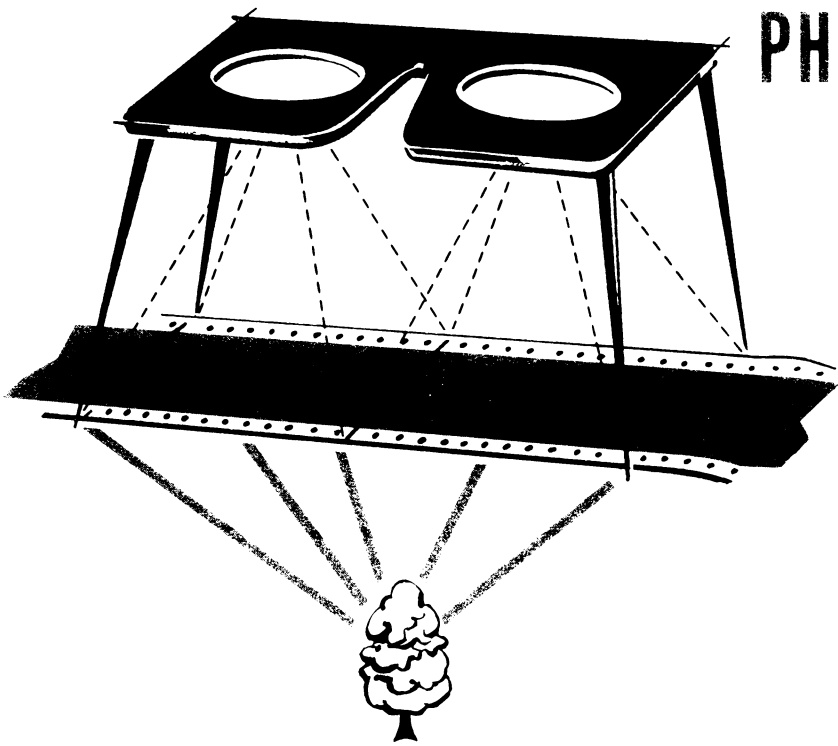
IDENTIFICATION OF TREE SPECIES ON LARGE-SCALE PANCHROMATIC AND COLOR AERIAL PHOTOGRAPHS



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IDENTIFICATION OF TREE SPECIES ON LARGE-SCALE PANCHROMATIC AND COLOR AERIAL PHOTOGRAPHS

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IDENTIFICATION OF TREE SPECIES ON LARGE-SCALE PANCHROMATIC AND COLOR AERIAL PHOTOGRAPHS

This report, which describes results of research conducted near Ely, Minn., in July 1960, indicates the best film and scale combination for identifying tree species. These results should be applicable not only to inventories of timber but also to other projects—such as those to assess damage to forests by destructive enemies, to appraise forest wildlife habitat, and to expedite forest administration.

Forest photo interpreters have recognized for some time their inability to identify images of individual tree species on small-scale aerial photographs (1:15840 or smaller). With experience and knowledge obtained by photo scrutiny, interpreters can now separate forest stands into broad species classes, but they can seldom determine the species of individual tree images at these scales.

Why must foresters identify trees? Those of us concerned with the national timber situation must know what is happening in the woods. How are the trees growing? What is the condition of the forest after harvesting? Is it regenerating? Are there destructive forces at work, such as fire, insects, or disease? And finally, how much and what kind of timber is available? Data are gathered in many ways to answer these important questions—most of it by expensive ground surveys. Because there are 490 million acres of commercial forest land in the United States (*9*)[1] and much of it is inaccessible, sampling techniques are used to make these ground surveys more rapid and less costly. Additional savings in time and money can be expected if more of this expensive ground sampling can be replaced by photo sampling, without sacrificing accuracy.

Study Area and Species

In northern Minnesota the terrain is rolling and interspersed with lakes, and it was previously glaciated. Forests cover about 85 percent of the land area. A boreal area was chosen, because fewer species needed to be compared.

Fourteen important tree species were selected on 29 separate locations. Nineteen replicates were taken of eight of the most important species, and fewer replicates of the other six species. This fact was not revealed to the photo interpreters; thus, equal consideration was given to all 14 species. All test trees were selected so the physiographic features would not help the interpreter identify individual trees.

The species involved in the test were:

1. *Abies balsamea* (L.) Mill.	balsam fir
2. *Picea glauca* (Moench) Voss	white spruce
3. *P. mariana* (Mill.) B.S.P.	black spruce
4. *Pinus strobus* L.	eastern white pine
5. *Thuja occidentalis* L.	northern white-cedar
6. *Betula papyrifera* Marsh.	white birch
7. *Populus tremuloides* Michx.	trembling aspen
8. *Acer rubrum* L.	red maple
9. *Pinus resinosa* Ait.	red pine
10. *P. banksiana* Lamb.	jack pine
11. *Populus balsamifera* L.	balsam poplar
12. *P. grandidentata* Michx.	largetooth aspen
13. *Sorbus americana* Marsh.	mountain ash
14. *Larix laricina* (Du Roi) K. Koch.	tamarack

Methods of Obtaining Data

Collection of Ground Data

Trees were identified in the field on large-scale (1:1000) black and white prints made from color transparencies.[2] To prevent possible bias, the ground identifications were made by a forester who did not take the interpretation test.

A detailed description was made of each tree selected. This included species, diameter at breast height, height, crown class, site class, and other associated features. Only dominant, co-dominant, and intermediate crown class trees were included since overtopped trees are not visible on air photographs.

[1] Italic numbers in parentheses refer to Literature Cited, p. 15.

[2] Since this study, a portable, battery-powered light table was developed to directly locate objects on color transparencies in the field. This device has been used in several other studies with great success.

Collection of Air Data

A Hulcher 70-mm. camera[3] with a 150-mm. (5.91-inch) focal length lens was used. Details about this camera and the modifications needed to adapt it for aerial photography were published in 1959 (*1*).

The films used were Super Anscochrome (General Aniline and Film Corp.), with an ASA rating of 125 for color; and Plus X Aerographic (Eastman Kodak), with an ASA rating of 80 for the black and white photographs.

Photographic scales were approximately 1:3960, 1:1584, and 1:1188 (fig. 3). These scales correspond to units of area measurement commonly used by foresters in the United States.

White panels were placed on the ground to provide identification of each of the 29 locations on the photos while the pictures were being taken.

All film was developed locally so that reflights could be made if necessary. Glossy contact prints with as nearly equal contrast as possible were made from the panchromatic film.

Office Procedures and Photo Interpretation

Cellulose acetate overlays were prepared; these showed the location and number of each tree located previously in the forest on each film and scale combination (fig. 1).

An effort was made to determine whether morphological features, such as crown apexes and crown margins, which may be associated with tree form and growth, would help increase interpreter accuracy. Botanical terminology was used when possible, and drawings were made to help the interpreter select the species (fig. 2).

[3] The identification and description of commercial products in this publication are solely for information purposes. Endorsement of any commercial product is not intended and must not be inferred.

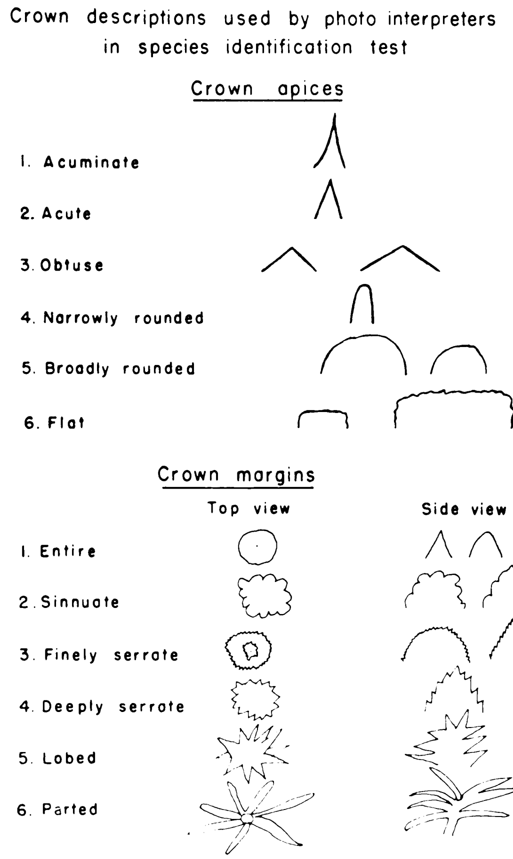

FIGURE 2.—Interpretation aid for describing tree crowns.

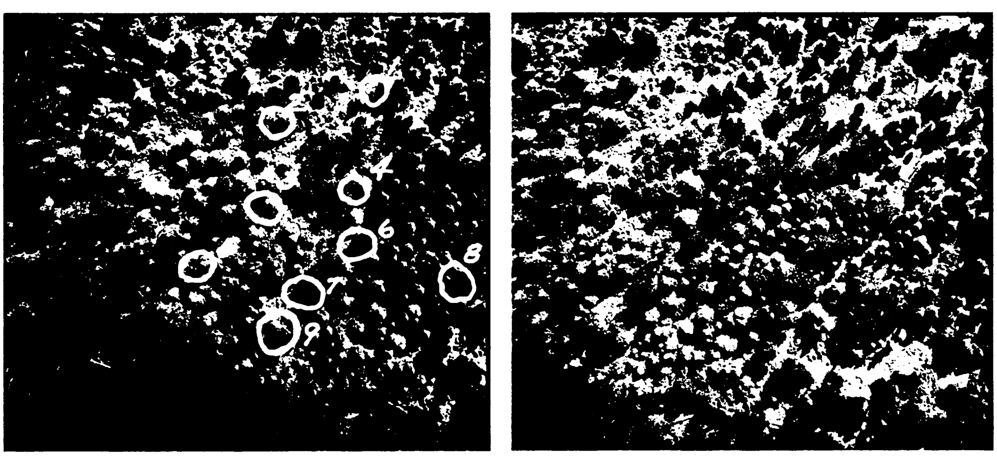

FIGURE 1.—Method of locating trees used in species identification test (Scale 1: 1584, Plus X film). Each number on the translucent overlay indicates a tree image to be identified by photo interpreter.

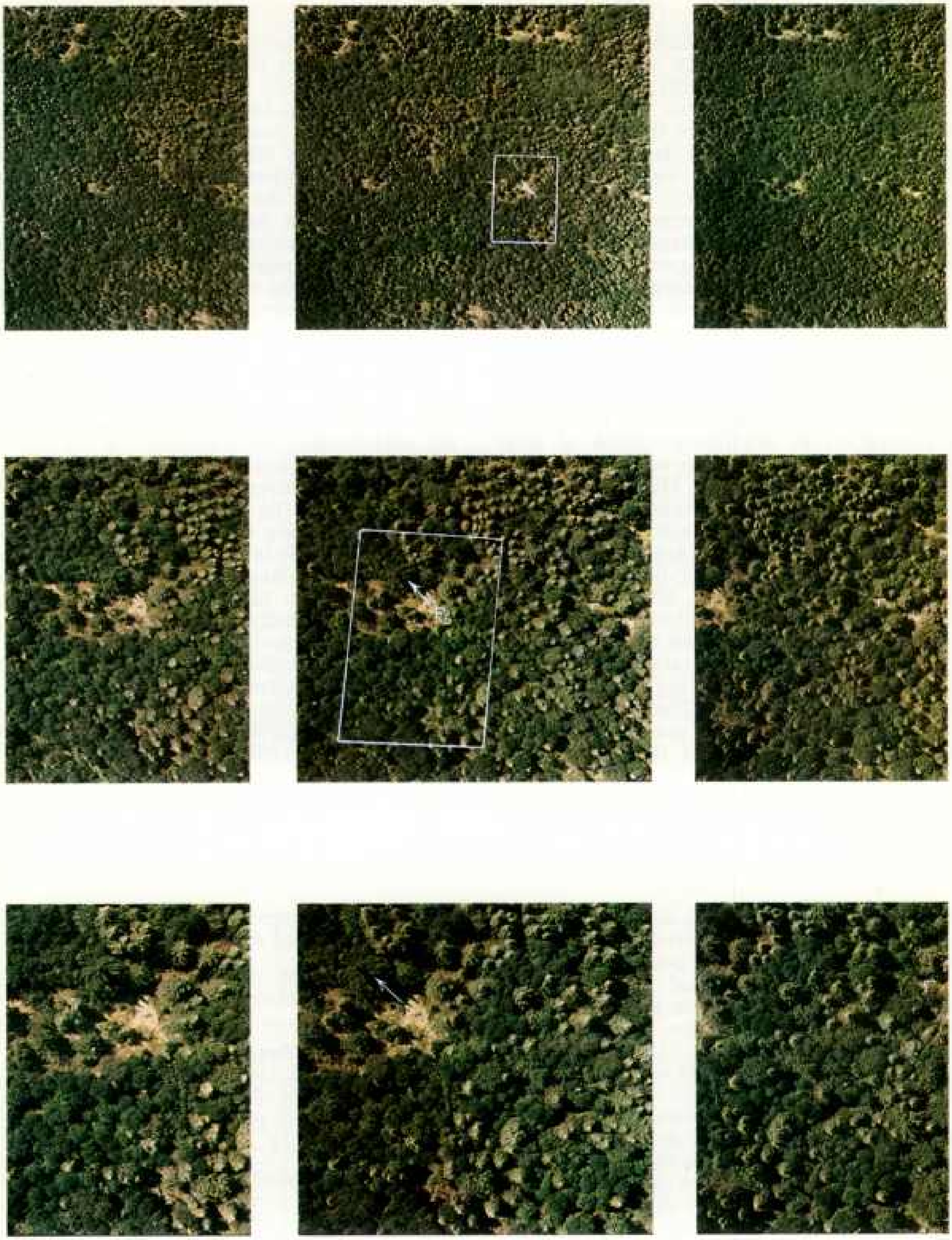

FIGURE 3.—Photographic coverage of one study plot copied from Super Anscochrome film. From top to bottom, the scales are 1:3960, 1:1584, and 1:1188, respectively; the rectangle outlines the identical area of coverage at each larger scale. The arrow with letters *Ps* points to a *Pinus strobus* referred to later in the paper. A lens stereoscope placed over any two adjoining pictures will permit the reader to see the images in 3 dimension.

The foliage density was classified as thin (less than 25 percent), medium (26 to 75 percent), and dense (more than 75 percent).

An entirely new set of terms was devised to relate the foliage arrangement of the species to the shape of the images on the large-scale aerial photographs. These foliage descriptions and drawings are shown in figure 4.

Five experienced photo interpreters examined sample trees to define these foliage and branching characteristics and to write specifications as to how each species looked on aerial photographs. This review of sample trees was used during the training of the four experienced photo interpreters and the one recent graduate from a forestry school who were used in the test.

A Munsell gray scale was used on the panchromatic prints to correlate tone with species.

An innovation in the interpretation of color film was the attempt to relate color represented on the transparencies with Munsell standard color chips (*5*, *6*). These standards represent spaced divisions of the three attributes of color: Hue, value, and chroma. According to the Munsell notation, the hue indicates a color's relation to red, yellow, green, blue, and purple; the value its lightness; and the chroma its strength. The color chips were remounted on special cards with prepunched holes to facilitate color matching (fig. 5). This type of mounting has previously been used for soil sampling. The color matching was done to see if the eye can associate tree species with any one or all of the attributes of color.

Another interpretation test was made of the same tree images on film exposed in July 1962. Instead of using the Munsell charts as before, they were copied onto 35-mm. color film. The roll of film was then inserted into a specially built reflecting device (fig. 6), permitting the photo interpreter to select the color chip that most nearly matched the tree image being inspected. This comparator device enabled the interpreter to compare transparencies of the Munsell chart and the tree image while viewing them stereoscopically with the same kind of light source. It also provided more uniform lighting than was possible when reflected light was used on the Munsell charts.

The panchromatic photographs were examined with a 2.25-power stereoscope under reflected light, starting with the smallest scale and proceeding to the largest.

The color transparencies were inspected with a 2.25-power stereoscope mounted on a specially built light table (fig. 7).

Uniform lighting and interpretation equipment were used by all interpreters. Two interpreters recorded their data (10 classes of information for each tree) on tape recorders and later transferred it to the tally forms. This procedure was much more efficient since it was faster and less tiring than immediately recording the interpretations on the tally forms.

All interpretation data were coded and put on specially designed forms before being transferred to IBM punchcards for tabulation and analysis.

Results

The IBM cards were sorted and tabulated by correct and incorrect interpretations for each species and interpreter. The percentages of the correct observations were used as a basis for subsequent analysis of variance after converting percentages to angles (arc sine transformation, Snedecor (*8*)). The analysis, based on photo interpretation of images of eight species replicated 19 times, showed the following:

1. *Interpreters.*—No statistically significant difference in accuracy was detected between observations made by any photo interpreters of color film. Their mean values and mean differences are shown in table 1; the difference in scale means required for significance at $p=0.05$ is 3.05, as computed by Tukey's range test (*8*). However, the observations of the five interpreters of panchromatic film were significantly different. One man interpreted significantly better than the two least accurate interpreters.

2. *Film.*—Interpretations of color transparencies were significantly more accurate than those of black and white prints.

TABLE 1.—*Mean photo interpretation accuracies made by five photo interpreters on color film* [1]

Interpreter		Difference among interpreter means			
	$\bar{x}$	A $\bar{x}-54.43$	C $\bar{x}-54.70$	B $\bar{x}-55.18$	D $\bar{x}-55.91$
F	57. 14	2. 71	2. 44	1. 96	1. 23
D	55. 91	1. 48	1. 21	. 73	
B	55. 18	. 75	. 48		
C	54. 70	. 27			
A	54. 43				

[1] Values shown are angles not transformed to percentages; a difference of 3.05 between interpreter means is required for significance at the 0.05 probability level.

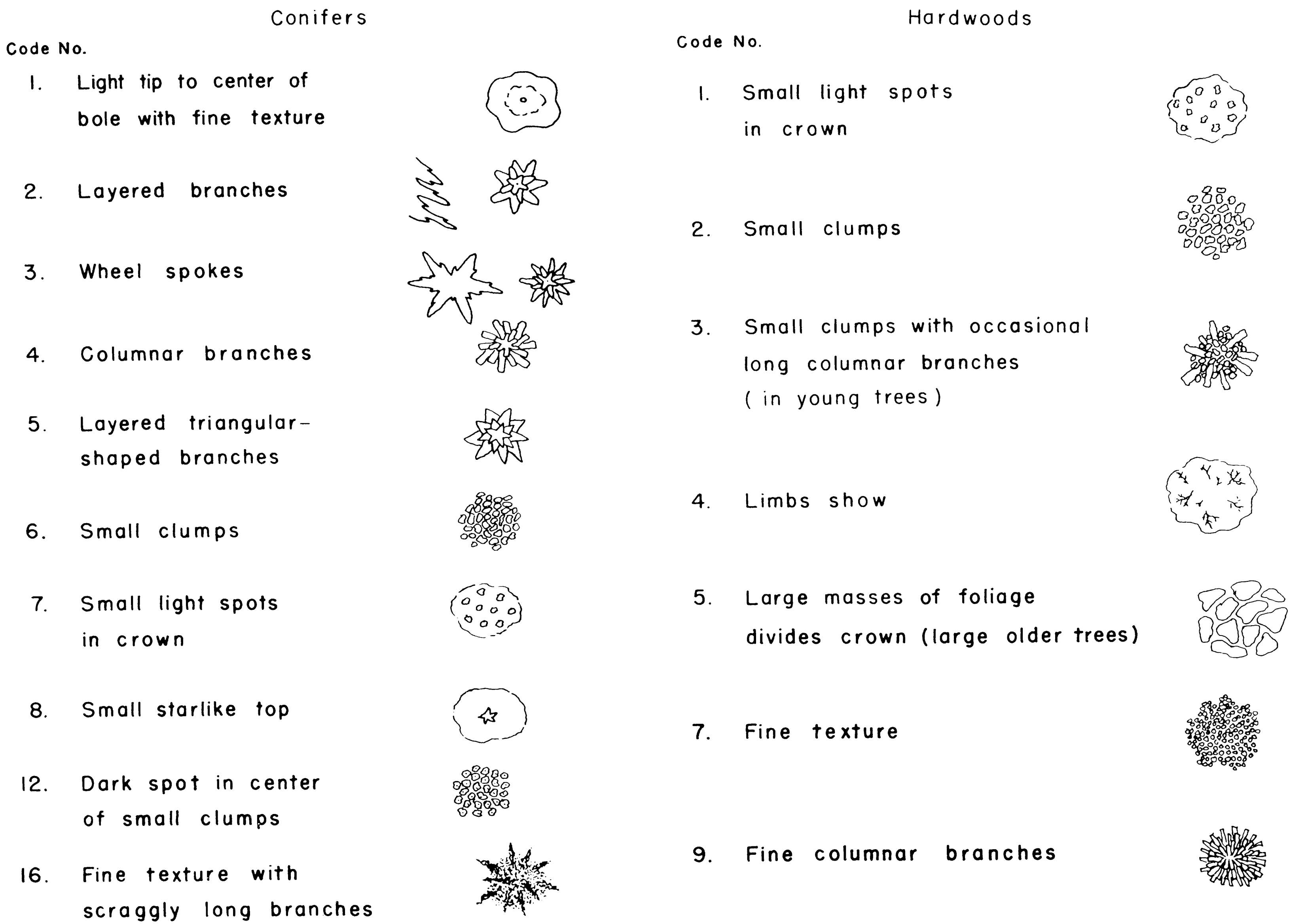

FIGURE 4.—Foliage characteristics most useful in separating 14 boreal tree species.

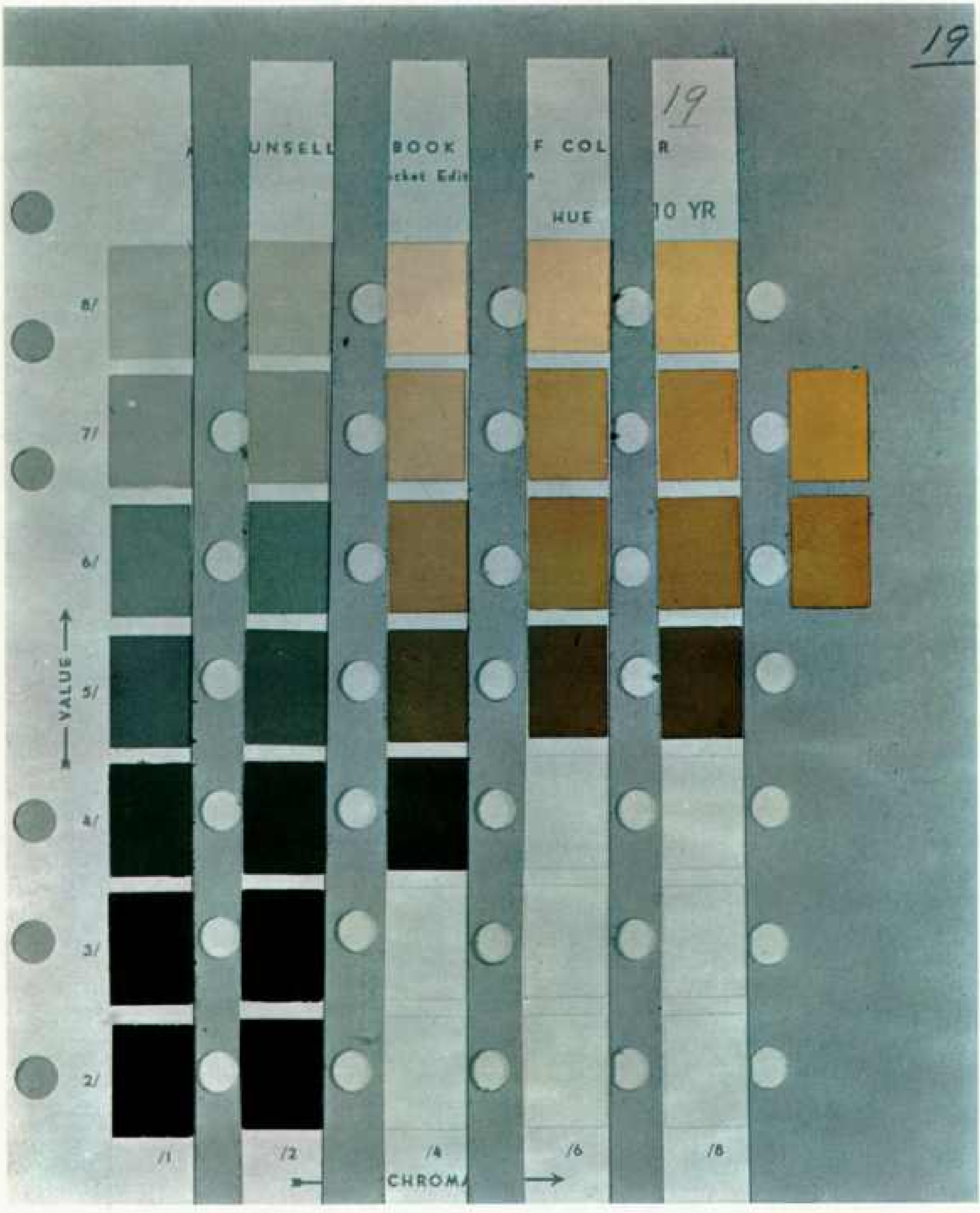

FIGURE 5.—Munsell color chart (10YR) used to compare color chip with tree image on a color transparency.

FIGURE 6.—Comparator device permits photo interpreter to select a matching color chip while viewing tree images in stereo.

3. *Photographic scale.*—Interpretation was poorer with the smallest scale than with the two larger scales (fig. 8). Differences in interpretation were highly significant among all scales on panchromatic film. For the color transparencies, the two larger scales were almost equally accurate, and both were significantly better than the 1:3960 scale at the 0.01 level (table 2).

4. *Tree species.*—Interpretation differences among the eight tree species were highly significant. Obviously, the morphological and color characteristics differ enough among tree species to make some species easier to recognize than others. Accuracy in interpreting color film was consistently higher for each tree species than accuracy in interpreting panchromatic film (fig. 9). The black and white spruces could not be separated accurately even on color film.

TABLE 2.—*Difference in accuracies attributable to scale on color film—average of five interpreters* [1]

Scale	Scale mean $\bar{x}$	Differences between scale means	
		(1:3960) $\bar{x}-47.04$	(1:1584) $\bar{x}-58.44$
1:1188	60.95	13.91 [2] (2.74)	2.51 (2.74)
1:1584	58.44	11.40	----------
1:3960	47.04	----------	----------

[1] Computed by Tukey's range test (Snedecor); values shown are angles and not percentages.
[2] Values in parentheses show difference required for significance at $p=0.05$.

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FIGURE 7.—70-mm. transparency viewer with interpreter comparing a Munsell chart with a selected tree image. Note tape recorder to facilitate recording data.

Three species will be discussed in detail (fig. 10). *Pinus strobus*, which ranked first in accuracy of recognition, showed little change between the two larger scales. *Betula papyrifera*, which ranked last, showed little improvement in accuracy with increased scale. Recognition of *Thuja occidentalis* was greatly improved with the increase in scale. Photo images of some species may be harder to recognize than others because of differences in their morphological features and color characteristics, as in the three sample species.

1. *Pinus strobus* was accurately identified by all interpreters. They consistently recognized its characteristic foliage arrangement, e.g., a pattern of massive triangular branches that radiate like the spokes of a wheel. Furthermore, this species has a greener hue than any of the other pines, making correct interpretations easier. A *Pinus. strobus* is illustrated in figure 3, p. 3; the arrow points to a typical specimen.

2. *Betula papyrifera* was identified correctly by its fine foliage texture when the tree was full crowned and vigorous, but when the tree was decadent and had thin foliage, its image was generally confused with that of *Populus tremuloides*. Both of these species have white bark that shows through the foliage on older specimens, and this similarity confused the photo interpreters. White birch had a consistently yellower hue (10Y) and a lower value (6.4) than any other hardwood species. Young trees had stronger chroma than old trees (fig. 11, *A* and 11, *B*).

3. *Thuja occidentalis* was recognized by sinnuate crown margins, pointed apexes, light spots in the foliage, and image color on the large scales. The interpreters consistently designated this species as

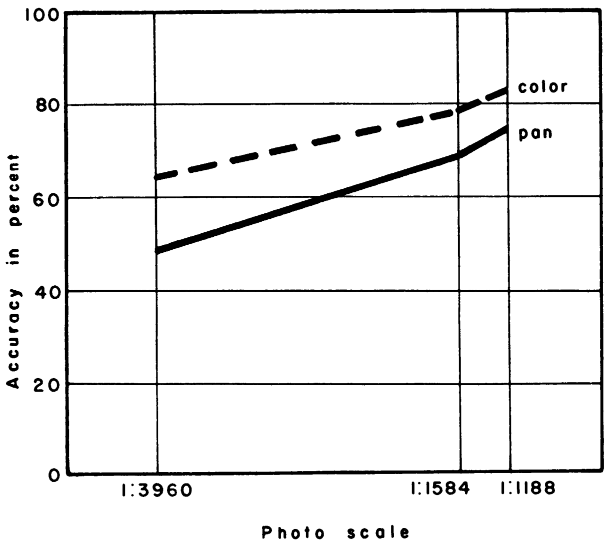

FIGURE 8.—Note improvement in accuracy obtained with all scales on color film. Graph shows the average interpretation of five observers for all species.

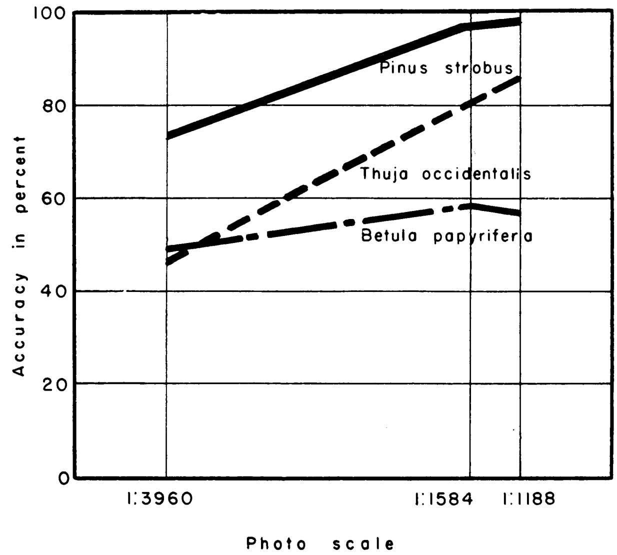

FIGURE 10.—How scale affects the photo interpretation accuracy of three particular species.

Species ranked in order of interpretation accuracy—in percent 1/

Panchromatic

Pinus strobus	Thuja occidentalis	Pinus resinosa	Pinus banksiana	Picea spp.	Abies balsamifera	Acer rubrum	Populus tremuloides	Betula papyrifera
95	81	80	80	77	73	70	59	44

Super Anscochrome

Pinus strobus	Pinus banksiana	Picea spp.	Pinus resinosa	Thuja occidentalis	Abies balsamifera	Acer rubrum	Populus tremuloides	Betula papyrifera
97	96	88	88	86	84	73	64	56

1/ Average of 5 interpreters — scale 1:1188

FIGURE 9.—Note better accuracies for each tree species on color film as compared with panchromatic film.

Figure 11.—Scale 1:1584, Super Anscochrome. *Betula papyrifera* (*Bp*) has fine texture and strong chroma when young and vigorous (*A*), but the foliage tends toward large clumps in older specimens (*B*). *Thuja occidentalis* (*To*) in *C* can be separated from other conifers by the light yellow spots in the foliage and the small starlike crown apexes. *Populus tremuloides* (*Pt*) also in *C* has large masses of foliage and is the greenest in hue of all hardwoods.

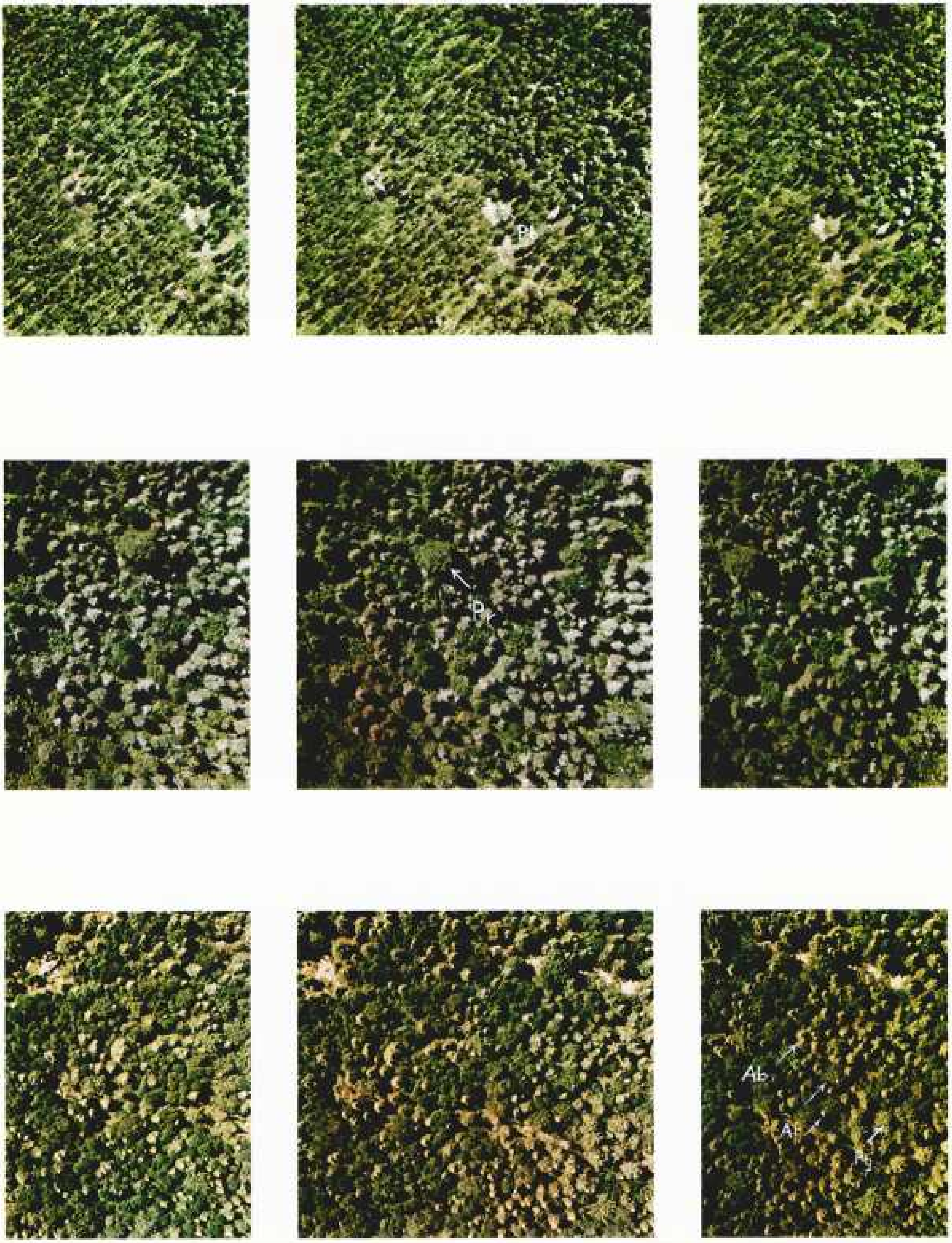

FIGURE 12.—Scale 1:1584, Super Anscochrome. *A*, *Pinus banksiana* (*Pb*), jack pine; *B*, *P. resinosa* (*Pr*), red pine; *C*, *Acer rubrum* (*Ar*), red maple; *Picea glacua* (*Pg*), white spruce; and *Abies balsamifera* (*Ab*), balsam fir. Note also many dead and dying balsam fir (*A. balsamifera*) damaged by the spruce budworm (*Choristoneura fumiferana*), Clem., which appear light gray to pink.

having the yellowest hue of any conifer (8.5 Y). None of these four characteristics were easily recognized on the small scale (fig. 11, *C*).

The other species that had high interpretation accuracies also had distinguishing foliage characteristics. For example, *Pinus banksiana* is recognized by its ragged branches (fig. 12, *A*). *P. resinosa* has foliage in small clumps with a dark spot in the center of each clump (fig. 12, *B*), and older trees have broadly rounded crowns. *Acer rubrum* has characteristically shaped columnar branches and the strongest chroma of any species studied (fig. 12, *C*). *Picea glauca* and *Abies balsamifera* are indicated in figure 12, *C* by arrows.

Consistency of results is important to photo interpreters. Therefore, three interpreters examined the same trees described in this paper on Super Anscochrome film exposed in the summer of 1962 at a scale of 1:1584 (fig. 13). Because of better exposure of the film, two of the interpreters obtained better species recognition than in 1960. The third interpreter's accuracies were of the same order as those found in the first interpretation. It is interesting and important to realize that the same or better accuracies are possible in using this photo interpretation technique with the two independent inspections.

From the tabulations made from the punchcards, we learned which morphological and color features contributed most to the correct identification of tree species. These are summarized in the appendix. Each feature is given a weight, so theoretically, if an interpreter identifies the correct features of an image, he may use the total of these weights to help him identify the species. For example, if a tree image is a conifer (weight 0), has an acuminate crown apex (1), an entire crown margin (1), a light tip to the center of the trunk (1), a hue of 10GY (green yellow) (3), a value of 8 (4), and a chroma of 4 (4), the image should key out to a balsam fir (*Abies balsamifera*), which averages a total weight of 14. When using large-scale color film, interpreters were able to separate conifers from hardwoods with almost 100-percent accuracy. The appendix table can also be used as a training guide for photo interpreters who are unfamiliar with the timber types and who should learn what crown, foliage, and color characteristics are most commonly associated with each species.

Pinus strobus	Picea spp.	Abies balsamifera	Pinus banksiana	Pinus resinosa	Thuja occidentalis	Populus tremuloides	Acer rubrum	Betula papyrifera	All spp.
100	97	97	97	97	90	90	74	67	90

FIGURE 13.—Average photo interpretation accuracies (in percent) obtained by two interpreters in 1962 test. Super Anscochrome 70-mm. film was used (Scale 1:1584).

Discussion and Conclusions

Color film is superior to panchromatic film for use in identifying individual tree species. Why? First, people are accustomed to seeing and identifying objects not only by shape and form but also by color. A ripe tomato is picked from the vine by its color rather than its shape, and cotton can be graded by the lightness and yellowness of the fiber (*7*). A forester trained to recognize trees by morphological features also associates a color with that tree. When he is trained to recognize the tree on aerial color photographs, he has one more factor on which to base his determination. Thus, it requires more training for an interpreter to be able to recognize objects by tones of gray than by the normal colors with which he associates the object. In panchromatic interpretation he must learn to relate the gray tone of the image to color, and by associating its form and texture, he tries to identify the object.

Evans (*4*) reports that the eye can separate 200 tones of gray which are seen by the rods (brightness-sensitive nerves), whereas the cones (color sensitive nerves) can distinguish 20,000 hues and chromas. This 100:1 ratio may help explain why the results from the color film were better than those from the black and white prints.

At Nickerson's[4] suggestion, the test data were plotted on a chart representing hue, value, and chroma (*7*) (fig. 14). Use of this chart indicated that value or degree of lightness helped the photo

[4] D. Nickerson, color technologist, Agr. Marketing Serv., U.S. Dept. Agr., gave considerable advice and assistance in evaluating the data. The authors express their appreciation.

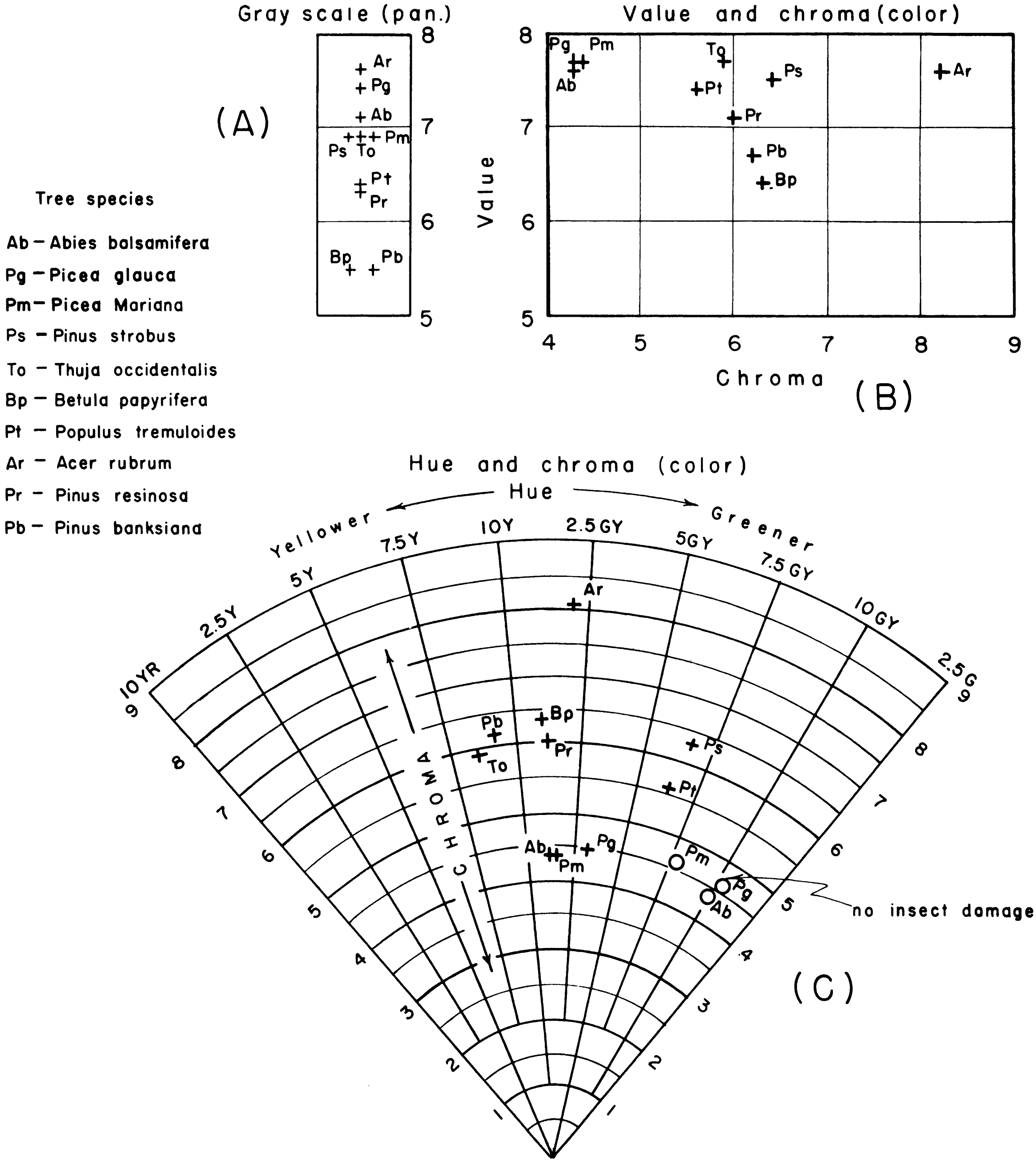

FIGURE 14.—Ten tree species depicted by by Munsell Color Notation. Graph shows gray-scale values for tree species on panchromatic prints (*A*) and two-dimensional plotting for value and chroma on color film (*B*) and hue and chroma on color film (*C*).

interpreter very little in separating tree species. On panchromatic prints, the values (or tones) were obtained by comparing a Munsell gray scale with images of each species. (Value on panchromatic prints can be represented in only one dimension, along the ordinate). For example, white birch had the lowest value rating (5.5 on panchromatic film and 6.4 on color) of any species and was the only species where value was of any help in separating it from a species similar in appearance. This was true on both color and black and white film. Most other species had such a narrow and overlapping range of values that no discrimination was possible. Gray-scale values and color values were comparable although somewhat lower for species on the panchromatic prints; this may be caused simply by differences in darkroom procedures (table 3).

TABLE 3.—*Comparison of the value scales for panchromatic and color film for 10 tree species, 1:1584 scale*

Species	Panchromatic film	Color film
Betula papyrifera	5. 5	6. 4
Pinus banksiana	5. 5	6. 7
P. resinosa	6. 3	7. 1
Populus tremuloides	6. 4	7. 4
Pinus strobus	6. 9	7. 5
Thuja occidentalis	6. 9	7. 7
Picea mariana	6. 9	7. 7
Abies balsamifera	7. 1	7. 6
Picea glauca	7. 4	7. 7
Acer rubrum	7. 6	7. 6

Value and chroma data derived from the color transparencies were plotted as they would be on a Munsell chart. While the differences in value among species are still small on color film, by adding another variable—chroma—greater separation between species can be seen (fig. 14, *B*).

Perhaps the greatest contribution to species identification that color film makes is the hue-chroma combination. Interestingly, before taking the test, most of the interpreters had a preconceived notion that tree images would appear green or blue green except for a few green yellows. Their data, however, showed that most of the species were tallied as yellow to green yellow and that only two approached green.

According to the Munsell notation, hue or color can be represented by 100 equally spaced increments of a hue circuit beginning with 1 red and ending with 10 red purple. The 10 major hues are:

R: red
YR: yellow red
Y: yellow
GY: green yellow
G: green
BG: blue green
B: blue
PB: purple blue
P: purple
RP: red purple

There is a wide spread in hue and chroma among the conifers; pines have more chroma than fir and spruces, and white pine averages three hues greener than red or jack pine. Of the hardwoods, red maple was consistently recorded with the strongest chroma, while trembling aspen was greener than red maple or white birch. These distinctions can be seen in fig. 14, *C*.

Because the 1960 color pictures were overexposed, the comparison of the color attributes was made with the 1962 pictures. Chroma seems to be most affected by camera exposure; overexposure tends to wash out the strength of the color, thus reducing the effectiveness of one color attribute.

The frequency of hues observed by photo interpreters for each species exhibited a definite central tendency such as that found in a normal curve of error. However, the upland spruces and balsam fir had a rectangular distribution of hue (7.5YR to 2.5G) caused by spruce budworm feeding damage to foilage of these species. Various degrees of budworm feeding caused foliage to change from green through yellow to red brown (YR). Thus, the hues can be correlated with the degree of damage that occurred. This relationship is particularly interesting to forest entomologists. In the absence of defoliation, the normal hues for these species were found to be greener than when all degrees of defoliation were included (see circles in fig. 14, *C*).

The slight range of hues for each species may be attributed to two factors: (1) A normal variation in hue within tree species and (2) an actual physiological difference in the receptivity of human eyes. This diversity of receptivity is particularly important; for example, about 8 percent of males do not have trichromatic vision. However, color blindness tests (*2*, *3*) are available and should be taken to avoid unwanted variation between interpreters, if much color photo interpretation work is contemplated.

On the basis of this test, accurate identification of individual tree species requires color film at a photoscale of 1:1584 or larger. Even on color film, the 1:3960 scale produced fairly low accuracies of interpretation (63 percent).

A recent forestry graduate, who had one previous course in forest photogrammetry, did as accurate a job of interpreting at these scales as did men having 20 years' experience. This man was given 3 days of intensive training on sample trees and sample photography before taking the test. Thus, the interpreter's experience can be disregarded as a variable in interpreting large-scale color transparencies if proper training and training aids are used.

The cost of using color film at large scales should be little more than that required for panchromatic film. While color film costs five times as much as panchromatic film, the important point is that film cost is only a small part of the total cost of aerial photography. When the equal aircraft costs, the same standby time for the flight crew, elimination of the need for prints, and reduction of photo handling by interpreting color film in rolls are considered, the extra cost of the color film is minor. Increased interpretation accuracy on color film would counterbalance the slight increase in cost.

Tree species were identified accurately enough on color film at large scales to suggest the possibility of using it on actual inventory problems. Further study of hardwoods, especially to associate their crown and foliage characteristics with age and physiographic features, should be helpful in improving identification of these tree species.

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Appendix

SPECIES ARRANGED ACCORDING TO MOST FREQUENTLY IDENTIFIED FEATURES ON COLOR PHOTOGRAPHS (1:1584 SCALE)—Con.

Identifying features	Conifers (0 weight)							Hardwoods (100 weight)				Weight
	Abies balsamifera	*Picea glauca*	*Picea mariana*	*Pinus strobus*	*Thuja occidentalis*	*Pinus resinosa*	*Pinus banksiana*	*Populus balsamea*	*Populus tremuloides*	*Betula papyrifera*	*Acer rubrum*	
Crown apexes:												
Acuminate	X											1
Acute		X	X		X							2
Obtuse				X								3
Narrowly rounded												4
Broadly rounded						X	X	X	X	X		5
Flat											X	6
Indefinite											X	7
Crown margins:												
Entire	X											1
Sinnuate			X		X	X		X	X	X	X	2
Finely serrate		X	X		X		X	X	X	X	X	3
Coarsely serrate		X					X				X	4
Lobed		X		X			X				X	5
Parted												6
Foliage arrangement:												
Conifers:												
Light tip to bole	X											1
Layered branches		X	X									2
Wheel spokes		X		X								3
Columnar branches		X		X								4
Large triangular branches				X								5
Small clumps			X									6
Small light spots					X							7
Starlike top					X							8
Dark spot in clump						X						12
Fine texture and scraggly branches							X					16
Hardwoods:												
Small light spots								X				1
Small clumps									X			2
Occasional long branches									X			3
Limbs show (old trees)									X	X		4
Large foliage masses										X		6
Fine texture										X		7
Columnar branches											X	9
Color attributes:												
Hue:												
5 green												1
2.5 green		X										2
10 green yellow	X											3
7.5 green yellow			X	X								4
5 green yellow									X			5
2.5 green yellow								X		X	X	6
10 yellow						X						7
7.5 yellow					X		X					8
5 yellow												9

Value:												
5												1
6										X		2
7				X		X	X	X	X			3
8	X	X	X		X						X	4
Chroma:												
2												2
4	X	X	X									4
6				X	X	X	X	X	X	X		6
8											X	8
Average sum of weights	14	19	21	25	30	35	42	123	125	128	139	

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