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PHENOLOGICAL AIDS TO SPECIES IDENTIFICATION ON AIR PHOTOGRAPHS

by

L. Sayn-Wittgenstein

Conclusions in French

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Phenological Aids to Species Identification on Air Photographs

by

L. Sayn-Wittgenstein[1]

INTRODUCTION

The extent to which tree species can be identified on air photographs is determined by a combination of many variable and often unknown causes. The weather, the film, the altitude of the sun, the printing and developing, and many other criteria control the key characteristics used as aids in recognizing species. The result is that sometimes trees, easily distinguishable on the ground, appear identical on air photographs. Some species of similar appearance may occasionally be identified because normally insignificant differences in their appearance have been enlarged through a fortunate combination of film and filter, or through the combined effect of other variables.

It would be a nearly impossible task to prepare descriptions of individual species for the unlimited number of such combinations of conditions that may prevail at the time of photography, but one can approach the problem of species identification on air photographs by dealing separately with each of the important factors that determine the appearance of tree species. By understanding the basic influences which contribute to the resulting photographs, the photo-interpreter will be in a good position to evaluate the complex situations that he will encounter during his work.

The value of crown form and branching habit as identifying marks of different species has previously been treated (Sayn-Wittgenstein 1960). This report is a supplement to that publication, dealing in detail with phenology, the study of periodic events brought about by seasonal changes in climate, as an aid to the recognition of tree species.

The commonly used panchromatic summer photographs often show only a few or no useful tone variations between species, but spring or fall photographs may provide excellent opportunities for distinguishing species or groups of species. Often these good results are achieved by accident. The date of photography may have coincided with the time when fall colouring was at its peak, or when one species was in leaf, while others were bare.

The extent to which the success of air photography depends upon chance can be reduced by investigating and recording the dates of phenological phenomena which help in the recognition of species. In this way it will be possible to take air photographs in the future under the same circumstances which prevailed when good results were previously obtained. Because many phenological phenomena, such as the flowering of some species, or the difference between the dates of leafing of two species, are of short duration, the timing of photographic flights should be very exact. Unfortunately this is often impossible because of bad flying weather.

Although this report deals with the interpretation of photographs for forestry purposes, the data concerning leafing and leaf-fall may be of use to those interested in air photography for geological and topographic mapping. In these fields photographs taken when the deciduous foliage is absent are generally preferred.[2]

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[1] Research Officer, Forest Inventories Section, Forest Research Branch, Ottawa.

[2] Lacate, D. S. 1960. Seasons for air photography. A review of specifications and preferences. Canada, Department of Forestry. Unpublished.

The phenological data summarized in this publication came, with the exception of Table 1, Appendix 1, from records of the Fire Protection Section and Experimental Stations of the Department of Forestry. Table 1, Appendix 1, is based on the author's phenological observations. The air photographs used as illustrations were drawn from the collection of sample photographs made by the Forest Inventories Section.

SPRING PHOTOGRAPHY

(1) Before the leaves appear

Photographs taken in the early spring, before the first trees leaf out, have much in common with late fall and winter photographs. Because deciduous trees are bare it is easy to distinguish them from the evergreens. Individual evergreens can often be successfully identified because the view of their crowns is not obstructed by deciduous foliage. Small and suppressed conifers, which would remain hidden on summer photographs, can be detected. Because of the prominent appearance of evergreens there is a tendency to overestimate their portion in a mixed stand.

If sharp photographs at relatively large scales are used, then the characteristics of the trunk, the branching habit, and the twig structure are guides to the recognition of hardwood species. For example the chalk-white trunks of white birch show up clearly, and this species can therefore be distinguished from the tolerant hardwoods, which have darker bark, and from aspen with its greyish bark.

Should colour photographs be available, then many trees can be identified by the colour of their bark. For example various species of poplar could be distinguished: the bark of trembling aspen is greenish-grey or whitish, that of largetooth aspen similar, but with an orange touch, while the bark of balsam poplar is dark. The twigs and the immature catkins of white birch are reddish-brown; the crowns therefore have a distinctive colour before leafing begins.

Since the ground surface can be seen in hardwood forests, such features as small drainage channels and rock outcrops can be noted. Site evaluation is thus facilitated and much indirect evidence of the occurrence of species is obtained.

(2) During the period of leaf development

As the foliage appears on trees, it obscures the trunk and branches and dominates the appearance of crowns on air photographs. It is easy to distinguish a tree that has leafed out from a bare one, and it is therefore important to ascertain whether species leaf out in a definite order that can be depended upon for photo interpretation. Because foliage changes as it matures it is necessary to describe it at various stages of its development and to investigate its rate of development. In a few cases the flowers of trees give the crowns a characteristic appearance.

(a) The order of leafing

Even a very casual observer of trees in the spring will notice that there are large differences between the dates when different trees leaf out. It commonly occurs that one tree will be in full leaf, while the buds on others appear dormant. In a year with a long, cold spring the time that elapses between the leafing of different trees is particularly great. In an effort to investigate this order of leafing, phenological records over a number of years have been summarized for many species from several parts of Canada (Appendix 1).

Before drawing any conclusions from such data, one should consider their limitations. Phenological events are part of a continuous process (as is illustrated by Figure 1) and it is difficult to describe their start or end by an exact date. One must therefore be cautious in ascribing significance to differences of only a few days that may appear in a phenological record, because the data are influenced by the subjective judgment of the observer.

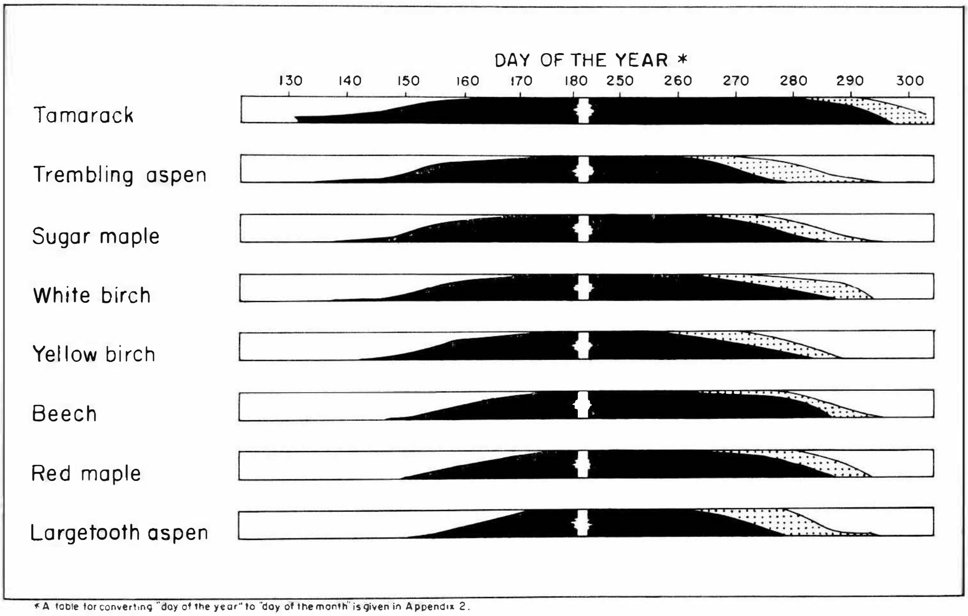

Figure 1. Illustration of the gradual nature of the development and fall of foliage. The portion of foliage developed in the spring and of green foliage remaining in the fall is indicated by the dark areas, while the light, dotted areas show the part of the foliage in fall colours. The figure is based on one year's observations on a small area and is not intended to show the typical sequence for the various species. (Drawn from data collected in 1948 near the Petawawa Forest Experiment Station by C. J. Lowe and D. G. Fraser.)

A general conclusion reached from Appendix 1, Table 1, is that there is some regularity in the sequence in which different species leaf out. Some are consistently among the first to leaf, while others are always among the last. In the first group we find for example tamarack, trembling aspen (Figure 2), and white birch, while beech, oak, and hickory are among the later species. Figure 3, which shows the time of leaf development and leaf fall for trembling aspen in various locations, could therefore be used as a very rough guide to the dates of leafing and leaf fall of other species.

A very definite relationship exists between the limits of the latitude of the natural range of a species and the time of leaf-flushing. Trees with a natural range extending to the far north (e.g. willow, tamarack, white birch) are among the first to leaf, while the more southern species (e.g. beech, hickory, yellow birch) leaf out later. The very last to flush are exotic species imported from the south (e.g. catalpa, Kentucky coffee-tree, sycamore).

On the other hand, the order of leafing varies from year to year for numerous species for a number of reasons including the following:

(1) Differences in site.

(2) Variations in temperature between dormancy and the flushing of the leaves.

(3) Genetic differences within one species.

(4) Age and vigour of trees, incidence of disease.

Differences in site, that is, mainly differences in local climate and soil, are very obvious reasons for variations in the date of leafing. On swampy locations and cool, north-facing slopes leafing will occur later than on warm and sunny sites. For example, on the same location sugar maple will leaf out earlier than red maple, but sugar maple growing on a cold and wet site, will leaf out later

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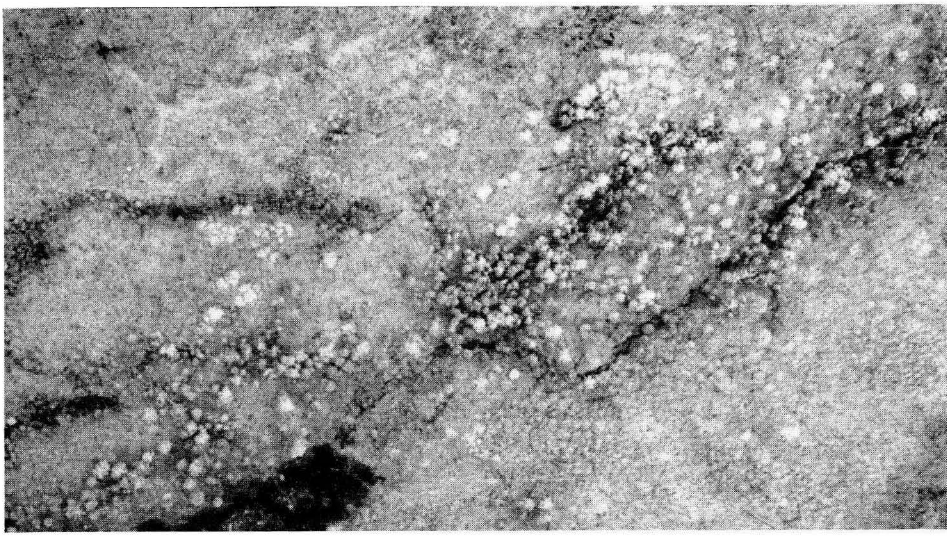

Figure 2. Infrared spring photograph showing how aspen, partly in leaf, can be distinguished from other hardwoods, which are bare. The very light crowns are aspen, the darker crowns various evergreens. The remainder of the area is covered by hardwoods. (2 × enlargement from an original scale of 1 inch = 660 feet, Chalk River, Ont., May 6, 1959.)

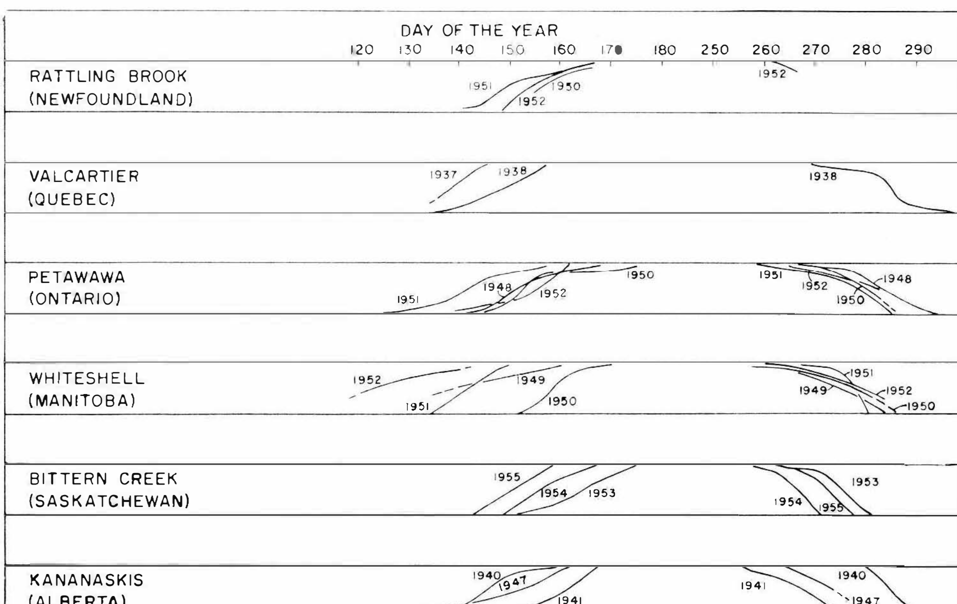

Figure 3. The portion of the foliage of trembling aspen developed or fallen on a given date is shown for various locations. The curves were drawn from data collected by the Fire Protection Section of the Department of Forestry.

than red maple on a dry and sunny site. Differences up to two weeks between the dates of leafing on different sites have been observed. MacHattie and McCormack (1960) have observed that, although numerous exceptions exist, the trend is for vernal phenological events to occur first on the ridge top, then on the south slope, and last on the north slope. The change to fall colours tended to occur in reverse order.

A change in the sequence of leafing of different species is best explained by variations in the early spring temperatures. There is a theory that for each species a certain summation of temperature (calculated as the sum of the products of time × temperature above a fixed minimum temperature) is necessary to produce a given phenological event. This theory, which implies a fixed order of leafing out, has been criticised in detail by Tamas (1959). The main criticisms are:

(1) The rate of growth activity does not vary directly with temperature, but for each species there is an optimum temperature at which activity will be faster than at any higher or lower temperature. Should the air temperature remain near the optimum temperature for any one species for a significant time, then that species will leaf out relatively earlier.

(2) The minimum temperature at which growth activity begins varies for different species. If this minimum temperature is +5° C. for species A and +7° C. for species B, then only A will advance during those periods when the temperature fluctuates between +5° C. and +7° C.

Often one can observe differences between individuals of one species growing on the same site that appear to be due to genetic variations. Leopold and Jones (1947) report differences in the time of blooming and leafing of trembling aspen clones, which were not related to site. In another instance (Anon. 1958) two adjacent clones of trembling aspen, in both cases males of similar ages, differed by about two weeks in time of leafing. After an intensive study of phenological variations in sugar maple, Kriebel (1957) came to the conclusion that the time of flushing is under rigid genetic control.

Age and vigour seem to influence phenology. Seedlings and sprouts leaf out earlier than mature trees. In a few cases diseased trees leafed out much later than healthy ones; on the other hand it is reported that certain virus infections stimulate early leafing.

(b) Characteristics of spring foliage

Young leaves are lighter than mature ones and often have a fresh green or yellowish colour. According to measurements by Shull (1929), young basswood leaves reflect up to three times as much light as mature ones. Differences of this kind were less in redbud and cottonwood, the two other native trees investigated. The tone contrast between hardwoods and evergreens in the spring is so pronounced that panchromatic photographs taken in that season resemble infrared photographs, with the hardwoods appearing almost white, the conifers dark. This contrast is further accentuated by the dark green or brownish winter colours, that still characterize conifers in the early spring. About three weeks after the leafing of hardwoods has begun the difference in tone between hardwoods and conifers is much smaller, owing to the darkening of the hardwood leaves and the growth of fresh green coniferous foliage (Figure 4). The slightly different colour of young spruce and fir foliage may help to distinguish these species.

The rate of growth of leaves varies between species, although these differences may be diminished by the sudden onset of very warm weather, that will cause rapid growth on all trees. The leaves of basswood and sugar maple appear to reach full size rapidly, while those of the oaks, white birth and elm grow slowly.

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Figure 4. Black spruce branches showing the tone contrast between young and old needles. (Chalk River, Ont., July 18, 1960.)

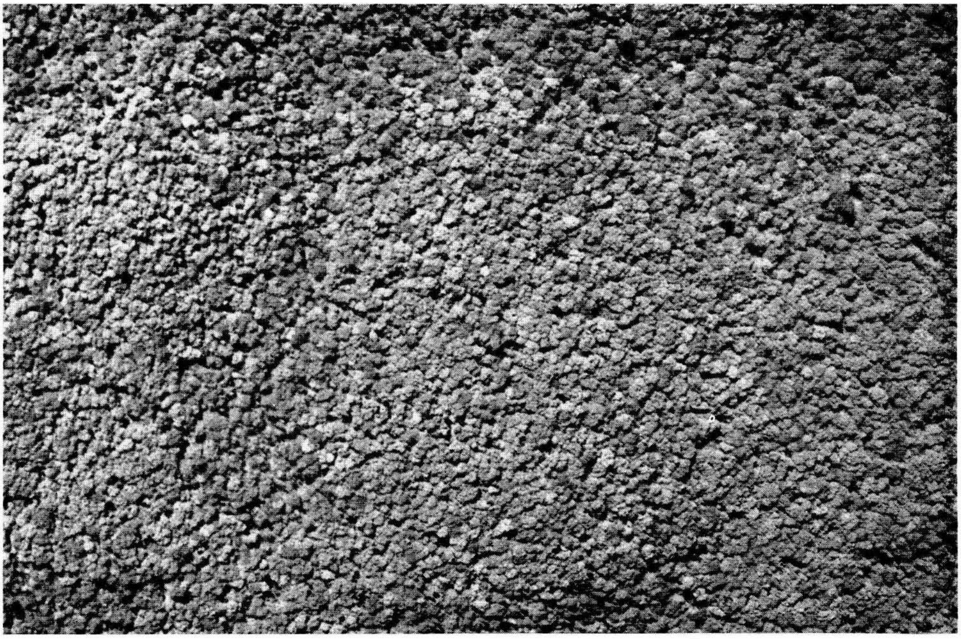

Figure 5. Distinction of yellow birch and sugar maple in the late spring. The darker, large crowns are yellow birch, the lighter ones sugar maple. (2 × enlargement from an original scale of 1 inch = 1,000 feet near the Goulais River, Ont., June 4, 1959.)

Spring and early summer photography is the best for distinguishing sugar maple and yellow birch. In one instance yellow birch appeared sufficiently darker than maple to make it possible to identify individual trees at a scale of about 1 inch = 1,000 feet (Figure 5). The tone contrast, greatest on photographs taken in the spring (Figure 6), has however also been observed on late summer photography. This distinction appears to be caused by phenological and other characteristics of the two species. Yellow birch has a more open crown and smaller leaves than sugar maple, with the result that it reflects less light and shows more of the shadows contained in the crown. In addition the leaves of sugar maple are lighter than those of yellow birch, particularly during the late spring, when they have a definite yellowish hue.

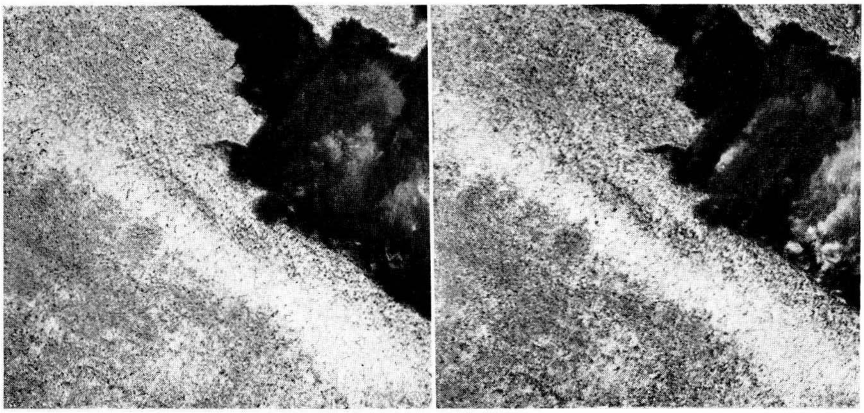

Figure 6. Stereogram showing the distinction of yellow birch and sugar maple soon after the flushing of the leaves. The bright band running from upper left to lower right is sugar maple. Yellow birch, which is slightly darker, grow on the adjoining slopes. The darkest patches on the lower left are partly due to small balsam fir and cedar. (Scale 1 inch = 1,000 feet, near Lake Temiskaming, Ont., May 24, 1959.)

On the basis of ground observations it is concluded that red oak with immature foliage will also appear in dark tones, because the very young leaves have a purplish tinge (Figure 7). When mature they are large and glossy and give the crown a light appearance on photographs.

Figure 7. Comparison of the tone of young foliage of red oak (right) and sugar maple (left). The oak leaves are significantly darker. (Ottawa, May 15, 1960.)

Largetooth aspen is easily distinguished from trembling aspen and from other hardwoods on spring photographs. First, it leafs out much later than trembling aspen, and secondly, its leaves are covered with a fine, white down that gives the crown an almost white appearance (Figure 8). This lightness may in part be due to the conspicuous catkins which appear before the leaves. The foliage loses its light colour about two weeks after leafing. Separation of the two aspen may seem inconsequential, yet by positively identifying largetooth aspen the photo interpreter may, through his knowledge of the forest, obtain evidence of the occurrence of other species.

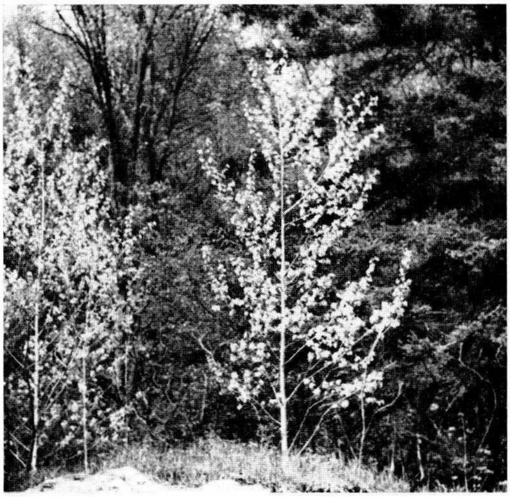

Figure 8. The light-toned, young foliage of largetooth aspen. (Ottawa, May 15. 1960.)

(c) The flowering of trees

Because most trees native to Canada have small and inconspicuous flowers, their appearance on air photographs is affected only if the flowers are very abundant and appear before the leaves. The date when flowering begins varies owing to causes corresponding to those affecting the time of leafing. In addition there is the difficulty that the end of flowering is subject to great irregularities. For example, a strong wind can blow the flowers off soon after they are formed.

The white catkins of the poplars and willows and the red flowers of the red and silver maple are very distinct and could be useful identifying features, especially on colour photographs. The brownish flowers of white elm add considerably to the mass of the crown and should therefore show on panchromatic and colour photographs. The flowers of elm appear two or three weeks before leafing, and usually persist until leafing, although they may fall before the leaves appear. The showy white flowers of mountain ash and choke cherry, that appear after the leaves, will identify these species on large-scale photographs.

An observer on the ground will notice how strongly the abundant yellow flowers of jack pine determine the colour of the crowns, as seen from a distance. Losee (1951) suggests that this yellow colour could be brought out, by the use of proper filters, to distinguish jack pine from spruce. With exact timing of photography this should be possible, but it is not known whether it has been tried.

SUMMER PHOTOGRAPHY

Summer is a very widely used season for photography because it is usually easy to find good weather for air photography and also one can be reasonably sure that the appearance of a single species will not vary over a large area, as it often does in spring and fall.

With this the advantages of summer photography appear exhausted, for it has nothing to offer that cannot be found on photographs taken in the late spring when the foliage is immature and presents many contrasts between species. As opposed to this, an experiment with colour photographs (Aerial Ektacolor, 1 inch = 730 feet) taken on July 23 led to few species distinctions. Mature hardwood foliage is darker than young foliage and as a result the difference between conifers and hardwoods is so insignificant (Figure 9) that it is usually necessary to resort to infrared photography to distinguish these two groups.

The tone contrast on infrared photographs results because conifers reflect less infrared radiation than broadleaved trees. Consequently one of these groups is either strongly over or under-exposed, which has a detrimental effect on the quality of the picture. The tone difference between conifers and hardwoods on infrared photographs appears to decrease gradually as the summer advances (Figure 10). One would therefore expect that infrared photography taken in the late summer is superior to that taken in the early summer, because excessive over or under-exposure of hardwoods and conifers is avoided. An annoying characteristic of infrared photography is that shadows are so dark that they obscure all detail.

The phenological changes of trees during the summer are usually inconspicuous or very gradual and are unimportant in the identification of species on air photographs. Two minor phenomena are the flowering of the basswoods and the fruiting of ironwood (Figure 11). In both cases the brightness of the crowns involved increases. On large-scale colour photography the light brown cones of white spruce may serve to distinguish that species from balsam fir with its purplish green cones. The cones of black spruce are purple when immature, but become brown at maturity. But identification of most trees must be based on crown form, the characteristics of their mature foliage, and a knowledge of their ecological and silvical characteristics and site requirements. Identification using these features, especially crown shape, has been discussed in a previous publication (Sayn-Wittgenstein 1960) and will not be dealt with here.

FALL PHOTOGRAPHY

(a) The changing of colour

The changing of colour in the fall is a gradual process, that partly overlaps with the loss of foliage (see Figure 1). Drought tends to hasten the early change of colour, and for this reason trees on rocky and dry sites assume their fall colours earlier. This, however, needs to be qualified. For example, red maple in swamps or depressions usually changes colour first because of frosts. Also, a high water table or flooding may cause early change of colour in the same species. The work of Kriebel (1957) suggests that the time of colouring is under strong genetic influences. It follows that there is grave danger that one will establish wrong species distinctions, because only a portion of the trees of one species will be in colour. Differences between individuals of one species in the time of colour change usually are too great to make this phenomenon of practical usefulness in species identification.

Among the first to turn colour are some, although by no means all, red maple and white elm trees. The other species then follow without any reliable order. Cottonwood, the oaks, silver maple and hawthorn remain green after most other trees have turned.

Figure 9. A comparison of spring, summer, and fall photography. The circles enclose the same location on the three photographs. Differences in topographic detail are due to erosion of the shoreline and changes in the water level. Note the good contrast between the dark conifer (white spruce) and the light hardwoods (balsam poplar) on the spring and fall photos (top and bottom, respectively). (Wood Buffalo Park, N.W.T., top: 1 inch = 2,000 feet, May 5, 1958, centre: 1 inch = 1,320 feet, August 20, 1945, bottom: 1 inch = 3,200 feet, September 23, 1955.)

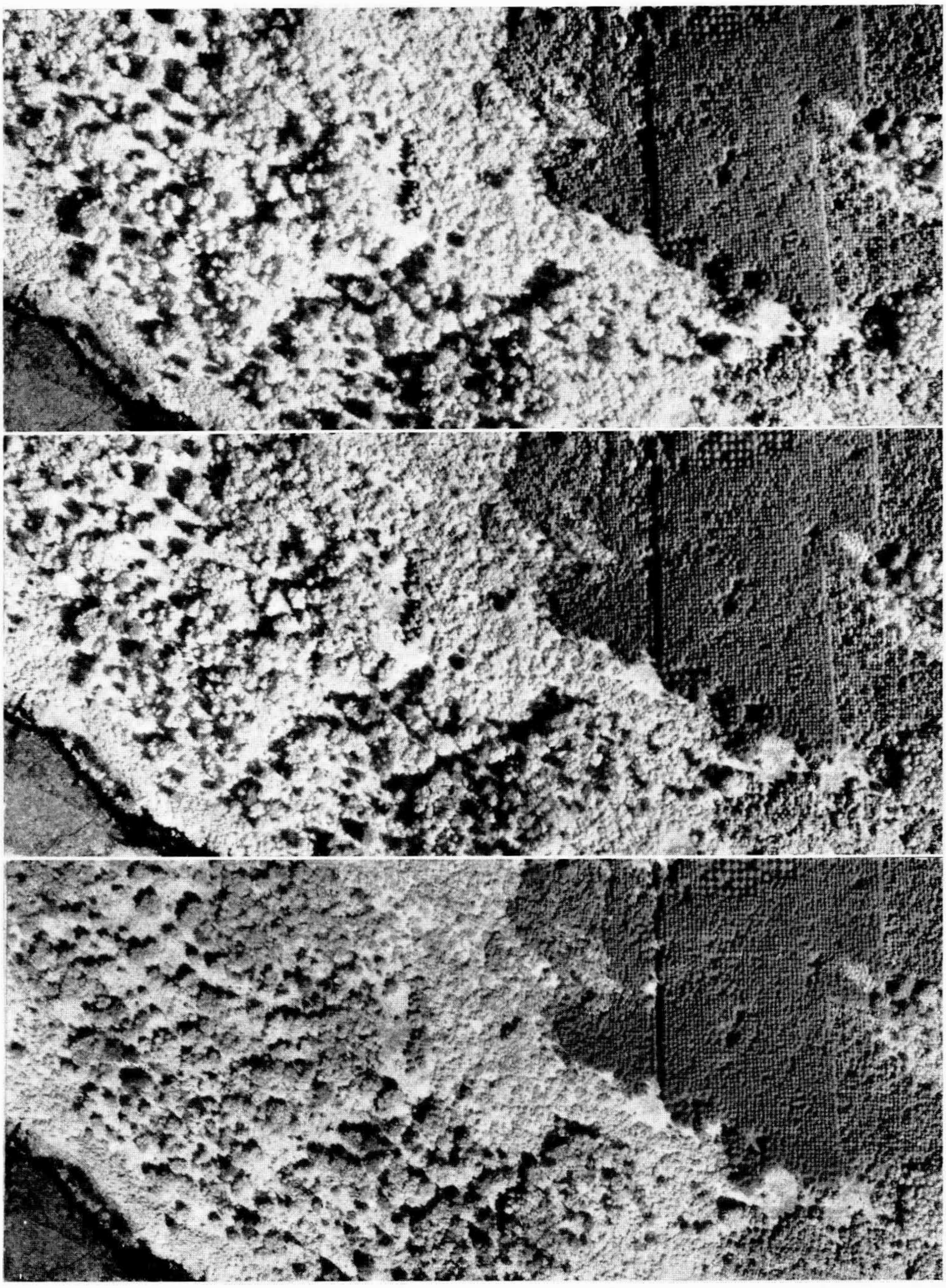

Figure 10. Infrared photographs taken at intervals of approximately one week. (From top to bottom: July 17, 23 and 31, 1958.) The tone contrast between the coniferous plantations (upper right) and the remaining area, which is predominantly covered by deciduous trees and shrubs, decreases as the season advances. (Scale 1 inch =330 feet, Chalk River, Ont.)

Figure 11. The abundant fruits of ironwood give the crown a light colour. (Chalk River, Ont., July 21, 1960.)

(b) The fall colours

As has been said above, the sequence in which trees change to their fall colours is erratic. In addition there are variations in the colours that one species may adopt, owing to genetic differences, the mineral content of the soil, the weather and other factors. For example, sugar maple foliage ranges from the usual yellow or orange to a deep red. One tree may also pass through several distinctly different phases of colouring, as for example beech, which first turns yellowish brown before reaching a more russet colour.

Yet, provided that heavy leaf-fall does not occur early, there will be several days during which most deciduous species will be in their fall colours and will exhibit characteristic differences in colour that will appear in the corresponding grey tones on panchromatic photos. At that time the distinction of deciduous trees and evergreens is easy because, as on early spring panchromatic or summer infrared photos, the evergreens are very dark (Figures 12 and 13).

The majority of the deciduous species turn yellow or light brown in the fall. In this group are the elms, poplars, birches, ironwood, silver maple, sugar maple and tamarack. Sugar maple sometimes turns organge-yellow or red. The leaves of red maple turn a brilliant red. The contrast between yellow and red trees can be increased on panchromatic photographs by the use of filters. Beech and oak have their own characteristic russet or reddish brown colours, and should therefore appear darker than other hardwoods. Basswood and willow lose many of their leaves while they are still partly green.

While many different species distinctions can be seen on fall photographs, the appearance of the foliage varies too much to make hard and fast rules for identification possible. In practice it will therefore usually be necessary to make field checks and to draw up a local key. An example of such a key is that by Chase and Korotev (1947). The successful identification of several species and species groups on fall photographs of the Petawawa area has been described by Losee (1942).

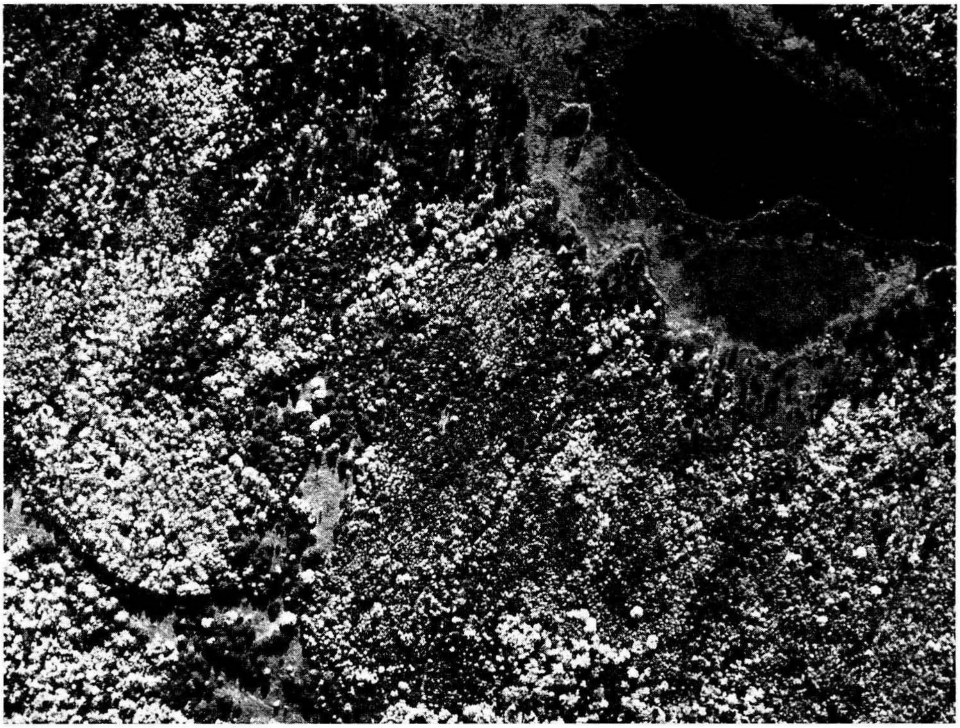

Figure 12. Fall colouring at its peak. Evergreens are dark, deciduous species light. Several fine differences in tone between deciduous species can be observed. (Scale 1 inch = 500 feet, Chalk River, Ont., Oct. 6, 1928.)

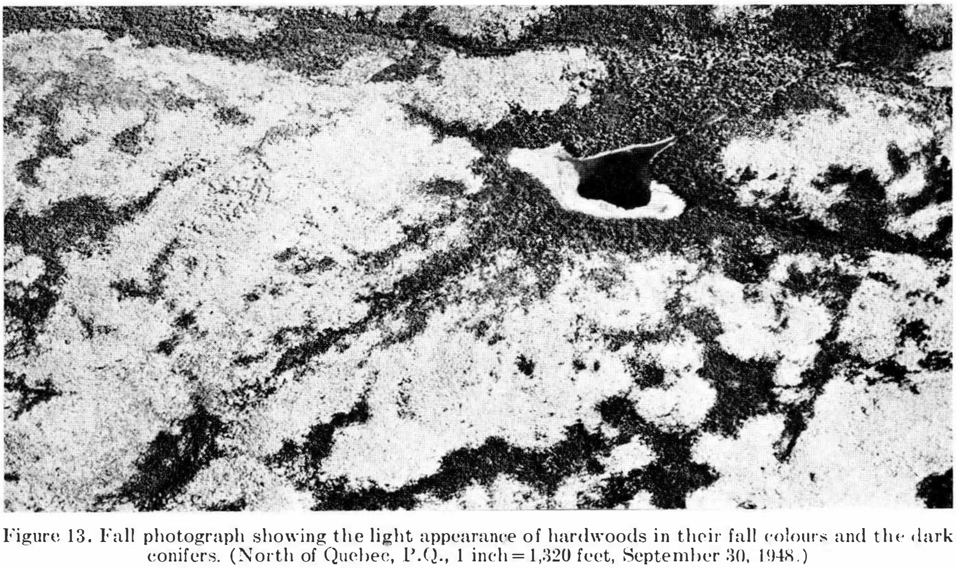

Figure 13. Fall photograph showing the light appearance of hardwoods in their fall colours and the dark conifers. (North of Quebec, P.Q., 1 inch = 1,320 feet, September 30, 1948.)

(c) The falling of the leaves

The order in which trees lose their leaves is an unreliable guide to their identification for, although it follows some rules, there are too many exceptions. Variations are often due to such causes as site, vigour of the tree, and exposure to the elements. Alternating freezing and thawing accelerates leaf-fall (Büsgen and Münch 1929). The extent to which trees are exposed to wind is one of the major factors affecting leaf fall. Another factor[3] is evident on burned areas where damaged trees retain their leaves longer than undamaged ones. However, frequently, and for no apparent reason, some trees are only beginning to lose their leaves, while others of the same species and growing nearby, are almost completely defoliated. The crowns of partly defoliated trees appear hazy and indistinct on air photos.

One of the general observations about leaf-fall is that the large and compound leaves are the first to fall. Thus black ash and butternut were the first trees in the Ottawa area to lose their leaves. Then followed the majority of species with no clear differences between them. The leaves of the elms and basswood were falling when cottonwood and the oaks were green. The oaks, beech, and the poplars were among the last to be defoliated. (Figure 2 shows the time of leaf-fall for trembling aspen in different locations.) Red oak kept its leaves longer than bur oak. In most cases white birch lost its leaves before both species of aspen. Some exotics such as Norway maple and honey locust were peculiarly late in dropping their foliage. Tamarack was the last species to lose foliage and its crowns retained a distinctive yellow colour (Figure 14) well into November. A few oak and beech trees, usually young ones, kept some of their foliage throughout the winter.

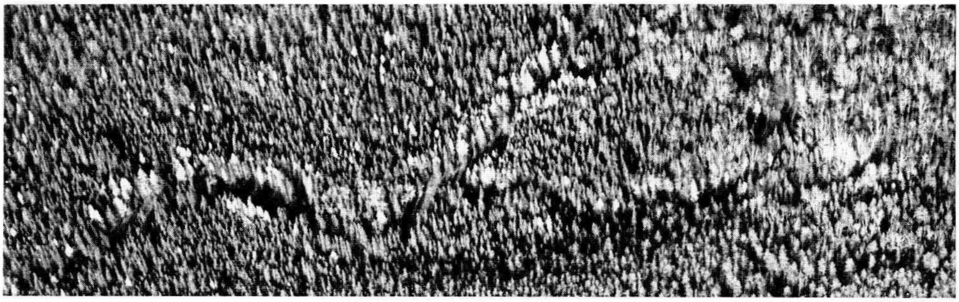

Figure 14. Fall photograph of tamarack scattered in a black spruce stand. Tamarack is in its fall colour and is easily identified by its light tone. Trees at upper right are defoliated aspen and white birch. (Tri-camera oblique, average scale 1 inch=200 feet, near Clova, P.Q., November 1, 1948.)

WINTER PHOTOGRAPHY

Winter photography is preferred in areas where evergreens are of primary interest because they are not hidden by deciduous foliage. Also the snow, while it obscures the fine detail on the ground surface, provides a bright background against which the trees and their shadows appear very clearly (Seely 1949), (Figure 15). Losee (1952) recommends photography taken after the first snowfall as excellent for surveys of evergreen regeneration.

During the winter the appearance of trees does not change and it is therefore more suited than spring and fall for definite descriptions of the identifying features of the various species. Evergreens will appear almost alike in winter and summer

[3] Suggested by H. E. Seely, in the report on a meeting to discuss the collection of phenological data, held in Ottawa November 16, 1939.

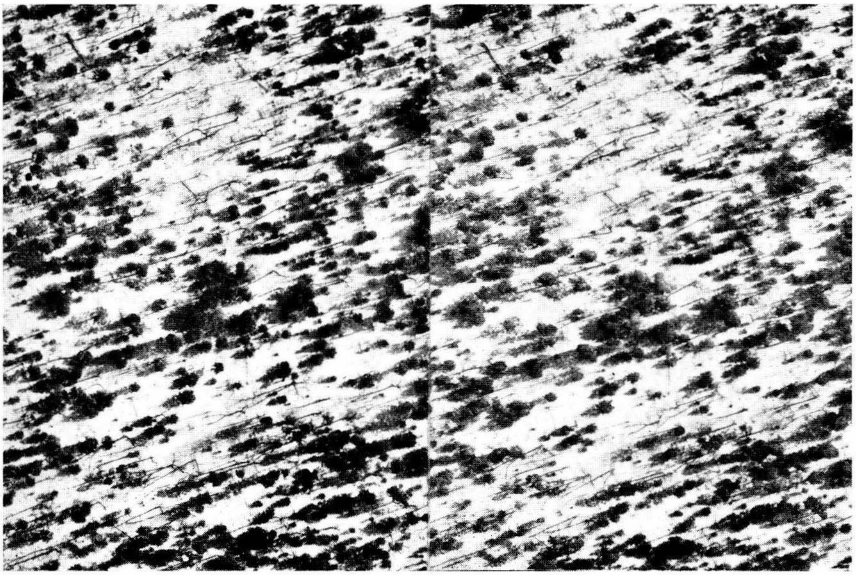

Figure 15. Winter photograph illustrating the prominent appearance of evergreen crowns against a background of snow. Note the tree shadows, which often show clearly, revealing crown form. (Scale 1 inch=200 feet, February 28, 1949.)

but the features used to identify deciduous species in the winter will be based mainly on the characteristics of the trunk and the leafless branches and twigs.

Provided that at least the medium-sized branches can be seen it is possible to identify many deciduous species (Sayn-Wittgenstein 1960). However, the snow on the ground often provides a background that acts as a highly intense source of reflected light, and excessive halation may follow. As a result of the combined effects of halation and image motion all but the coarsest limbs and the trunk of deciduous trees may then be invisible on the photograph. A further minor disadvantage of winter photographs is that snow, lying on the branches of evergreens, may restrict interpretation. Also it may be impossible to distinguish bodies of water from open muskeg, and in general soil and site will be difficult to interpret.

CONCLUSIONS

The following phenological information is the most useful in the identification of species:

(1) The date of leaf flushing.
(2) Description of the immature foliage.
(3) The date of flowering and fruiting.
(4) Description of flowers and fruits.
(5) The time of fall colouring.
(6) Description of the fall colours.
(7) The time of leaf-fall.

The opportunities presented by changes in the appearance of trees owing to phenological events can be exploited to great advantage for the identification of species on air photographs. To do this, the timing of air photography must be very exact for often a phenological phenomenon that may present a unique opportunity to identify a species, will last only a few days. The extra work and cost involved in rigid planning is justified by the results.

The season and the date of photography ought to be determined by the purpose for which the photos are taken. Should one be interested in rapidly locating and identifying evergreens, then winter photography is usually best. Early spring and late fall photography, when the deciduous foliage is absent, are probably most suitable for sampling photographs at very large scales, such as 1 inch = 50 feet. One may not be able to identify conifers as well as on winter photographs, but hardwoods can be better recognized, because small branches and twigs will resolve more clearly, owing to the absence of halation.

Photos taken during the period of leaf flushing may result in the identification of the very early or very late leafing species. But in general the order of leafing is subject to too many variations to make it a reliable guide to identification. The flowering of trees is of minor importance in their recognition.

Probably the best time for identification is immediately after all deciduous species have leafed out. During that period it is easy to separate evergreens from deciduous trees by a strong tone difference. The young foliage of evergreens develops more slowly and the tone of evergreen crowns is still determined by the very dark, old needles, while young deciduous foliage generally has a fresh, green colour. Tone differences between various hardwoods, such as between sugar maple and yellow birch, are much stronger during this period than during the summer. Colour photography is considered to have a particularly great potential, for there are many differences between the colours and hues of the young foliage of broadleaved trees, that are characteristic of certain species.

Summer is a period of few phenological changes and a bad time to take photographs for purposes of species identification. Often hardwoods and conifers can not be distinguished on panchromatic photographs, and the tone contrasts between various hardwood species are at a minimum. Should one be interested mainly in the distinction between hardwoods and softwoods, then infrared and modified infrared photography will serve as well as panchromatic spring or fall photography. Infrared summer photography however will not show good tone distinctions between hardwood species. A point in favour of summer photography is that one can be reasonably certain that one species will present a uniform appearance over a large area.

During the fall the colours of deciduous trees make it easy to distinguish them from evergreens and striking tone differences between various species of hardwoods often occur. A problem with fall photography is that the appearance of one species is often very variable, for on the same day some trees will be green, while others will be in different fall colours and various stages of defoliation. Yet fall photography, taken when colouring is at its peak, may be excellent, provided one is aware that sometimes strong differences in tone may separate individuals of the same species.

CONCLUSIONS

Les données phénologiques les plus utiles à l'identification des essences sont les suivantes:

(1) la date de la pousse des feuilles
(2) la description des jeunes feuilles
(3) la date de la floraison et de la fructification
(4) la description des fleurs et des fruits
(5) la période de la coloration automnale
(6) la description des couleurs automnales
(7) le temps de l'effeuillaison.

Les possibilités qu'entraînent les changements d'apparence des arbres par suite d'événements phénologiques, peuvent être exploitées avantageusement pour l'identification des essences sur les photographies aériennes. Pour ce faire, la prise de photographies aériennes doit se faire juste aux bons moments, car il arrive souvent qu'un phénomène phénologique qui constitue une occasion unique d'identifier une essence, ne persiste que quelques jours. Le travail et les frais supplémentaires qu'occasionnent des plans précis, sont justifiés par les résultats.

La saison et la date de la prise de photographie devraient être déterminées par le but qu'on se propose en prenant ces photographies. Lorsqu'il s'agit de localiser rapidement et d'identifier des essences à feuilles persistantes, la photographie en hiver est d'ordinaire la plus efficace. La photographie effectuée au début du printemps et à la fin de l'automne, lorsque les feuillus sont dépouillés, est probablement préférable s'il s'agit de photographies d'échantillonnage à très grande échelle, par exemple à l'échelle de 50 pieds au pouce. Il peut être impossible d'y reconnaître les résineux aussi bien que sur les photographies prises en hiver, mais on y reconnaît plus facilement les feuillus, car les branches et les rameaux de petites dimensions s'y distinguent plus clairement par suite de l'absence de halo.

Les photographies prises durant la période de la pousse des feuilles peuvent permettre d'identifier des essences dont la foliation se produit très tôt ou très tard. Mais de façon générale, l'ordre de la foliation est sujet à de trop nombreuses variations pour en faire un guide sûr d'identification. La floraison des arbres est d'importance secondaire lorsqu'il s'agit de les reconnaître.

Le meilleur temps pour l'identification est probablement immédiatement après la foliation de toutes les essences feuillues. Il est alors facile de distinguer, grâce à une forte différence de ton, les arbres à feuilles persistantes et les arbres feuillus. Le jeune feuillage des arbres à feuilles persistantes a une croissance plus lente que celle des arbres feuillus et le ton de leur cime est encore déterminé par la teinte très foncée des aiguilles âgées, tandis que le feuillage des jeunes feuillus est généralement de teinte fraîche et verte. Les différences de ton entre divers feuillus, par exemple entre l'érable à sucre et le bouleau jaune (merisier), sont plus prononcées à cette période que durant l'été. La photographie en couleurs semble avoir de grandes possibilités, car il y a chez le jeune feuillage d'arbres feuillus plusieurs différences de couleur et de ton qui sont caractéristiques de certaines espèces.

En été, on n'observe que très peu de changements phénologiques et cette saison est peu propice à la photographie à des fins d'identification d'essences. Il arrive souvent que les feuillus et les résineux ne peuvent être différenciés sur des photographies panchromatiques et que les contrastes de tons entre les diverses essences feuillues soient minimes. Si l'on est surtout intéressé à faire la distinction entre les feuillus et les résineux, la photographie en infra-rouge et la photographie modifiée en infra-rouge seront aussi utiles que la photographie panchromatique, au printemps ou à l'automne. La photographie en infra-rouge en été ne donne cependant pas de bons contrastes de tons entre les essences feuillues. Un bon point de la photographie d'été, c'est qu'on peut être relativement sûr qu'une même essence aura une apparence uniforme dans une grande superficie.

A l'automne, les couleurs des feuillus permettent de les distinguer facilement des arbres à feuilles persistantes et il y a souvent des différences marquées de tons entre les diverses essences feuillues. Le fait que l'apparence d'une essence est souvent variable, constitue un problème de la photographie d'automne, car le même jour certains arbres de cette essence seront verts, alors que d'autres auront des teintes automnales différentes et seront à des phases différentes de défoliation. Par ailleurs, la photographie d'automne peut être excellente alors que les couleurs sont à leur meilleur, à condition qu'on s'attende qu'il y ait parfois des différences marquées de tons entre divers sujets de la même essence.

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APPENDIX 1

Table 1.—Date of leaf flushing (day of the year)

Species	1958	1959	1960
Willow	100	111	114
Tamarack	110	114	116
Manitoba maple	119	116	118
Trembling aspen	110	122	118
Balsam poplar	135	123	118
Ironwood	115	124	120
Choke cherry	119	114	121
Sugar maple	122	123	122
White birch	117	119	123
Black cherry	129	124	123
Silver maple	132	115	125
Pin cherry	—	123	127
Red maple	132	125	127
Basswood	131	126	127
Butternut	130	—	128
Largetooth aspen	143	127	129
Beech	128	128	129
White elm	120	125	130
Yellow birch	128	130	130
Carolina poplar	142	130	130
Eastern cottonwood	133	124	131
Bur oak	132	126	131
White oak	130	131	—
Hawthorn	—	126	132
White ash	132	126	132
Norway maple	—	128	132
Bitternut hickory	142	135	135
Honey locust	140	137	136
Shagbark hickory	149	137	137
Sycamore	143	—	140
Catalpa	—	138	142
Kentucky coffee tree	150	142	144

(Species are listed in the order of leafing in 1960. The data were collected in the Ottawa area.)

Table 2.—Variations in date (day of the year) of flushing from year to year

Plot	Species	1940	1941	1942	Plot description
1	Balsam poplar	126	108	110	Altitude 4,450 feet, slope 10%, aspect N40W.
	Trembling aspen	129	116	120	
2	Willow	109	86	—	Altitude 4,700 feet, slope 35%, aspect N65W.
	Trembling aspen	130	107	115	
	White birch	127	109	110	
	Lodgepole pine	135	112	118	
	White spruce	140	124	144	
	Douglas fir	140	125	144	
3	Willow	—	86	96	Altitude 4,475 feet, slope 20%, aspect N70W.
	Balsam poplar	129	119	125	
	Trembling aspen	133	122	125	
	Lodgepole pine	132	119	117	
	White spruce	139	122	138	
	Douglas fir	155	122	141	
4	Willow	109	86	87	Altitude 4,600 feet, slope 10%, aspect N15W.
	Balsam poplar	129	121	114	
	Trembling aspen	134	—	131	
	Lodgepole pine	134	122	121	

(Five trees per species, per plot, were tagged and observations were made on the same trees each year. The day when leaf buds were bursting is recorded. The data were collected at Kananaskis, Alberta, by N. V. German, O. G. Larsson and H. A. Parker.)

Table 3.—Variations in date (day of the year) of flushing in the same general area

Year	Species	Plot 1	Plot 2	Plot 3	Plot 4
1939	Tamarack	—	—	129	129
	White birch	137	135	135	137
	Trembling aspen	140	135	142	142
	Red maple	137	135	142	142
	Wire birch	140	149	156	156
1940	Tamarack	—	—	124	127
	White birch	130	132	123	122
	Trembling aspen	136	130	134	127
	Red maple	128	133	126	131
	Wire birch	125	136	134	134
1941	Tamarack	—	—	119	117
	White birch	125	125	121	117
	Trembling aspen	130	122	122	122
	Red maple	121	121	121	128
	Wire birch	125	127	125	135
	Plot description	Moist, low-lying, slope slight, N.W. exposure.	Moist, low-lying, slope slight, S.W. exposure.	Dry, near top of ridge, slope moderate, S.E. exposure.	Dry, near top of ridge, slope moderate, N.W. exposure.

(Day of the year when leaf buds burst on four plots in the area of the Acadia Forest Experiment Station, New Brunswick. Data collected by W. B. M. Clarke and H. D. Long.)

Table 4.—Frequency of colouring and leaf fall
(Number of Times)

Period (Days of the year)	Colouring begins	Peak of fall colouring reached	Significant leaf-fall begins	Most leaves fallen
236–240	—	—	—	—
241–245	3	—	—	—
246–250	3	—	—	—
251–255	1	—	2	—
256–260	—	—	—	—
261–265	—	1	2	—
266–270	—	1	3	—
271–275	—	4	—	—
276–280	—	1	—	1
281–285	—	—	—	4
286–290	—	—	—	2
291–295	—	—	—	—

Dates of leaf colouring and leaf-fall during a seven-year period are roughly indicated. This table was derived from phenological observations made at Chalk River, Ontario. The main species involved are sugar maple, yellow and white birch, aspen, beech, basswood and red maple.

The data were collected by members of the Fire Protection Section of the Department of Forestry.

APPENDIX 2

Conversion of day of the month to day of the year

Day of the month	Day of the year				
	April	May	June	September	October
1	91	121	152	244	274
2	92	122	153	245	275
3	93	123	154	246	276
4	94	124	155	247	277
5	95	125	156	248	278
6	96	126	157	249	279
7	97	127	158	250	280
8	98	128	159	251	281
9	99	129	160	252	282
10	100	130	161	253	283
11	101	131	162	254	284
12	102	132	163	255	285
13	103	133	164	256	286
14	104	134	165	257	287
15	105	135	166	258	288
16	106	136	167	259	289
17	107	137	168	260	290
18	108	138	169	261	291
19	109	139	170	262	292
20	110	140	171	263	293
21	111	141	172	264	294
22	112	142	173	265	295
23	113	143	174	266	296
24	114	144	175	267	297
25	115	145	176	268	298
26	116	146	177	269	299
27	117	147	178	270	300
28	118	148	179	271	301
29	119	149	180	272	302
30	120	150	181	273	303
31	—	151	—	—	304

(NOTE: For leap-years add 1 to day of the year figures shown.)

APPENDIX 3

Common and Botanical Names of Trees

Balsam fir . . . . *Abies balsamea* (L.) Mill.
Balsam poplar . . . . *Populus balsamifera* L.
Basswood . . . . *Tilia americana* L.
Beech . . . . *Fagus grandifolia* Ehrh.
Bitternut hickory . . . . *Carya cordiformis* (Wang.) K. Koch
Black ash . . . . *Fraxinus nigra* Marsh.
Black cherry . . . . *Prunus serotina* Ehrh.
Black spruce . . . . *Picea mariana* (Mill.) BSP.
Bur oak . . . . *Quercus macrocarpa* Michx.
Butternut . . . . *Juglans cinerea* L.
Carolina poplar . . . . *Populus* × *eugenei* Simon-Louis
Catalpa . . . . *Catalpa speciosa* Warder
Choke cherry . . . . *Prunus virginiana* L.
Douglas fir . . . . *Pseudotsuga taxifolia* (Poir.) Britt.
Eastern cottonwood . . . . *Populus deltoides* Marsh.
Hawthorn . . . . *Crataegus* L.
Honey-locust . . . . *Gleditsia triacanthos* L.
Ironwood . . . . *Ostrya virginiana* (Mill.) K. Koch
Jack pine . . . . *Pinus banksiana* Lamb.
Kentucky coffee-tree . . . . *Gymnocladus dioica* (L.) K. Koch
Largetooth aspen . . . . *Populus grandidentata* Michx.
Lodgepole pine . . . . *Pinus contorta* Dougl.
Manitoba maple . . . . *Acer negundo* L.
Mountain ash . . . . *Sorbus americana* Marsh.
Norway maple . . . . *Acer platanoides* L.
Pin cherry . . . . *Prunus pensylvanica* L.f.
Red maple . . . . *Acer rubrum* L.
Red oak . . . . *Quercus rubra* L.
Redbud . . . . *Cercis canadensis* L.
Shagbark hickory . . . . *Carya ovata* (Mill.) K. Koch
Silver maple . . . . *Acer saccharinum* L.
Sugar maple . . . . *Acer saccharum* Marsh.
Sycamore . . . . *Platanus occidentalis* L.
Tamarack . . . . *Larix laricina* (Du Roi) K. Koch
Trembling aspen . . . . *Populus tremuloides* Michx.
White ash . . . . *Fraxinus americana* L.
White birch . . . . *Betula papyrifera* Marsh.
White elm . . . . *Ulmus americana* L.
White oak . . . . *Quercus alba* L.
White spruce . . . . *Picea glauca* (Moench) Voss
Willow . . . . *Salix* L.
Wire birch . . . . *Betula populifolia* Marsh.
Yellow birch . . . . *Betula alleghaniensis* Michx. f.