SECTION 117

THE USE OF KODAK AEROCHROME INFRARED COLOR FILM, TYPE 2443, AS A REMOTE SENSING TOOL

by

G. R. Cooper
Department of Botany
University of Maine
Orono, Maine

and

R. L. Bowen and H. W. Gausman
Soil and Water Conservation Research Division
Agricultural Research Service
U. S. Department of Agriculture
Weslaco, Texas

INTRODUCTION

The use of black and white infrared light sensitive film in "remote sensing" of natural resources is a relatively recent development. It was followed closely with the use of Eastman Kodak's false color infrared film for camouflage detection (1, 2). The film is well known as Kodak Ektachrome Infrared Aero, type 8443[1]. It was made available to interested researchers "over the counter." A new infrared color film, Kodak Aerochrome, type 2443, has replaced the 8443 film (3, 4), providing a new horizon and challenge for remote sensing applications with aerial photography. The 2443 had lower contrast than the 8443 film (3, 4), and allowed the researcher to "probe" deeper into areas that would have appeared as solid black shadows on the 8443 film. The cyan (infrared sensitive) layer of 2443 is approximately 1 1/2 stops slower, at a density of 1.4, than the yellow and magenta emulsion layers.

---

1 Use of a company name by the Department does not imply approval or recommendation of the product to the exclusion of others that may be suitable.

PROCEDURES AND RESULTS

Test procedures applied to the 35 mm Ektachrome Infrared color film and compared with results for the 70 mm infrared color film indicated that Eastman Kodak may be marketing two different films. When each was processed to a negative, the 35 mm film produced a blue base color, whereas the 70 mm film base color ranged from essentially neutral to a slight magenta. The data reported here are on the 70 mm film unless otherwise indicated.

COMPARISON OF 8443 AND 2443 FILMS

Because infrared color prints are needed for publication and as a tool for field crews doing "ground truth" work, the development of the new type 2443 Aerochrome Infrared film to a negative was investigated (5). A panel of research workers was asked to select "the print" they would prefer to use from both positive and negative transparencies of the 8443 and 2443 films. Eighty-six percent of the panel indicated a preference for "the print" made from the negative processing of the 2443 film. A reproduction of the test given the panel is portrayed in Fig. 1.

A general comparison of the old 8443 with the new 2443 infrared color film indicated that the 2443 film had a lower contrast and some loss of the vivid coloration that characterized the 8443 film. However, the 2443 film was superior in yielding details among shadows of plant canopies whether processed to a positive or negative. The negative processing, in particular, reveals much more detail in plant canopies than does the old 8443. This is apparent in the examples portrayed in Fig. 1.

Quality Control and Analysis of Variance of Density Readings of Sensitometric Strips Exposed on an EG and G Mark VI Sensitometer

The quality control of taking and processing photographs was investigated. An EG and G Mark VI sensitometer (Wratten No. 15 filter) was used for exposing the film. A Joyce, Loebl microdensitometer was used to obtain optical density readings of the step wedges printed on the 2443 film. Readings were logged on paper tape for IBM-1800 computer input and subsequent statistical analyses. The negative processing of 70 mm film allowed 21 steps of the step wedge to be accurately measured for all three colors, whereas the positive transparency processing would yield only 19 steps for all colors.

The analysis of variance shown in Table I was conducted on transformed (log base 10) densitometric data from negative transparencies. Considering main effects, wedges, steps, and filters had highly significant variance ($p = 0.01$). Significant differences among steps and filters were expected, but differences among wedges seem undesirable until consideration is given to their means and the interaction of wedges with steps. The optical counts for wedges 1, 2, and 3 were 27.2, 27.7, and 27.0, respectively. The interaction of wedges with steps was not statistically significant, indicating that results were repeatable regardless of the steps or wedges used.

The statistical significance ($p = 0.01$) of the interaction of wedges with filters was mainly caused by the response of wedge 3 with the white filter. Readings that were lower with this combination are believed to be in error. The statistical significance ($p = 0.01$) of the interaction of filters with steps was expected.

Results, therefore, indicate that repeatable densitometric readings can be obtained on sensitometric strips exposed on an EG and G Mark VI sensitometer.

Processing of Kodak Aerochrome, Type 2443, 70 mm Film to a Negative

This processing requires essentially no modification of the normal C-22 processing to a positive. The film is exposed as it would be for a positive with no apparent gain or loss of film speed. Two modifications are: (a) the developer pH is adjusted to pH of 10.6, and (b) developer time is reduced from 14 to 12 minutes. The result is a clean, unmasked, color negative that is easy to print.

The film base responds to aging at room temperature to produce a magenta tint that becomes more intense with increased storage time at room temperature. Frozen film taken from a freezer, thawed at room temperature, loaded, exposed, and developed immediately shows an almost neutral base coloration with only a 0.10 density. Successive development of individual sensitometric strips, developed individually in a Nikor tank and reel, showed the procedure to be reliably reproducible if temperature, timing, and pH were carefully controlled. Individual printing equipment varies too much to allow recommendations for initial filter packs, but a white light print (no filtration, halogen lamp) will give results that allow an easy assessment of the need for further filtration.

Processing Kodak Aerochrome Infrared, Type 2443, 70 mm Film to a Positive in Kodak Ektachrome E-4 Chemistry

This was done according to Eastman Kodak recommendations. However, pH of the solutions made up from the 1-gallon and 3 1/2-gallon size packages varied rather widely among lots. Accordingly, the solutions were adjusted to uniform pH values following recommendations of the photographic section of NASA at Houston, Texas. The effects of these variations are still being investigated, and no specific recommendations will be made at this time.

Other Aspects of Processing Kodak Aerochrome, 2443

The effect of agitation on the E-4 process as applied to 2443 film appears to be more critical than with SO-397 normal color film in the same process and should therefore be carefully standardized and watched for signs of improper agitation.

Research on the storage of 2443 film indicates that film storage conditions are more critical for 2443 than they were for 8443 film. Thus, it is necessary to keep the 2443 film refrigerated or actually frozen for all storage time other than loading, exposing, and processing.

REFERENCES

1. Applied Infrared Photography. 1968. Kodak Publication No. M-28. Eastman Kodak Company, Rochester, New York. 96 p.

2. Fritz, N. L. 1967. Optimum methods for using infrared-sensitive color films. Photogram. Eng. 33:1128-1138.

3. Data Release. 1971. Eastman Kodak Company, Rochester, New York. 5 p.

4. Earth Observations Division Technical Bulletin, 1970. TF6/TB1, NASA, Manned Spacecraft Center, Houston. 2 p, 4 fig.

5. Pease, R. W. 1969-1970. Color infrared film as negative material. Remote Sens. Environ. 1:195-198.

QF

Table I.- Summary table for the analysis of variance for transformed (log base 10) density readings of sensitometric strips exposed on an EG and G Mark VI Sensitometer.

Source of variation	DF	MS
Among runs (R)	1	0.0062
Among wedges (W)	2	0.01140**
Steps among wedges (S)	18	3.42589**
Among filters (F)	3	2.27717**
W x F	6	0.00090**
W x S	36	0.00032
F x S	54	0.06694**
W x F x S	108	0.00025
Error 1/	227	0.00025

** Denotes statistical significance, p = 0.01

1/ Interactions comprising error

Source of variation	DF	MS
W x R	2	0.00005
F x R	3	0.00086
W x F x R	6	0.00144
S x R	18	0.00014
W x S x R	36	0.00024
F x S x R	54	0.00035
W x F x S x R	108	0.00014

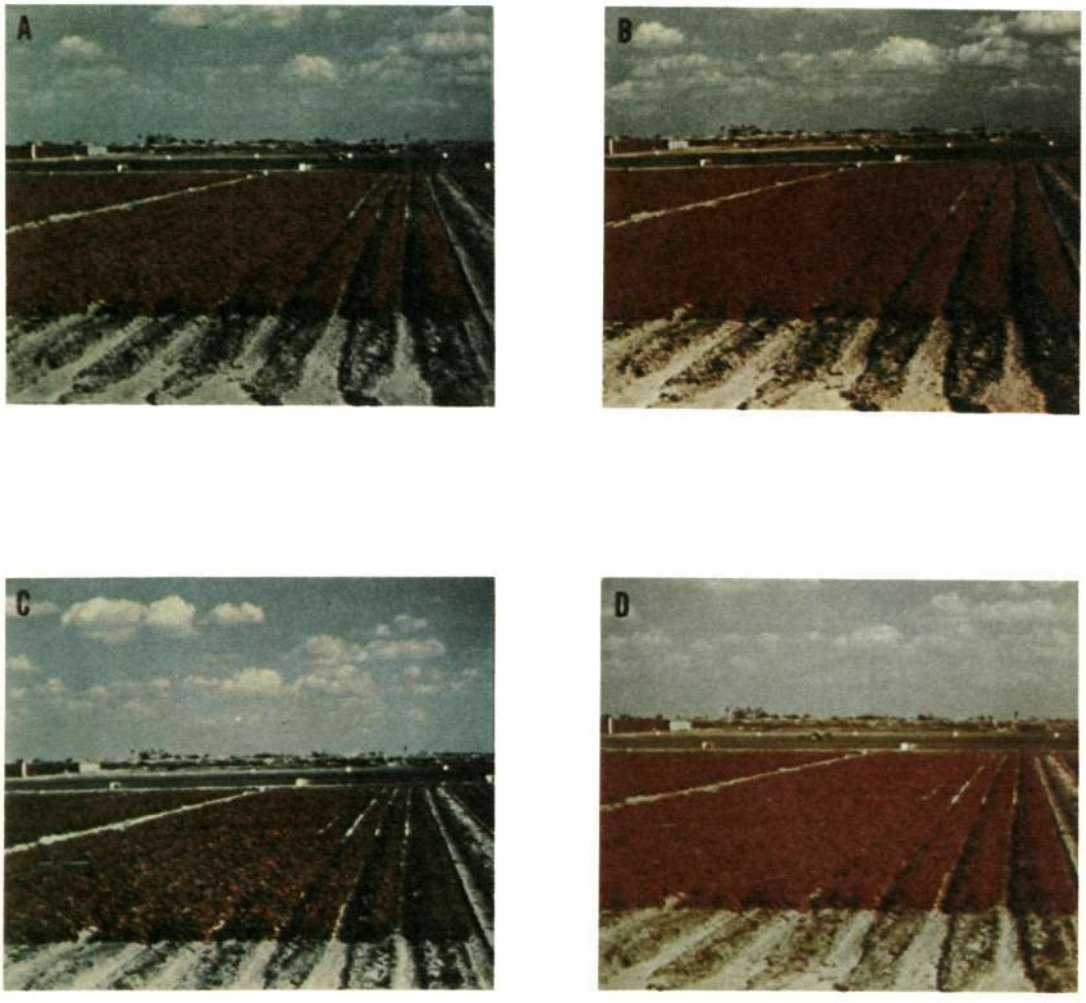

Figure 1.- Representative prints obtained by processing Kodak Ektachrome Infrared Aero, type 8443, and Kodak Aerochrome, type 2443, films to both positives and negatives. Print A is from a positive transparency of 8443, print B is from a negative transparency of 8443, print C is from a positive transparency of 2443, and print D is from a negative transparency of 2443 film.