Detection and Classification of Ash Dieback on Large-Scale Color Aerial Photographs

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Acknowledgments

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Surveys of ash trees killed by ash dieback in the Northeastern United States indicate that the disease is slowly spreading and becoming more intense. In a ground survey, Tegethoff and Brandt (1964) found that 27.2 percent of sampled ash trees in the six-state area surrounding New York State were either dead or dying.

Both white ash [1] and green ash are susceptible to this disease, but green ash comprises only a small part of the ash component of hardwood stands in that region. Consequently, white ash--a valuable species in great demand--bears the brunt of the losses. Since trees of all ages arc known to be susceptible, ash dieback will cause a future shortage of white ash logs because of current mortality in the sapling and pole sizes--even if it subsides quickly.

The first symptoms of the disease are dwarfing of the leaflets and the appearance of a sickly yellow-green color of the foliage. The disease begins in the smallest twigs and spreads to larger branches. As the dead twigs are shed and stagheadedness develops, the tree may produce epicormic branches below the active infection (Brandt 1963; Silverborg *et al.* 1963). Killing of the twigs, branches, and limbs continues rapidly; within 2 to 7 years the tree is dead.

A primary causal agent has not been found, but forest pathologists agree that ash trees never recover from ash dieback (Brandt 1961; Zabel *et al.* 1963; Tegethoff and Brandt 1964). Ross (1963) reported that two fungi, *Cytophoma pruinosa* (Fries) Hohn. and *Fusicoccum* sp., are secondarily associated with the disease. Similar declines of other hardwood species have been observed.

Forest pathologists suspect that both ash dieback and other hardwood declines may be induced by drought (Yops *et al.* 1964). New York State has had three major periods of drought since the early 1950's. The reduction in vigor caused by droughts or other adverse climatic conditions (Hepting 1960, 1963; Ross 1964) may lead to an intensification of damage from these secondary fungal invaders that are thought to be ordinarily saprophytic or only weakly parasitic.

Despite the lack of knowledge about the causes of ash dieback, its effects and widespread distribution on valuable host species warrant periodic surveys so that trends of spread and intensity can be followed. The large geographic area already involved suggests that aerial methods of surveying arc desirable, if feasible.

This paper reports on a study to determine if ash trees could be identified on large-scale aerial photographs and then be placed into broad classes according to dieback symptoms. If ash could be distinguished from other hardwoods and classified on film, an aerial survey technique could readily be designed and made operational.

Methods

Preparation of Training Aids

The first need was to determine the appearance of ash, associated species, and ash dieback, on aerial film so that interpreter training aids could be prepared. Color photography was selected because the symptoms of ash dieback include a distinct yellowing of the foliage and because the foliage of many hardwood species shows differing hues and chromas which may make separation easier. An area known to have ash dieback was photographed on August 18, 1964, near Red

[1] Scientific names of trees and shrubs are listed in the appendix.

Hook, New York, using photographic scales of 1: 1,584 and 1: 7,920.[2] A Hulcher[3] 70-mm. camera with a 150-mm. focal length lens was used to expose Anscochrome D-200 color film with a skylight (1A) haze filter. This film has an ASA rating of about 160 when used in aerial photography.

After the film was developed, the color transparencies in strip form were taken to the field and used in a portable, battery-powered light table to enable ground identification of selected healthy ash, diseased ash, and trees of associated species. Each ash tree chosen was given a dieback rating of 1 through 5, based on the following dieback-symptom classes:[4]

Class 1: Trees healthy; leaves dark green; no dead bare twigs in living crown.

Class 2: Top thin; leaves tending to clump at end of twigs; foliage paler green than normal; leaves may be dwarfed; some dead twigs; possibly some cankers at base of twigs.

Class 3: Twigs dying back; less than 50 percent of crown dead; leaves clumped at ends of twigs and branches, and leaflets dwarfed; foliage pale green; cankers possibly visible on branches and stems.

Class 4: Branches dying back; more than 50 percent of crown dead; epicormic branches may be present, leaves clumped and leaflets dwarfed; foliage pale green; cankers sometimes visible on branches and stems.

Class 5: Tree dead.

After a tree was identified and classified on the ground, it was located, circled, and numbered directly on the color transparency.

In the laboratory, these circled trees on the film were carefully studied stereoscopically and detailed descriptions were prepared for each of the five classes of ash plus each of 13 associated species at both scales. From these descriptions it became a fairly simple matter to produce a dichotomous key containing all 13 species and all classes of ash dieback. Part of the film was used together with the descriptions and key to train four interpreters; the remainder was reserved to test their abilities after they were considered proficient.

Preliminary Test

With all training aids available to them, the interpreters were asked to identify a number of circled trees on the film as to species. If a tree was thought to be ash, they were to indicate its dieback class.

The results of this test were encouraging. The four interpreters identified ash with better than 92 percent accuracy at the larger scale and 78 percent accuracy at 1:7,920 scale. The five dieback classes were correctly interpreted (within one class) 88 percent of the time at 1: 1,584 and 71 percent at 1:7,920. We then decided to determine if the interpreters could scan an area on the film and select the ash satisfactorily, when trees were not circled.

Final Scan Test

Ash stands infected by dieback were selected and marked on the ground within the boundaries of forests owned by the New York State Conservation Department. Stable ownership of the test area was desired because of the long-range nature of the study. The study area was located in Dutchess County near the Taconic Parkway east of Poughkeepsie, New York. Markers of white butcher paper were placed in clearings adjacent to the areas to be photographed to aid in spotting these test areas from the air. The photographs were taken on June 11, 1965, with the same scales, film, and equipment used in the first photographs. This date was selected because by then the new growth on ash was fully expanded. Dwarfing of the leaflets is an important characteristic of trees infected with dieback (fig. 1), and this symptom could have been confused with normal but immature leaves if an earlier date had been chosen.

Many of the seriously diseased ash on the 1964 Red Hook film strip (photographed in late summer during a drought year) had all brown leaves. Others showed yellow and red colors on certain portions of their crowns and the remainders were yellow-green. We suspected that these were not the true characteristic colors of ash dieback, but expressions of premature fall coloration induced by the interaction of dieback and drought. Therefore the Red Hook area was rephotographed, at the larger scale only, on June 11, 1965. Of the many individual ash trees compared on the two

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[2] A photographic scale of 1:7,920 means that 1 inch, measured on the photo, represents 7,920 inches on the ground. These unusual scales were chosen because they become whole numbers when converted to chains per inch: 1:1,584 equals 2 chains per 1 inch, and 1:7,920 equals 10 chains per inch.

[3] Trade names and commercial products or enterprises are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

[4] Tegethoff and Brandt (1964) used the same classification system in their ground survey of ash dieback.

Class 1 Class 3 Class 5

Figure 1 --*Three classes represented by healthy, diseased, and dead ash trees. Leaflets have become dwarfed and foliage thin in the center tree.*

films, most had refoliated in the spring of 1965. Although the foliage was slightly sparser, the trees had produced new leaves of a pale green color rather than the browns, reds, and yellows present during the previous autumn. These atypical dieback colors were therefore removed from the training key.

After the film for the Poughkeepsie study area was developed, additional sample trees of ash, associated species, and ash dieback just outside the new study area were identified on the ground and located on film. This procedure was necessary because the trees in the new Poughkeepsie area to be interpreted were some 17 miles from the trees at Red Hook upon which the training aids were based. No differences in ash appearance were found at the new location, so no further updating of the training material was needed.

Fourteen plots were selected on the transparencies, each placed near the center of a photo frame to minimize tree image displacement. Each plot represented roughly $^1/_2$ acre, making a total study area of about $6^1/_4$ acres. The plots were outlined in ink on the transparencies, with the boundaries meandering between tree crowns to assure that all interpreters would be examining the same borderline trees.

The film (figs. 2, 3) was interpreted by three photo interpreters, none of whom had seen the study area on the ground. Use of training aids was encouraged during the test. The smaller scale film was interpreted first to eliminate bias caused by memory. Interpreters were asked to circle on transparent plastic overlay material every ash within the plot boundaries and to assign each one a dieback class number. For this test the number of dieback classes was reduced from five to three, but class numbers 1, 3, and 5 were retained so that the results could be more easily compared with those of the preliminary study. Comparison

Figure 2.--*Stereogram of a part of the Poughkeepsie, New York, study area at a scale of 1:7,920. See fig. 3 for larger-scale view of area outlined.*

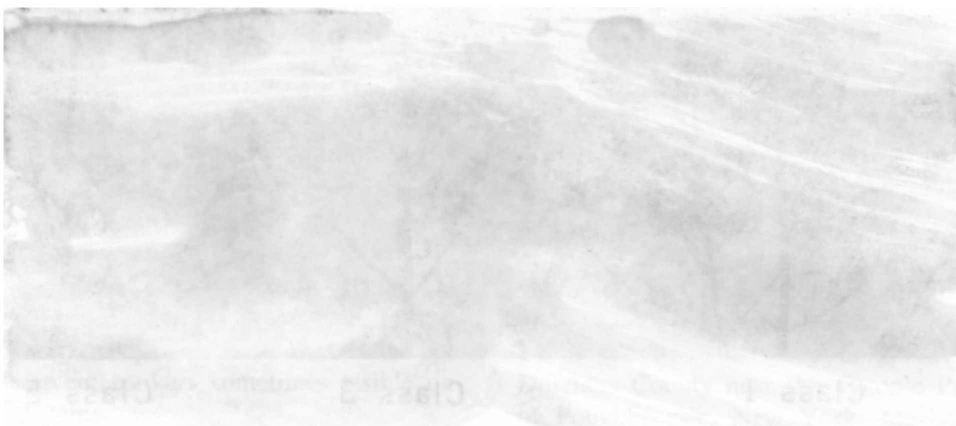


Figure 3.--*Stereogram of a portion of the same area as fig. 2 at a scale of 1:1,584. Species indicated are:* A, *healthy ash;* B, *healthy American elm;* C, *class 3 ash;* D, *dead American elm (twigs fine, many crooks);* E, *dead ash (twigs coarse, rather straight); F, healthy black willow;* G, *healthy sugar maple;* H, *healthy red maple;* J, *paper birch badly damaged by a leaf skeletonizing insect.*

of dieback class ratings for the two tests showed the following:

Dieback classes used. in preliminary test	Dieback classes used in area-scan test
1	1
2	
3	3
4 (lower 1/2)	
4 (upper 1/2)	
5	5

A master template prepared for each plot contained all tree images identified as ash by each interpreter. Each circled tree on these templates was carefully examined on the ground. Information was gathered not only about species and dieback classification but also diameter at breast height (d.b.h.), total height, crown class, crown diameter, and soil moisture. At the same time, any ash trees not identified by the interpreters were located in the field and accurately plotted to provide information on errors in which interpreters failed to see existing ash trees. We found that the study area actually contained 155 ash trees--four were black ash and the remainder white ash. Because these ash species looked alike on the film they were combined in the analysis.

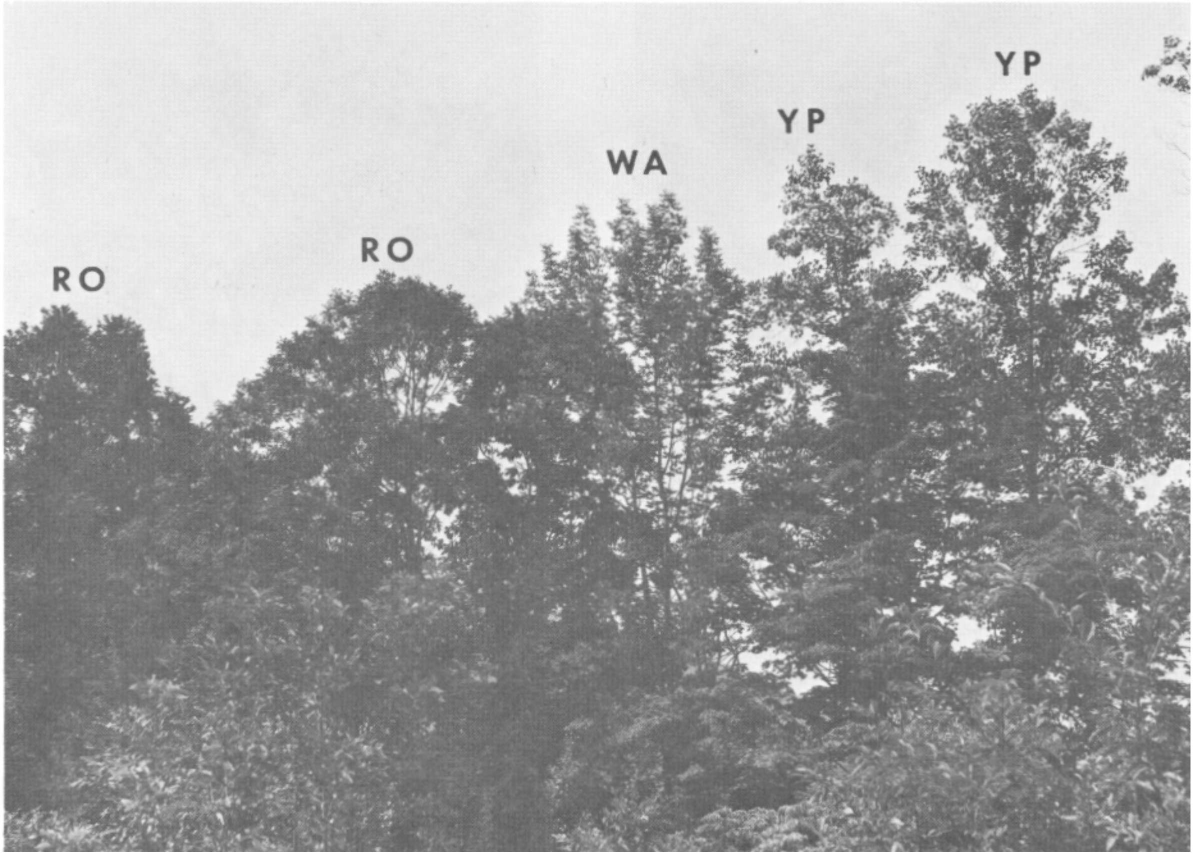


Figure 4--*Skyline view of red oak, white ash, and yellow-poplar crowns clearly shows the upswept finger-like branching habit of white ash.*

Ash Characteristics

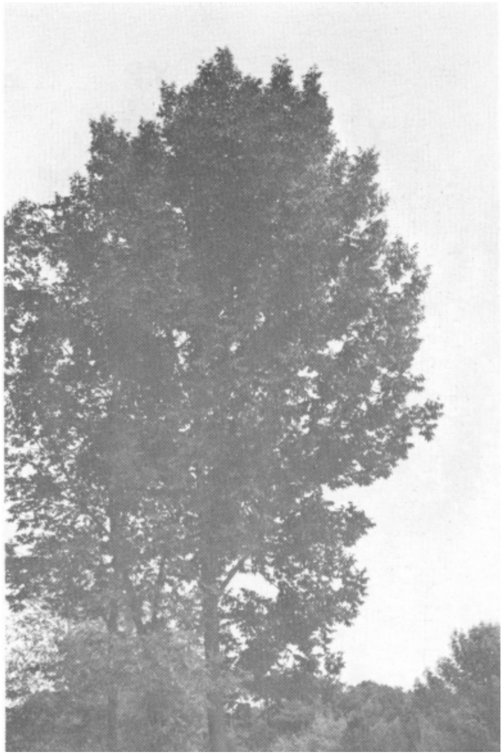
Fortunately, ash has several distinctive characteristics that enabled it to be distinguished from the associated species on color film. Certain of these attributes came to light during the final scan test; the principal ones are listed below in order of their importance:

1. The limbs, branches, and twigs of ash are upswept and erect (figs. 2, 3). On healthy ash the leaves are distributed well down the twigs, giving a columnar effect. Therefore, from above an observer sees the ends of many vertically-oriented columnar twigs. In side views of ash crowns, it is easy to visualize why the vertical view gives this upswept finger-like appearance (figs. 4, 5). American elm (figs. 3, 6) lacks this characteristic.

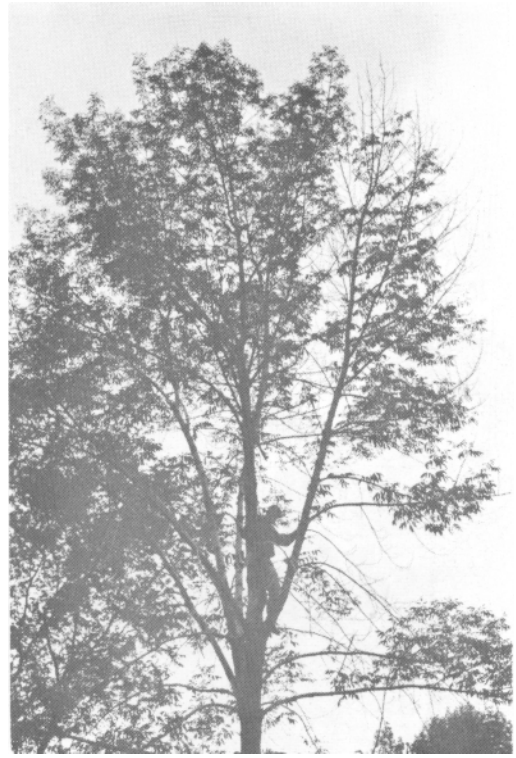
2. The ends of most of the adjacent terminal shoots are at varying heights above the ground, resulting in a ragged and irregular crown when viewed from above.

3. Twigs are well separated in the tops of the crowns, allowing the observer from above to look down deeply into the crown interior. These intertwig openings appear as dark shadows regularly spaced over the crown surface.

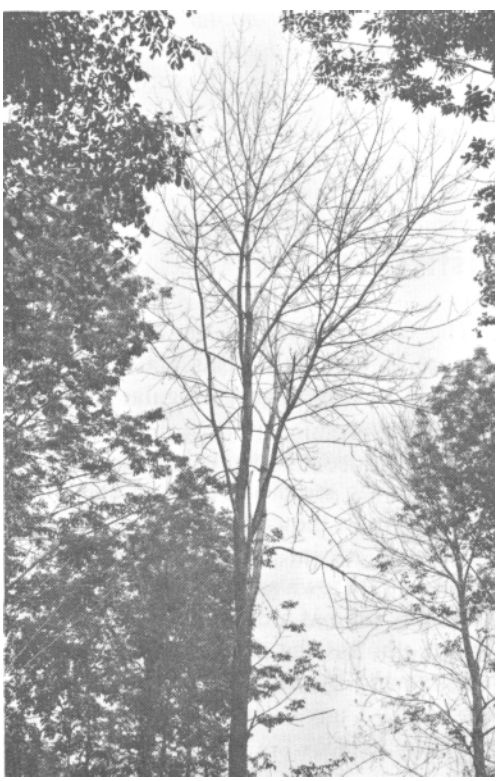
4. Healthy ash has a dark green color. Although American elm has the same color, it would have been eliminated by any of the first three characteristics listed. Conversely, red maple has the first three characteristics, but healthy red maple is notably yellow-green. Furthermore, the columns



Class 1



Class 3



Class 5

Figure 5.--*The three dieback classes of ash show differences in crown density, leaflet size, and dead twig distribution. Trees are 11 inches d.b.h.*

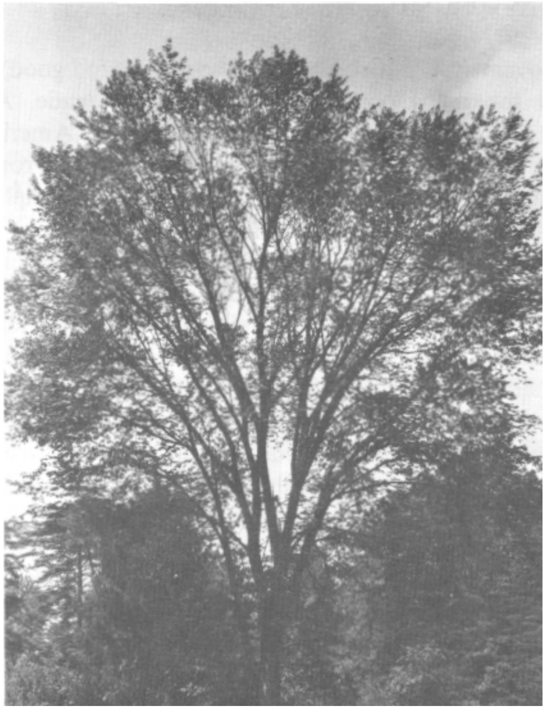
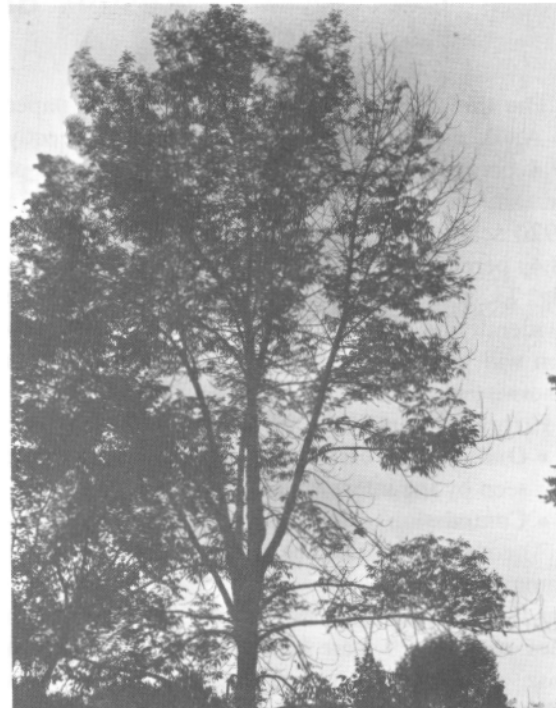
 

Figure 6.--*Differences in branching habits between an American elm,* left, *with branches and twigs extending radially in all directions, and a white ash,* right, *with branches and twigs upswept and vertically oriented. These characteristics are apparent on the vertical photography. The white ash has ash dieback.*

of foliage on red maple are much smaller (and more numerous) than ash since red maple has small simple leaves and ash has large compound leaves.

5. Ash has an opposite arrangement of the leaves and therefore, when viewed from above, the terminal leaf pair is superimposed upon the third and fifth pairs below it, and the second pair is directly above the fourth and sixth pairs. This arrangement quite often results in a distinct four-pointed star shape at the twig tip. Occasionally this star shape can be found on other species through the chance superposition of tree parts but never as often as on ash crowns.

6. The immature leaves at the tips of ash twigs reflect, absorb, and reemit incident light differently than the older leaves farther down the twigs. Therefore on healthy ash a light green spot is visible at the twig ends, and the rest of the foliage is dark green.

7. In the Poughkeepsie area, healthy black ash cannot be distinguished from white ash. However, local color variations of healthy black ash are to be found. Healthy black and white ash on the Poughkeepsie film were compared with many images of healthy black ash recorded on film in previous years near Ely, Minnesota. Healthy Minnesota black ash has a decided yellow-green color. Ash dieback has not appeared as yet in that part of the Lake States, but if it should reach Minnesota, accurate classification of dieback would be hindered by this color variation. Minnesota black ash also did not display the wide spacing of twigs over the crown as described in 3 above.

8. As the symptoms of dieback become progressively more severe, certain of the above traits become more prominent. Dwarfing of the leaves and leaflets reduces the interpreter's ability to resolve the outline of the tree, but this condition is more than offset by the clarity which results from the accompanying clustering of leaves at the twig tips. Without the distraction of a background of lower leaves, the cross shapes at the tips become much easier to see. The clumping of leaves at the twig tips is a helpful dieback clue in itself. On color film the change from dark green to pale yellow-green is an enormous advantage in identification and classification.

Results and Discussion

Ash Identification

The three interpreters--identified in this paper as A, B, and C--were able to identify correctly 59.4 percent, 65.2 percent, and 70.3 percent of the ash, respectively, at 1:1,584 scale. At the 1:7,920 scale, the results were about half as good: 28.4 percent, 36.8 percent, and 41.3 percent (fig. 7). The 1:7,920 scale is clearly unfit for use in identifying ash. Therefore all further discussion will pertain only to the 1:1,584 scale, unless otherwise indicated.

Errors in identifying ash can be of two types:

- **Omission errors:** existing ash trees are not seen by the interpreter.
- **Commission errors:** non-ash trees are erroneously interpreted as ash.

Commission errors were much more of a problem than omission errors (fig. 8). Of the 155 ash trees present, 29 were in the intermediate crown class and 4 were suppressed. Suppressed trees will never be visible, and probably not more than half the intermediate crown class trees will be seen from the air. Therefore 88 percent represents the probable maximum accuracy. Since ash decreases in shade tolerance as it becomes older (Fowells 1965) these invisible trees in the lower crown classes perhaps would not survive anyway.

Although the percentage of ash accurately identified could be accepted with only moderate improvement (75 percent would be considered good), far too many commission errors were made. A total of 27 species were mistaken as ash. American elm contributed most to this type of error, but black cherry, black birch, and sugar maple also were often incorrectly identified (table 1).

The study area purposely included a considerable extent of site I cove-type, hemlock-hardwood stands that were densely stocked and had tall small-crowned trees. Both the density and the small crowns made species separation difficult. Furthermore, on such sites a maximum number of species can endure. By coincidence the study area was located in a transition zone where, according to Oosting (1956), the hemlock-hardwoods association is changing to deciduous forests. This change also contributed to the variety of the flora, and the greater the number of species present, the greater the odds that some of them will show images similar to ash. Thus the study area chosen approached the ultimate in difficulty of species identification by photo interpretation. The modest percentages of success quoted above should be viewed in that light.

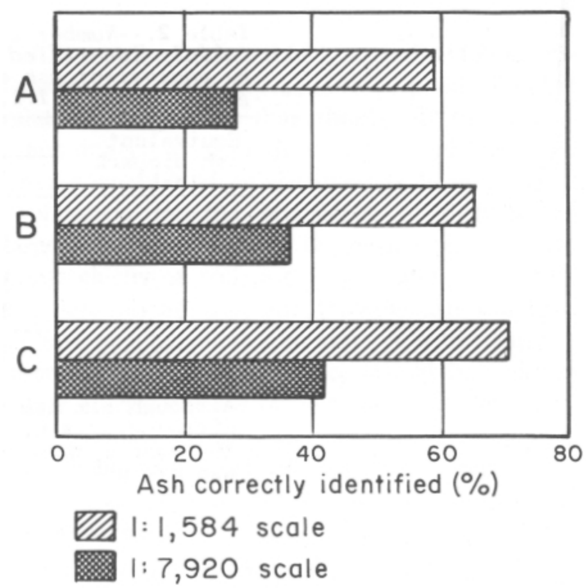
Except for American elm, at least one of the interpreters was able to avoid making many commission errors for each of the troublesome species (table 1) . That is, at least one interpreter was able to grasp the essential differences between species

Table 1.--Distribution of commission errors,[1] by species, among three interpreters (photographic scale: 1:1,584)

Species	Total commission errors by interpreter		
	A	B	C
	Percent		
American elm	35.9	40.1	26.5
Black cherry	11.7	9.0	3.9
Red maple	8.3	3.4	2.0
Sugar maple	1.4	6.7	13.7
American hazelnut	5.5	0	16.7
Bigtooth aspen	8.3	1.1	1.0
American basswood	5.5	6.0	2.0
Black birch	2.8	9.4	7.8
American beech	.7	6.0	0
Northern red oak	4.8	3.4	4.9
Other	15.1	14.9	21.5
Totals	100.0	100.0	100.0

[1]Commission error is one in which a non-ash tree is identified as ash.
[2]Includes: red elm, black locust, staghorn sumac, butternut, white pine, common apple, black oak, chestnut oak, ironwood, blue beech, quaking aspen, paper birch, eastern hemlock, shagbark hickory, pignut hickory, false pignut hickory, and black willow.

Figure 7.--*The percentage of ash trees correctly identified by three interpreters was much greater at the larger photographic scale. (Basis: 155 trees.)*



even with the weak training aids available to him. All three interpreters were hampered by using training aids prepared from small samples. The information gained in the present study should make it possible to strengthen training aid material and upgrade identification accuracy above the level of *75* percent.

Even the most troublesome species--American elm--did not thwart all interpreters to the same degree (table 1). Furthermore, when commission errors, in which elm was identified as ash, are examined in terms of the elm's dieback class (table 2), it is apparent that interpreter A could separate either healthy or slightly diseased elm from ash, and interpreter C was not inclined to call elm as ash regardless of its disease class. This situation indicates that better training of interpreters should produce better results in distinguishing between these two species.

As expected, the greatest difficulty in ash identification occurred on small trees less than 8 inches d.b.h., 50 feet tall, and 10 feet in crown diameters. Little improvement can be expected here for the lack of resolution results largely from screening and shading by the foliage of adjacent overtopping crowns.

Interpreters became progressively more accurate at identification as the symptoms of dieback worsened (table 3). With data from all three interpreters combined, we found that only 26.8 percent of the healthy (class 1) ash trees were correctly called ash. But moderately diseased (class 3) trees were correctly identified 33.5 percent of the time, and dead or dying (class 5) ash 39.7 percent of the time.

For wet, moist, and intermediate sites the percentage of correct ash calls remained fairly constant, but the omission and commission errors decreased steadily as dryness of site increased (table 4). This results partly from a decrease in numbers of species which occupy dry sites and partly from

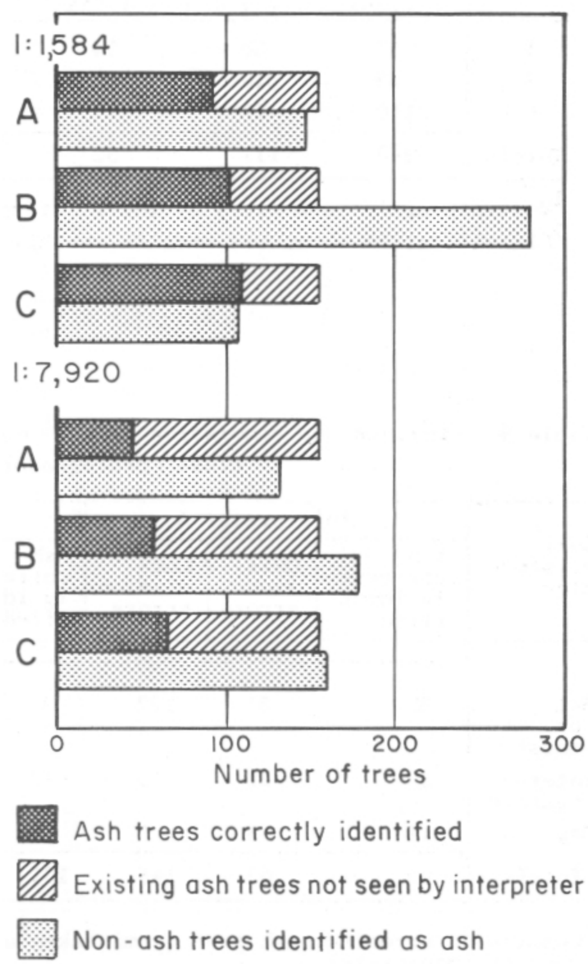


Figure 8.--*At the 1:1,584 scale, interpreters made fewer errors in identifying existing ash trees than they made at the 1:7,920 scale. At both scales, many non-ash trees were interpreted as ash.*

Table 2.--*Number of American elm trees mistakenly identified as ash by interpreters, by equivalent ash dieback class*[1] *(photographic scale: 1:1,584)*

Equivalent ash dieback class[1]	Interpreter A	Interpreter B	Interpreter C
	- Number of trees -		
1	9	39	5
3	11	32	10
5	32	36	12
Totals	52	107	27

[1]Although elm has a different disease (*Ceratocystis ulmi* (Buism.) C. Moreau), the same symptom classes were used as for ash dieback.

Table 3.--*Combined attempts*[1] *at classifying ash trees at two scales, by ash dieback class*

Ash die-back class	No. of ash correctly classified		No of ash incorrectly classified		No. of ash not seen, thus not classified/		Total attempts	
	1:1,584	1:7,920	1:1,584	1:7,920	1:1,584	1:7,920	1:1,584	1:7,920
1	67	30	14	2	105	154	186	186
3	63	10	38	28	49	112	150	150
5	110	77	10	18	9	34	129	129
Totals	240	117	62	48	163	300	465	465

[1]Multiplying 155 ash trees by three interpreters gives 465 attempts at classification.

[2]Classification shown was made on the basis of ground survey.

Table 4.--*Omission and commission errors" made in identifying ash trees, by soil moisture class (photographic scale: 1:1,584)*

Soil moisture class	Interpreter A			Interpreter B			Interpreter C		
	Ash correct ly ident-ified	Omis-sion errors	Com-mission errors	Ash correct-ly ident-ified	Omis-sion errors	Com-mission errors	Ash correct-ly ident-ified	Omis-sion errors	Com-mission errors
	Number								
Wet or moist	39	31	122	38	32	163	46	24	61
Inter-mediate	39	27	18	47	19	85	45	21	29
Dry	14	5	5	16	3	19	18	1	12
Totals	92	63	145	101	54	267	109	46	102

[1]Commission error: non-ash tree is mistaken as ash. Omission error: existing ash tree is not seen by interpreter.

the tendency toward larger crowns to be present where a poorer soil moisture regime causes lower stocking levels. On a dry site, root competition is more severe, and each tree occupies more space, permitting a better crown development.

Ash Dieback Classification

We found no evidence either to corroborate or to contradict Pomerleau's [5] contention that ash dieback is correlated with wet site conditions. In the present study 56.9 percent of the ash on the four wet-site plots had ash dieback, whereas 61.5 percent of the ash on the combined moist, intermediate, and dry plots had the disease. These small disparities in percentages may be of a random nature. None of the four black ash was diseased. The four ranged from 3 to 13 inches d.b.h. and all were in the intermediate crown class.

Sixty percent of the 155 ash trees growing in the study area had ash dieback and will eventually die. Of these diseased trees, 32.2 percent were in the intermediate stage and 27.8 percent were dead or dying (table 5).

In the d.b.h. classes 2 through 6, there were more healthy trees than diseased but in classes 7 through 19, more were diseased. The Chi-square test shows a significant difference at the .001 level of probability. One might infer that trees greater than 6 inches d.b.h. are more susceptible to dieback than the smaller trees. Furthermore, the fact that every ash less than 2 inches d.b.h. was healthy and every ash greater than 14 inches was diseased, reinforces this supposition that larger size is positively correlated with the frequency of attack by ash dieback.

The underlying cause for this relationship is obscure but we may speculate. Oppenheimer (1960) observed that desert plants often have extensive and deeply penetrating root systems. Conversely, he described one situation where "Poplars dried up in desiccated river beds where their roots ran near the surface as an adaptation to [shallow] soil aeration in normal times, but survived at higher elevations where the roots had already penetrated to nine feet in five years." The latter is analogous to the ash study area, which normally has a high water table.

[5] Pomerleau, R. *The relation between environmental conditions and the dying of birches and other hardwood trees.* 1953. (Unpublished report of the Symposium on birch dieback, on file at Forest Biology Div., Dep. Agr., Ottawa, Canada.)

It is a well-established fact, according to Oppenheimer, that under dry conditions plants develop relatively more roots than shoots and that this is a hereditary character. If we can assume that the reverse would hold on wet sites, we have a logical explanation for the prevalence of dieback on larger ash trees. It can be postulated that ash grows chiefly on soils with high water tables, that soil aeration is poor, and that the ash will tend to have small shallow root systems with relatively large crowns. This imbalance would be efficient under normal periods of high rainfall well distributed in time, but such trees would suffer quickly and severely when extended drought desiccates the upper soil levels containing the bulk of the ash root systems.

Regardless of its cause, the fact that large-sized ash trees are attacked more often by ash dieback than are small trees, has not been previously reported. This finding may help future investigators of the disease. Zabel and his co-workers (1963) thought that ash dieback appeared most commonly in sapling and pole-size trees, but provided no supporting evidence. Ross (1966) found that the disease occurred nearly uniformly in all d.b.h. classes, but possibly his poor representation in the upper size classes (fewer than 35 trees over

Table 5.--*Distribution of healthy and diseased ash trees, by diameter breast height*

D.b.h. (inches)	Healthy trees (class 1)	Diseased trees (class 3+5)	Total ash	
	Number			
1	0	0	0	
2	2	0	2	
3	4	3	7	
4	5	6	11	1/
5	8	6	14	
6	13	8	21	
7	11	13	24	
8	4	10	14	
9	3	6	9	
10	3	4	7	
11	5	15	20	
12	2	4	6	
13	0	6	6	
14	2	4	6	2/
15	0	2	2	
16	0	4	4	
17	0	0	0	
18	0	1	1	
19	0	1	1	
20+	0	0	0	
Totals	62	93	155	

[1] More healthy than diseased.

[2] More diseased than healthy.

8.0 inches d.b.h.) obscured the trend. Below 8.0 inches d.b.h., his data did show a tendency for larger sizes to have a greater incidence of disease.

From our standpoint in remote-sensing technique research, it is a definite advantage to know that the trees most susceptible to dieback (the larger ones) are also the ones which are most easily seen by the photo interpreter and which the ground crews see indistinctly through the screen of understory vegetation.

While working on 1: 1,584-scale photographs, all three interpreters were consistent and were able to place 77.2 percent, 77.2 percent, and 80.7 percent of their attempts exactly into the proper dieback class (table 3). At the 1:7,920 scale, so few ash trees were identified that their subsequent classification was not meaningful. As expected, the interpreters could classify dead and nearly-dead trees at this scale much easier than either class 1 or class 3 trees.

We had some difficulty in deciding whether parts of multiple-stemmed trees had been correctly classified by the interpreters. In the ground data collection, trees forked below 4.5 feet were tallied as separate trees and each was given a dieback class rating. Even when the interpreter could see crown separation, he obviously could not tell whether the tree forked above or below breast height. He had to make this decision at least once on every crown. And his decision influenced the agreement between numbers of ground classification attempts and photo classification attempts. Also a given tree that forked at 5 or 6 feet above ground could show different stages of dieback within each fork. The interpreter in this case would be inclined to classify each fork separately and identify it incorrectly. There were many variations of this problem. In future studies multiple-stemmed trees should be described in detail while investigators are on the ground.

Summary and Conclusions

1. Of the 155 ash trees on the $6^1/_4$-acre study area, 60 percent had ash dieback and are doomed to die. The disease had attacked trees ranging from 2 to 19 inches d.b.h.

2. Frequency of attack by ash dieback was strongly and positively correlated to increased d.b.h.

3. Black and white ash could not be differentiated on the film. Black ash being more tolerant of wet soils, is almost always found along streams and on the edges of swamps, however, and these terrain features are evident on the photographs. None of the four black ash was diseased.

4. Ash had several distinctive identification characteristics: upswept and erect branching habits, irregular crown peripherys caused by variable heights of adjacent twigs, well-spaced openings in the crowns that appeared as dark shadows, a dark green color of healthy foliage, and frequent star shapes and light green spots at the twig tips.

5. Ash can be identified with fair accuracy at 1 : 1,584 scale, but not at 1 :7,920.

6. Once they had identified ash, interpreters could classify ash dieback disease well and consistently at the 1 :1,584 scale, but not at 1:7,920 scale.

7. The ability of interpreters to identify and classify ash and ash dieback at the 1:1,584 scale is acceptable at present, but the number of errors in which other species were mistaken as ash must be reduced. Improvement can be expected. Since the most efficient photographic scale is near 1: 1,584, further study should be directed towards scales of 1:1,584, 1:2,376, 1:3,168, and 1 :3,960.

8. Demanding of fertile amply-watered sites, ash has a large number of associates. Interpreters will have to be well-trained to distinguish ash from these associates.

9. The fact that at least one of the interpreters could differentiate ash from each of the difficult associated species indicates that improvement in training aids is the key to the identification problem.

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Appendix

Common and scientific names of trees and shrubs mentioned in this paper.

Apple, common	*Malus pumila* Mill.
Ash, black	*Fraxinus nigra* Marsh.
Ash, green	*Fraxinus pennsylvanica* var. *lanceolata* (Borkh.) Sarg.
Ash, white	*Fraxinus americana L.*
Aspen, bigtooth	*Populus grandidentata* Michx.
Aspen, quaking	*Populus tremuloides* Michx.
Basswood, American	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Beech, blue	*Carpinus caroliniana* Walt.
Birch, black	*Betula lenta* L.
Birch, paper	*Betula papyrifera* Marsh.
Butternut	*Juglans cinerea* L.
Cherry, black	*Prunus serotina* Ehrh.
Elm, American	*Ulmus americana* L.
Elm, red	*Ulmus rubra* Muhl.
Hazelnut, American	*Corylus americana* Walt.
Hemlock, eastern	*Tsuga canadensis* (L.) Carr.
Hickory, false pignut	*Carya ovalis* (Wang.) Sarg.
Hickory, pignut	*Carya glabra* (Mill.) Sweet.
Hickory, shagbark	*Carya ovata* (Mill.) K. Koch.
Ironwood	*Ostrya virginiana* (Mill.) K. Koch.
Locust, black	*Robinia pseudoacacia* L.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus montana* Willd.
Oak, northern red	*Quercus rubra* L.
Pine, eastern white	*Pinus strobus* L.
Sumac, staghorn	*Rhus typhina* L.
Willow, black	*Salix nigra* Marsh.
Yellow-poplar	*Liriodendron tulipifera* L.

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