seasonal environmental variations. The dark spots, characteristic of fire ant mound signatures on CIR photographs taken during the winter or early spring (Plate 1a and 1b), were the result of a lack of near-infrared light reflectance from fresh moist earth excavated by the ants during a period of prolonged rainfall and cool temperatures. Such climatic conditions are characteristic of the Texas coastal plains during this time of year and are conducive to a high level of fresh mound building activity by fire ants in this region of the state. The red halo surrounding each dark spot was due to a greater degree of near-infrared light reflectance from the lush vegetation immediately surrounding each mound as compared to that reflected from the less vigorous vegetation growing at some distance from the mound. The dark spot-red halo signature was the type most easily detected by visual interpretation; therefore, the percentages of mounds detected on CIR photographs taken during December 1971 and March 1972 were correspondingly the highest recorded for any of the photographic missions (Table 2). The state of ant mounds and vegetation on the Texas coastal plains during the winter and early spring months also appears to be the condition that allows for the most obvious signatures on BWIR photographs (Plate 1e). Again, the percentages of ant mounds detected on BWIR photographs taken at scales of 1:1000 and 1:2000 during March and June 1972 were quite high and corresponded to percentages detected on CIR photographs (Table 2). With the onset of warmer summer and early fall temperatures, a reduction in mound building activity, and a corresponding increase in vegetative cover on individual mounds, the mound signatures on BWIR photographs become obscure and are much more difficult to detect than are the signatures on the CIR photographs. The fire ant mound signatures on the latter type of photographs taken during the warmer months also are less distinct. However, the contrast between the CIR signature and the background color is adequate to allow for rather high percentages of mound detection (Plate 1d, Table 2).

The differences between fire ant mound signatures on photographs taken in June 1972 (Plate 1e) and those on photographs taken in August 1972 (Plate 1d) were due to the sharply contrasting moisture conditions that occurred in the Texas coastal plains during the summer of 1972. In periods with above average summer rainfall such as occurred in the August of 1972, the vegetative cover on ant mounds becomes quite dense resulting in mound signatures characterized as dark red spots (Plate 1d). However, in dry months such as occurred during June 1972, vegetative growth is retarded and the mounds are not completely covered. The mound signatures on CIR photographs taken under these latter conditions appear as white spots surrounded by dull red halos (Plate 1c). These findings agree with those of Colwell (1967), who states that dry areas having little or no vegetation usually appear white on infrared Ektachrome photographs.

Conclusions

The data from these studies indicate that CIR and BWIR film types are superior to regular color film for detecting fire ant mounds during periods of the year when vegetation is low. As vegetation increases in height and begins to cover the individual mounds during the summer months, CIR film becomes superior to BWIR. Of the five dates analyzed in the study, December proved to be the optimum month for detecting fire ant mounds in the Texas coastal plains.

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