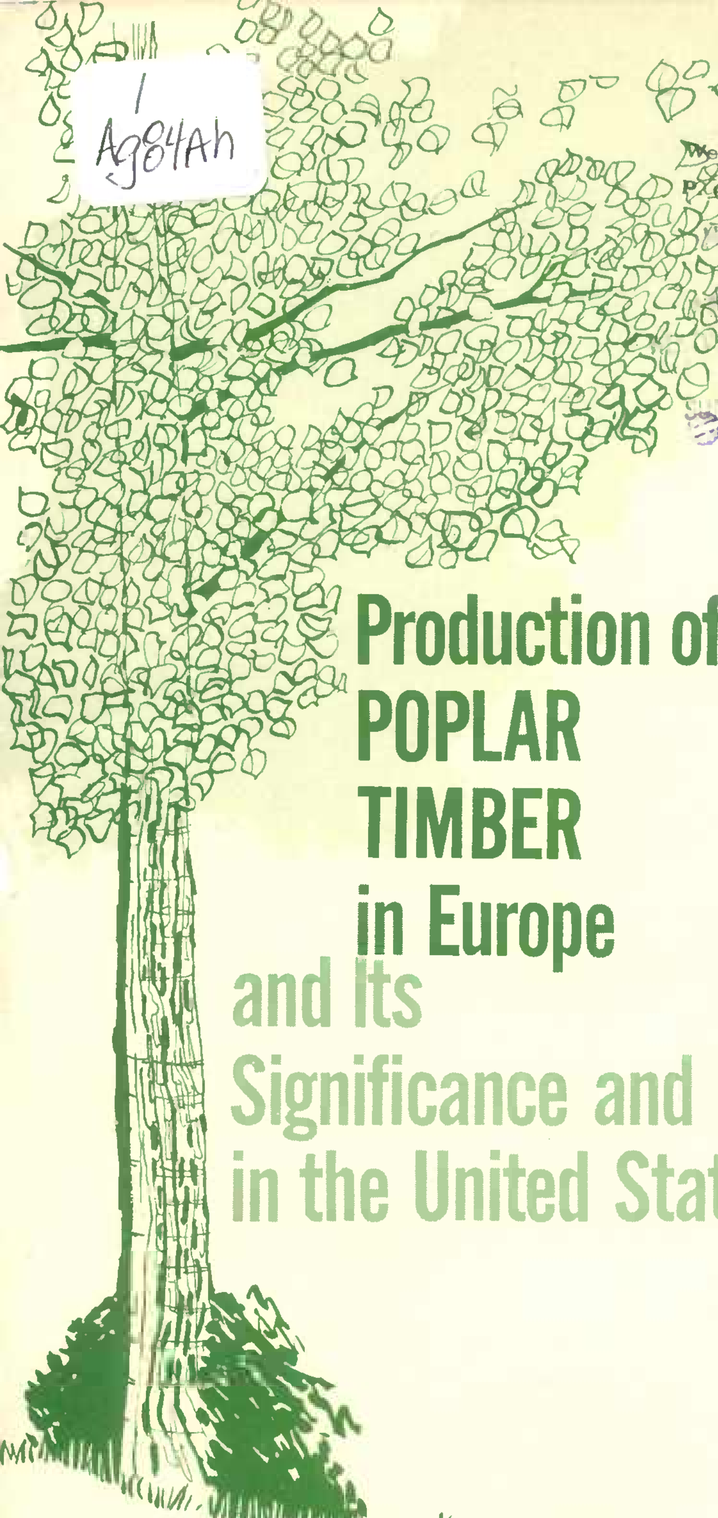

Production of POPLAR TIMBER in Europe and Its Significance and Application in the United States

AGRICULTURE HANDBOOK NO. 150
U. S. DEPARTMENT OF AGRICULTURE • FOREST SERVICE

Production of POPLAR TIMBER in Europe and Its Significance and Application in the United States

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Washington, D. C.

FOREST SERVICE
February 1959

Acknowledgments

Acknowledgment is made particularly of the wholehearted cooperation of the late Prof. Dr. G. Houtzagers of the Instituut voor Bosbouwkundig Onderzoek, Afd. Houtteelt, in Wageningen, The Netherlands, who made all arrangements for the author's travels through the poplar regions of Europe. His comprehensive firsthand knowledge of European poplar culture and his personal acquaintance with the poplar specialists of Europe made the highly successful study tours possible.

The author is also heavily indebted to Prof. Dr. G. Piccarolo, Director, Instituto de Sperimentazione per la Pioppicoltura, Casale Monferrato, Italy, who spent 3 weeks showing him the intensive poplar culture in the Po Valley.

Appreciation and thanks are also expressed to the following individuals who conducted the author on poplar study tours in their respective countries:

Prof. Dr. F. Bauer, Waldbau Institut der Universitat Freiburg, Freiburg i. Br., Germany.

Prof. Ola Børset, Norges Landbrukshøgskole, Instituut for Skogskjøtsel, Vollebekk, Norway.

Dr. B. Bouvarel, Station de Recherches et Expériences Forestières, Nancy, France.

Mr. J. Chardenon, Service de Plantations de Peupliers du SEITA, Saintines (Oise), France.

Oberforstmeister F. Eichbaum, Deutche Pappelverein, Bonn, Germany.

Mr. H. Erhelens, Director, Nederlandsche Algemeene Keuringsdienst voor Boomkweekerijgewassen (NAKB), The Hague, The Netherlands.

Dr. Fritz Fischer, Eidgenössische Anstalt f.d. Forstliche Versuchswesen, Zurich, Switzerland.

Mr. F. Flon, Forester, Belgium Match Co., Grammont, Belgium.

Mr. H. J. Gerritsen, Nederlandsche Heidemaatschappij, Arnhem, The Netherlands.

Dr. A. Herbignat, Directeur Général de Eaux et Forêts, Brussels, Belgium.

Prof. Dr. H. H. Hilf, Director, Forschungsstelle f. Flurholzanbau d. Lignikultur, Reinbek b. Hamburg, Germany.

Mr. F. Jaime, Ingeniero de Montes, Jefe de la Brigada de Teruel, Zaragoza, Spain.

Dr. Helge Johnsson, Director, Föreningen för Växtförädling av Skogsträd, Ekebo, Källstorp, Sweden.

Dr. W. Langner, Director, Institut f. Forstgenetik u. Forstpflanzenzüchtung, Schmalenbek ü. Ahrensburg, Germany.

Dr. C. Muhle Larsen, Directeur Scientifique, Institut de Populiculture, Grammont, Belgium.

Dr. C. Syrach Larsen, Director, Arboretum, Royal Veterinary and Agricultural College, Hörsholm, Denmark.

Dr. R. Müller, Director, Wissenschaftliches Institut des Deutchen Pappelvereins, Brühl, Germany.

Mr. M. Navarro, Ingeniero de Montes, Jefe de la Brigada de Aragon, Zaragoza, Spain.

Prof. A. Pavari, Director, Stazione Sperimentale di Selvicoltura, Florence, Italy.

Mr. T. R. Peace, Forest Pathologist, Forestry Commission, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, England.

Dr. J. Pourtet, Ingenier Principal de Eaux et Forêts, Station de Recherches et Expériences Forestières, Nancy, France.

Dr. Ernst Rohmeder, Director, Institut f. Forstsamenkunde u. Pflanzenzüchtung, Munich, Germany.

Dr. René Rol, Le Sous-Directeur de l'École Nationale de Eaux et Forêts, Nancy, France.

Mr. J. M. Sanz-Pastor, Ingeniero del Patrimonio Forestal del Estado, Jefe de la División Hidrológico-Forestal del Tajo, Madrid, Spain.

Dr. H. van Vloten, Director, Bosbouwproefstation T.N.O., Wageningen, The Netherlands.

Dr. W. Wettstein, Leiter Doz., Abteilung Forstpflanzenzüchtung, Forstlichen Bundesversuchsanstalt Mariabrunn, Vienna, Austria.

In addition to the help and cooperation acknowledged above, the author owes a debt of gratitude to several hundred European foresters, poplar specialists, nurserymen, and poplar growers. The success of the study reported here stems primarily from the information they so kindly provided.

Schreiner, Ernst Jefferson, 1902–

Production of poplar timber in Europe and its significance and application in the United States. Washington, U. S. Dept. of Agriculture, Forest Service, 1959.

iv, 124 p. illus., map. 24 cm. (U. S. Dept. of Agriculture. Agriculture handbook no. 150)

Bibliographical footnotes.

1. Poplar. (Series)

SD397.P85S35 634.9723 Agr 59-29

U. S. Dept. of Agr. Libr. 1Ag84Ah no. 150
for Library of Congress †

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Production of Poplar Timber In Europe and its Significance and Application in the United States

INTRODUCTION

Between October 1951 and October 1952 the author studied poplar culture and research in western Europe, partly under a Fulbright Research Grant and partly under the auspices of the U.S. Forest Service. He attended the International Poplar Commission meetings and study tours in Spain in 1955, and in France in 1957, as official representative for the United States.

During these visits, which involved more than 30,000 miles of automobile travel (fig. 1), and through personal correspondence with poplar experts and growers in all the western European countries, he has had the opportunity to observe and collect information about European experience in poplar culture and research. This is his report on these studies, with special reference to the significance of European poplar work for the United States.

Since hybrid poplar culture started in Europe, there is much to be learned from the practices that have developed during the past 200 years. European poplar culture is impressively extensive and successful; but practice, and to some extent research, still lean heavily on traditional concepts and methods. The author has attempted to differentiate among the traditional, the biological, and the economic aspects of poplar production. Research will be necessary to test the biological and economic validity of some of the traditional practices.

There is now a worldwide interest in the use of hybrid poplars for timber production. Within recent years the interest in hybrid poplars has grown rapidly in the United States. For example, during the past 3 years the Northeastern Forest Experiment Station has received about 8,000 letters from farmers, landowners, and forest industries that wanted information about planting stock, planting methods, culture, and markets for poplar wood. This publication will, it is hoped, answer many of these questions.

The question of probable markets for hybrid poplar timber can be answered only for localities within the commercial range of our native poplars (cottonwoods and aspens); that is, where there is a present market for poplar timber. It will seldom be possible to profitably market the limited poplar production of one or even several small landowners where there is no industry that utilizes poplar within reasonable transportation distance.

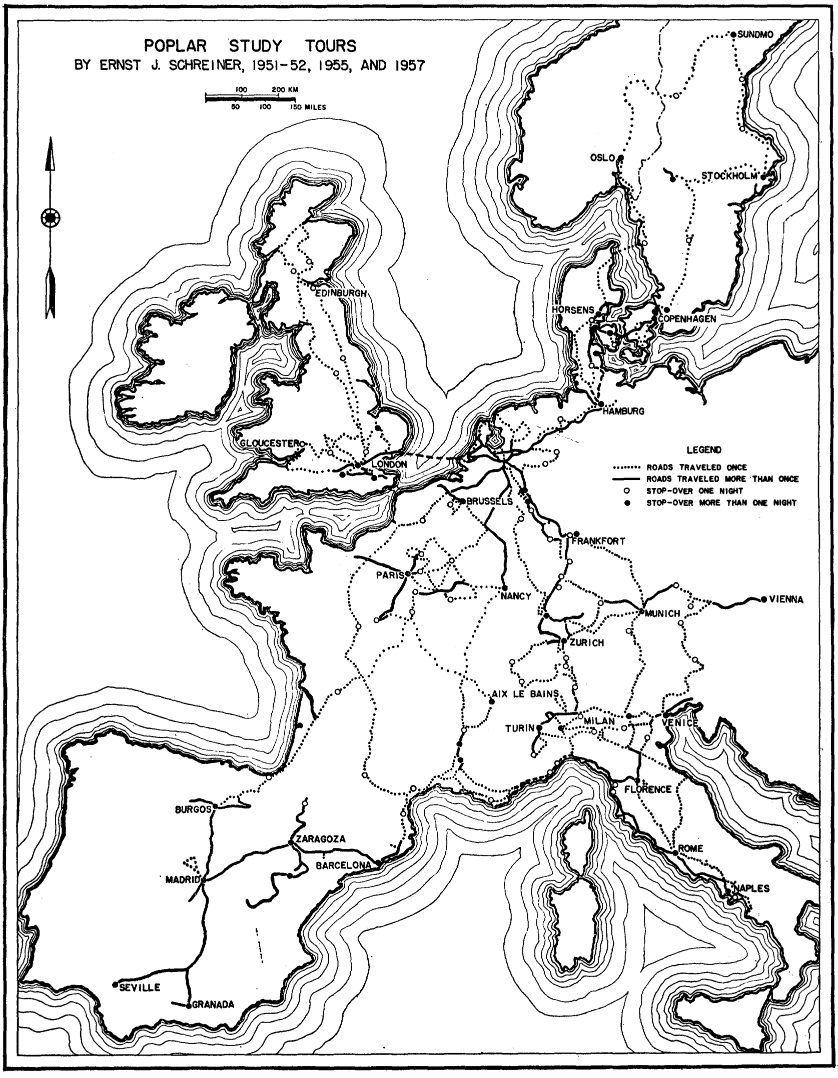

FIGURE 1.—The author traveled more than 30,000 miles by automobile in his studies of poplar culture and research, forest genetics, and general forestry, during visits to Europe in 1951–52, 1955, and 1957.

Where there is no present market, hybrid poplars can be expected to produce their potential share of the local timber wealth only if they are grown in sufficiently large quantities to attract industry. Existing local industries are not essential; with a sufficient and continuing supply of good poplar timber in sight, industry can be expected to compete for the product and even for the establishment of local conversion plants.

In localities where climate and soils are apparently suitable for poplar culture, but where there now are no available markets, it would require the cooperation of many farmers and landowners to foster a production program on a scale that would create a profitable market. An essential first step in such new territory is the establishment of test and demonstration plantings. It would also be necessary to determine—

1. The economic limits of the proposed production area.
2. How much suitable poplar land would be available within the production area.
3. How many landowners would agree to plant poplar, and the acreage of suitable land the prospective growers would use for poplar production.
4. The possibility of agreement among prospective growers on a plan for continuous annual production (sustained yield). This would require agreement on a minimum acreage to be planted annually.
5. Whether the estimated annual production would create a reliable market.
6. The need and desirability for a local poplar-growers organization for mutual protection, cooperation, and exchange of ideas and information.

Demonstration and test plantings and a survey of local possibilities could be made by interested individuals, independently or under the sponsorship of local organizations. Successful demonstration plantings, established a few years before an action program on large-scale planting is contemplated, would provide the best argument for concerted action.

Predictions of costs and returns from hybrid poplar in the United States have not been included in this report for the following reasons:

1. European figures, based on the use of relatively cheap hand-labor and proportionately high prices for timber products, cannot be converted for American conditions with sufficient accuracy to justify their use.
2. Costs and returns in the United States will depend in large measure on the extent to which poplar production can be successfully mechanized. There is a lack of experience and cost information on this problem both in Europe and in this country.

HISTORY AND IMPORTANCE OF POPLAR IN EUROPE

It is usually convenient to have a more or less definite starting date for any historical sketch, but this is not possible for poplar culture in Europe. There is evidence that the native poplars of the Po Valley, which stretches across northern Italy from the French border to the Adriatic, were heavily exploited in Roman times. Here, as well as in southern Italy, the native poplars have been important for hundreds of years, to some extent planted but more often protected or at least favored where they occurred naturally.

In the Caudina Valley, a region of small land ownerships northeast of Naples, the poplar is used in a custom that has been handed down from generation to generation: at the birth of a daughter, it is customary for the father to plant a small number of poplars, usually about 100; and when the daughter marries, these trees are her dowry.

The native black poplar has also been used for centuries in parts of France, in the Low Countries, and in Germany along the lower Rhine. Poplar lumber has been found in German farm buildings old enough to indicate that the European poplar was used long before the American cottonwood brought hybrid vigor into European poplar culture.

Modern European poplar culture stems from the introduction of our American cottonwood about 250 years ago. During these two and a half centuries countless numbers of hybrids have been produced by natural hybridization between the American species and the European black poplar, followed by crossing between the hybrids and backcrossing between hybrids and the European parent species. Many of these hybrids were superior to the parent species in such characters as rate of growth, disease resistance, stem form, or other desirable characteristics. Since such natural hybrids could be propagated easily from cuttings, superior and especially vigorous wildlings were frequently used in local plantations.

The nurserymen and growers of the Parisian Basin were the first to select and exploit outstanding natural hybrids. Although France leads Europe in poplar acreage, in recent years it has been surpassed by several other countries in the intensity and efficiency of its poplar culture. A recent estimate indicates that there are, in round figures, 247,000 acres of poplar in France; and that approximately 40 percent (98,800 acres) of these plantations are in the Parisian Basin.

An annual increment between 150 and 160 cubic feet per acre is a reasonable estimate of the average productivity of all poplar plantations in France. On the basis of 155 cubic feet per acre per year, the total annual growth is approximately 38.3 million cubic feet (roughly 426,000 cords or 192 million board-feet).

The American cottonwood is reported to have been introduced into the Po Valley in northern Italy in 1770. Free and easy natural hybridization with the native black poplar followed the same pattern here as it did north of the Alps, but the earliest industrial use of hybrid poplars in this region was for pulpwood about 1890.

Expansion in Poplar Culture

Although poplar has long been an important bottom-land timber tree in many localities, recognition of its importance to the forest economy of Europe has increased astoundingly since the end of World War II. On the initiative of French, Belgian, and Netherlands poplar experts, the International Poplar Commission was organized in 1947 under sponsorship of the Food and Agriculture Organization of the United Nations.

The aim of the International Commission is to promote international collaboration in the study of scientific, technical, and economic questions relating to poplar. Most of the twenty-one member countries (France, Belgium, The Netherlands, Italy, the United Kingdom, Sweden, Switzerland, Austria, Hungary, Western Germany, Spain, Turkey, Argentina, Egypt, Iraq, Iran, Syria, Greece, Lebanon, Pakistan, and Yugoslavia) have national poplar commissions to promote the study and culture of poplars.

There are two major reasons for the great importance of poplar in Europe today: (1) the drastic shortage of wood in all countries, and (2) the rapid growth of poplar under proper culture on suitable sites. Farmers and small and large owners of land suitable for the growth of poplar can harvest these trees profitably in 12 to 25 years. In especially favorable localities in France, Germany, The Netherlands, and particularly Italy, poplar is the farmer's or landowner's most profitable crop.

Netherlands figures, based on all costs over a 25-year rotation (including soil rent, taxes, and interest at 3 percent on the invested capital) indicate a net profit of $9.50 to $12.50 (36 to 48 guilders) per tree. On the basis of 64 trees per acre (based on an average loss of 8 percent of the 70 trees originally planted) this is a net profit of $608 to $800 per acre.

The German Poplar Society has reported that the normal yield of widely spaced poplars on the bottom lands of the lower Rhine is 285.8 cubic feet per acre per year—a gross value of $96 per acre per year.

In the Po Valley of northern Italy, poplars grown on fertile agricultural land on 12- to 25-year rotations are said to produce a greater net return than any other agricultural crop.

Significance for the United States

The diverse and extensive timber supplies in the United States and our nationwide effort to conserve our forest heritage should prevent the drastic timber shortages that have made the role of hybrid poplar so important in Europe. Nevertheless, the rapid growth of hybrid poplars and their high productivity on sites suitable for their growth offers a profitable addition to our forest wealth. There is some land on most farms, and extensive areas in some of our major river valleys, on which hybrid poplars would be more productive than any other timber tree.

There is a demand for poplar in many parts of the United States at the present time. And hybrid poplar timber can meet the requirements of industries that are now using other and less rapid-growing native species. Since the International Poplar Commission has become the worldwide clearing house for the exchange of information on the production and utilization of poplar timber, poplar culture in the United States can reap rich benefits from the work of the Commission.

POPLARS GROWN COMMERCIALLY IN EUROPE

Northern Europe

Denmark, Sweden, Norway.—The match industries in these countries are strongly prejudiced in favor of aspen for matchwood and are reluctant to use the Aigeiros hybrids. In some respects aspen wood does make a somewhat better match, but the difference seems rather insignificant for purposes of usability and salability. This observation is based on the almost exclusive use of Aigeiros hybrids for matchwood on the Continent.

There are sound biological reasons for the importance of aspen in Sweden and Norway. Most important are the naturally regenerated aspen stands (*Populus tremula* L.). Furthermore, river bottom-land sites, generally considered essential for the most profitable culture of Aigeiros hybrids, are much more limited than on the Continent.

The strongest demand at present for poplar planting stock in Denmark, Sweden, and Norway is for first generation (F_1 hybrids between European and American aspens (*P. tremula* $\times$ *tremuloides* Michx.). This demand is so large that it cannot be met by the nurseries that are engaged exclusively in mass production of these F_1 hybrids.

Aigeiros poplars and hybrids have been planted to some extent in Denmark for windbreaks but many of these are branchy types that are not used by the match industry. Tacamahaca hybrids of the type of *P.* $\times$*berolinensis* Dipp.[1] have grown well but have not been generally disease resistant. Specimens of both Aigeiros and Tacamahaca hybrids in gardens, hedgerows, and along roadsides indicate that carefully selected clones of these poplars might fill an important niche in the forest economy of Denmark.

The Netherlands.—Occasional natural hybrids were undoubtedly selected in the past for clonal propagation by farmers and nurserymen, but the number of clones cultivated in The Netherlands was never so large as in some other countries of Europe. One probable reason is that natural regeneration from seed, which under European cultural conditions almost invariably produces new hybrids, was limited in The Netherlands by the intensive utilization of land along the rivers and canals for agriculture—particularly for forage. Hay and grazing in the poplar plantations and on the overflow lands along the riverbanks is extremely unfavorable to survival of poplar seedlings.

The excellent studies of the late Prof. G. Houtzagers of the Forest School in Wageningen, published under the title "Het Geslacht Populus in Verband met Zijn Beteekanis voor de Houtteelt"

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[1] The poplar names used in this report conform to the International Code. The application of these rules to the cultivated poplars, and synonymous names in European poplar literature or in local use, are discussed in the appendix.

(The Genus Populus and its Significance in Silviculture) laid the groundwork for clonal certification in The Netherlands. The following poplars are now in commercial use: *P.* 'Heidemij,' 'I–214,' 'Robusta,' 'Robusta Zeeland,' 'Robusta Vernirubens,' 'Robusta Bachelieri,' 'Marilandica,' 'Gelrica' (fig. 2), 'Manitobensis,' 'Serotina,' and 'Serotina Keppelse Groene.' Most of these clones have been studied and tested for more than 20 years. They have been subjected to pathological tests intensive enough to justify their certification as resistant to the type of bacterial canker that is present in The Netherlands.

Photo by G. Houtzagers

Figure 2.—Twelve-year-old poplar clonal test in Best, The Netherlands. At left is *Populus* 'Gelrica,' at right 'Marilandica.' Note the difference in size and stem form.

Clonal identity is controlled under strict government regulation. Every poplar sold must carry a tag of the Netherlands Inspection Service for Nursery Stock certifying the clonal identity and plant quality. Certified cuttings are available only from a central nursery, originally established by the Netherlands Land Reclamation Society.[2]

Commercial nurserymen are permitted to take cuttings from each purchase of certified cutting stock only as long as the State inspector is certain that there is no danger of mixing clones. State inspectors go through every commercial nursery twice during the first year and once in each succeeding year until the stock is sold. Before the trees are dug for sale, an inspector labels each tree with a certification tag (fig. 3). This is the most intensive federal certification system in Europe.

[2] Early in 1956 this nursery was transferred to the Foundation for Improvement of Breeding Basic Materials for Forest Stands (Stichting ter Verbetering van Voortkwekingsmaterial van Houtopstanden).

N. A. K. B. photo

FIGURE 3.—Certification of poplars in a Netherlands nursery by an inspector of the Netherlands Inspection Service for Nursery Stock. This nursery stock is ready for sale. Each tree is individually tagged.

Central Europe

Belgium.—The poplars most generally planted in the past were the same mixtures of clones used in France, but in recent years the certified Netherlands clones have come into increasing use in Belgium. Between 1940 and 1950 the Belgian Match Company [3] used *Populus* 'Robusta' almost exclusively in its plantations. About 1950, 50 to 60 percent of their plantings were 'Serotina Erecta' and the remainder 'Robusta.' Select clones from many countries in Europe are being tested at the Company's Poplar Institute in Grammont.

Germany.—The poplar types commonly planted in the past in the principal poplar regions of Germany were *P.* 'Robusta,' 'Serotina,' 'Regenerata,' and 'Marilandica.' Types of *P.* ×*berolinensis* were widely planted in the northwest. Although their susceptibility to disease has brought them into disrepute, they are still used rather extensively for roadside and street trees. In Schleswig-Holstein and the coastal region along the North Sea, *P.*×*canescens* (Ait.) Sm. cultivars are still favored for windbreaks because of their windfirmness and their adaptability to coastal conditions.

The extensive poplar plantings in the Rhine bottom lands in Baden exhibit clonal mixtures that have probably been derived through local selection and clonal propagation of natural hybrids. Such natural crossing could have been between hybrids (apparently the older French hybrids) and backcrosses to the native *P. nigra* L., which is still surprisingly common on the flood lands of the Rhine.

Since 1950 the German Poplar Society has certified poplar nursery stock, on the basis of nursery inspections, as to cultivar name, condition, and health. Certified stock bears a protected trademark label, which is attached to individual trees or to bundles of not more than 10 trees. Participation by commercial nurseries is voluntary. Following are some of the cultivars certified for sale during the winter of 1956–57: *P. alba* L., *P.* ×*canescens*, and *P. trichocarpa* Torr. & Grey, all with indication of clone; *P.* 'Heidemij' and 'Gelrica,' both from The Netherlands; and 'Regenerata,' 'Robusta,' 'Serotina,' 'Eugenei Feminine,' 'Robusta Vernirubens,' 'Marilandica,' 'Eukalyptus,' 'Allenstein,' 'Bietigheim,' 'Drömling,' 'Eckhof,' 'Grandis,' 'Isar,' 'Leipsig,' 'Löns,' 'Neupotz,' and 'Flachslanden.'

Great Britain.—Poplar culture has not been extensive in Great Britain. A few commercial plantations have been established from time to time; but in general, poplars have been produced in only small quantities by commercial nurseries for ornamental and windbreak planting.

As on the Continent, the poplar types that have been planted in Great Britain represent a mixture of clones. Even the artificial hybrid *P.* ×*generosa* Henry is a clonal mixture because Henry

[3] The Union Allumettière S.A., which does not lend itself to exact translation, is referred to in this report as "The Belgian Match Company." In the same way, the Service d'Exploitation Industrielle des Tabacs et des Allumettes (SEITA) is referred to as "The French Match Company."

distributed cuttings of a number of taxonomically similar F_1 male and female seedlings under this name.

In addition to the natural species (*P. alba, P. tremula* L., *P. nigra, P. deltoides* Bartr., *P. trichocarpa,* and *P. balsamifera* L.), one or more clones of the following hybrids have been grown in Great Britain: *P.* 'Serotina,' 'Regenerata,' 'Eugenei,' 'Robusta,' 'Marilandica,' 'Lloydii,' ×*generosa* and ×*berolinensis.*

On the basis of climatic adaptability, growth and development, and particularly disease and insect resistance, the Forestry Commission has for the present limited its recommendation for commercial planting to the following clones: *P.* 'Serotina,' the so-called 'Serotina Erecta,' 'Robusta' (fig. 4), 'Gelrica,' and 'Eugenei.' *P.* ×*berolinensis* is recommended for shade and ornamental planting.

France.—The poplars that have been most commonly planted in France are *P.* 'Italica,' 'Blanc de Garonne,' 'Vert de Garonne,' 'Carolin,' 'Angulata,' 'Virginiana,' 'Monilifera,' 'Serotina,' 'Serotina de Champagne,' 'Serotina du Poitou' 'Regenerata,' 'Robusta,' 'Eugenei,' Marilandica,' and 'Regenerata d'Hautervive.' These names have not in all cases characterized or assured pure (single) clones as in The Netherlands.

In the region of Parthois, in the Marne Valley, there are reported to be approximately 49,000 acres of poplar, 80 percent of which is called *P.* 'Virginiana,' the remaining 20 percent 'Robusta' and 'Regenerata.' The 'Virginiana,' although rather crooked in stem form, grows about as well as 'Robusta' on the good sites and somewhat better than 'Robusta' on the poorer sites. The occurrence of both sexes in plantations believed by the owners to be 'Virginiana' is irrefutable evidence of a clonal mixture. Considerable variation in stem form (crookedness) is collaborative evidence, because on any particular site uniformly spaced ramets of a single clone would exhibit only slight variation in growth habit. The new terms "ramet" and "ortet," which are used in this report, are defined in the appendix, p. 112.

In the valley of Garonne, a poplar locally called Carolinensis was most common until about 30 years ago. It is said to be the best type for this region but does not root so readily from cuttings as other clones. *P.* 'Robusta,' 'Regenerata,' 'Vert de Garrone,' and 'Blanc de Garonne' are now most commonly planted here.

P. 'Italica' has been widely planted in southern France, where the wood is preferred for construction lumber. It is obvious from the wide variation in growth habit (from fastigiate to columnar) and the occurrence of both sexes that this name has covered a mixture of clones. The cultivars 'Robusta,' 'Regenerata,' and 'Serotina' are now most extensively planted.

Excellent naturally regenerating stands of *P. alba* occur in some of the river valleys of southern France. *P.* ×*canescens* cultivars (hybrids between *P. alba* and *P. tremula*) are generally considered to grow better than Aigeiros poplars on dry and on excessively wet sites; and like *P. alba* they are used frequently as ornamental and roadside trees. Cultivars of *P.* ×*canescens* are occasionally planted for lumber production but not for matchwood because the wood is said to be too rough.

GREAT BRITAIN FORESTRY COMMISSION photo

FIGURE 4.—*Populus* 'Robusta' about 18 years old, at Kett's Wood, Ryston Hall, England.

The following poplars are recommended by the French Forest Service for planting in the several poplar regions of France:

Western Parisian Basin: *P.* 'Serotina de Champagne,' 'Serotina du Poitou.'

Eastern Parisian Basin: *P.* 'Serotina de Champagne,' 'Robusta,' 'Virginiana.'

Western Region (Bretagne, Secteur Ligerien, Charentes): *P.* 'Serotina du Poitou,' 'Robusta,' 'Regenerata,' 'Virginiana.' Southwestern Region: *P.* 'Blanc de Garonne,' 'Regenerata,' 'Virginiana Carolin.'

Southeastern Region (Secteur Rhodanien): *P.* 'Regenerata,' 'Angulata,' 'Robusta,' 'Virginiana.'

Switzerland.—Poplar culture in Switzerland has been limited by the scarcity of available bottom-land sites. *P.* 'Robusta,' 'Regenerata,' and 'Serotina,' are now most commonly planted. The types grown during the past 50 years in the vicinity of Yvonand on Lake Neuchatel and Noville at the head of Lake Geneva are believed to have been imported originally from French nurseries. In Tessin, in the valley below Bellinzona, there are some small poplar plantations for which the planting stock may have come from Italy. There is some evidence that a few clonal derivatives of local natural hybridization have come into cultivation in Switzerland within the present century.

Southern Europe

Italy.—The introduction of the American cottonwood into the Po Valley in 1790, and of the older European hybrids somewhat later, set the stage for extensive natural hybridization with the native black poplar (*P. nigra*). The natural hybrid population now represents many kinds and degrees of intercrosses and backcrosses to the originally more abundant *P. nigra*.

The almost phenomenal economic importance of hybrid poplar in Italy today is attributable in large measure to the excellent work and enthusiasm of Prof. Giacomo Piccarolo and his associates at the Institute for Poplar Research at Casale Monferrato. By 1928, when epidemic spring dieback (Defogliazone primaverile), and to a lesser degree leaf rust, had become a serious threat to profitable poplar culture, the plantations in northern Italy already contained innumerable natural hybrids.

As a result of selection and tests of thousands of natural hybrids during the past 20 years by the Poplar Institute and several other organizations, the following clones are recommended for planting in Italy: *P.* 'I–37,' 'I–137,' 'I–154,' 'I–214,' 'I–262,' 'I–455,' 'I–477,' and 'I–Caroliniano Bianco de Cercenasco.' With the exception of the last, these clones have not yet (1957) been given clonal names. They are grown and sold under clonal numbers, the capital "I" indicating Italian origin. The greatest demand is for clone 'I–214' because of its vigorous growth and disease resistance.

Spain.—European black poplars, especially columnar and fastigiate types like the Lombardy poplar, have been planted along many Spanish highways and river bottom lands. For centuries they have characterized the Castilian roadsides under conditions that are too dry for many trees. Poplars are often the principal source of lumber and of fagots for fuel; in some localities even the fallen leaves have been used for fuel.

Poplar culture has been locally important for centuries, particularly in the Mediterranean region and in the Duero and Tajo Valleys of Spain. In addition to numerous cultivars of the European black poplar, there are also many Aigeiros hybrids in cultivation (fig. 5). The original source of most of these hybrids is obscure, but the most probable guess would be imported cultivars and local selections of natural hybrids.

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FIGURE 5.—A 6-year-old poplar plantation in the Genil River Valley near Granada, Spain. The first thinning had been made in this plantation during the previous winter.

In the region between Barcelona and Gerona, the four cultivars that have been most widely planted are *P.* 'Mainou,' 'Bordils,' 'Poncella,' and 'Polla Carolina.' The last was practically eliminated by disease some 35 years ago. *P. alba* occurs naturally and as occasional trees in plantations of other cultivars; it is not commonly planted. Two cultivars, 'Blanquillo' and 'Nigrito,' are recognized in the region of Granada. In the Province of Logrono the most commonly grown poplars are the locally called canadensis and 'Italica.' In Aragon, cultivars of the European black poplar are grown as pollards from which 10 to 15 stems are cut at 10- to 12-year intervals.

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Significance for the United States

One of the objectives of this study was an investigation of the silvicultural characteristics (such as site requirements, growth rate, and disease and insect resistance) of the poplars that are grown commercially or are being tested in Europe. Only empirical and inconclusive answers are available on these questions, primarily because of the confusion in naming hybrid poplar clones and the impossibility of exactly identifying taxonomically similar clones. We should avoid similar confusion in the expansion of poplar culture in the United States. (See appendix p. 112, Identification and Naming of Poplars.)

The search for, selection, and testing of superior individual trees of native poplars, and of natural and artificial hybrids, has greatly increased in recent years in various parts of the United States. Such selections should always be maintained as single clones, never as mixtures of ramets from trees that appear to be similar. Clones should be carried under number till they have been adequately tested and are ready for commercial distribution. With a continuous and increasing number of new clones, national registration will eventually become necessary for the protection of the grower.

SELECTION AND BREEDING

Clonal Selection

Selection of superior individual trees is a major activity of poplar specialists and growers in almost every European country. They generally recognize that there is an essential and continuing job to obtain better clones for future use and to replace those that may fall prey to unusual environmental conditions or to new diseases and insects. Selection offers excellent possibilities in many sections of Europe because of the many hybrid clones in the plantations and the ease and frequency of natural hybridization.

In the Rhine Valley near Bonn there is an excellent example of the possibilities for frequent and abundant natural hybridization and backcrossing. A female *Populus* 'Regenerata' and a male 'Serotina,' estimated to be at least 90 years old, are growing a short distance apart on an old estate. These two clones, and possibly others including early local hybrids, have been planted extensively in mixed or adjacent plantations. In an open area near such a 50-year-old stand there were, in 1952, literally thousands of seedlings from the 1949 seed crop. Dr. Müller, director of the Research Institute of the German Poplar Society, had selected a large number of the best of these natural hybrids for clonal tests.

Except for the Swedish tests, very few clonal tests have been designed for precise statistical analysis. Many new selections are being multiplied for immediate use on the basis of phenotypic excellence of the ortet and the nursery performance of the cuttings.

Where new selections have been tested in plantations, the field layout was seldom designed to permit statistical evaluation of results. One or more factors, such as type of planting stock, time of planting, planting methods, culture, site differences, or soil heterogeneity within the plantation, are almost always completely confounded. Although such clonal selection will bring some elite clones into immediate use, these empirical testing methods will not provide the basic comparisons that are required for scientifically sound clonal evaluation.

The Netherlands.—The clones selected by the late Prof. Houtzagers during the 1930's as the best of those grown in The Netherlands have been under test on 3 different sites for more than 20 years by the Netherlands Land Reclamation Society (fig. 6). These are among the clones now certified by the State for commercial planting. New clones must be tested for 5 years before they can be included in the list of poplars that can be certified for sale.

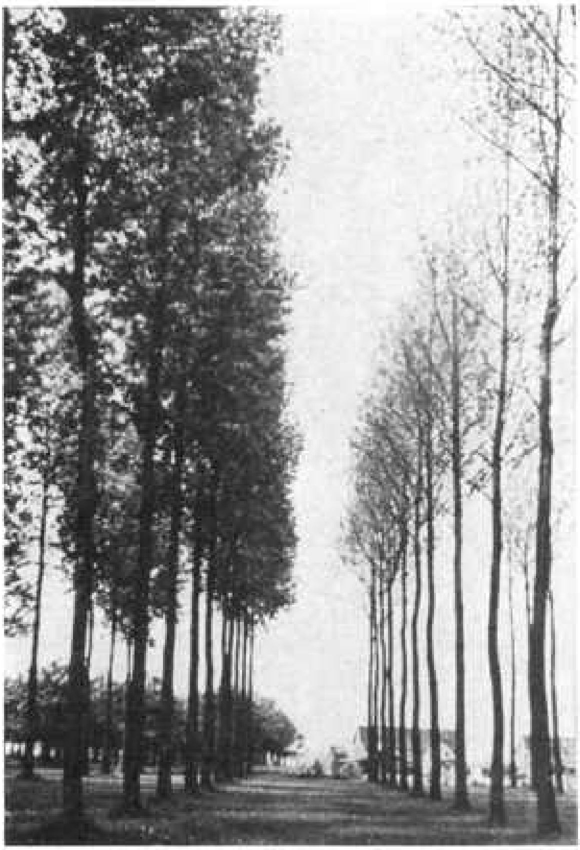


Photo by G. HOUTZAGERS

FIGURE 6.—A spring photograph in the clonal test plantation of the Netherlands Land Reclamation Society at Elst, The Netherlands. At left is *Populus* 'Heidemij,' at right 'Serotina Erecta.' There is considerable difference in time of leafing.

Additional certified clones are needed and desired in The Netherlands, but conditions do not favor the production and survival of natural hybrids in sufficiently large numbers for profitable selection. A relatively few local selections are being made, but the emphasis is quite correctly put on controlled breeding and on testing the best clones from other countries.

The most promising clones from many countries are being propagated in the central poplar nursery formerly located at Keppel but now at Wageningen. A full-time pathologist is assigned to investigate disease resistance in these clones, particularly resistance to artificial inoculation with bacterial canker.

Clones that had demonstrated satisfactory growth and reasonable disease resistance in the nursery were outplanted in 1950 in an extensive and well-designed clonal test on the new Northeast Polder. It was planned to inoculate trees at regular intervals throughout the test plantations with bacterial canker and other native diseases to permit evaluation of clonal resistance to natural infection—the procedure used for more than 25 years in poplar research in the northeastern United States.

Italy.—Clonal selection and testing has been extensively practiced in Italy along two different lines: (1) propagation and testing of seedlings from open-pollinated seed of selected mother trees; and (2) selection and direct propagation (by cuttings) of outstanding trees.

The Institute for Poplar Research at Casale Monferrato has carried on large-scale selection through naturally pollinated seed from selected mother trees. In past years the Institute has grown more than 20,000 seedlings per year (in some years 100,000) for nursery selection. The most vigorous seedlings that are resistant to spring dieback and leaf rust and have good stem and crown form have been tested for rooting ability. After the second year in the nursery the very best have been planted in a selection arboretum and then multiplied for 15- to 20-year clonal plantation tests. By 1948 more than 1,800 clones derived from open-pollinated seed of selected mother trees had been established in test plantations by cooperators in various localities in northern Italy. Several ramets of each clone were planted in each test plantation. Selections of the best clones in the oldest of these plots are already being propagated for commercial planting.

Prof. Aldo Pavari, director of the Forest Experiment Station in Florence, established a test plantation of 24 clones at Monsummano in 1941, 1942, and 1943. Ten of the best early selections of the Institute at Casale Monferrato (including 'I–214') and 14 named clones of Italian origin were included in this test. The clone *Populus* 'I–Caroliniano Bianco de Cercenasco' was considered the best in 1952.

Germany.—Since the war there has been tremendous activity in the selection of excellent local trees in all the poplar-growing regions of Germany. Local selections are being propagated by farmers, nurserymen, estate foresters, State foresters, and research stations. Propagation is usually from single ortets and these can be registered in several of the States as single clones.

Cuttings from several taxonomically similar ortets may also be propagated under a single name or number, but these must be registered as a clonal mixture—"Clone Gemisch." In most cases the phenotypic excellence of the selected ortets, supported only by vigorous nursery growth, is accepted as sufficient evidence to warrant multiplication for immediate use in practice.

The Forschungsstelle für Flurholzanbau der Lignikultur in Reinbek near Hamburg, as the name implies, is sponsoring the production of wood outside the forest; i.e., windbreak, hedgerow, and roadside planting of poplars and willows. Although this research station is testing poplar selections from all countries, it is particularly stressing local selections from northwestern Germany. If these local selections appear satisfactory after several years in the test nursery they are recommended for use in the locality where the ortet was selected. By this procedure the station expects to find the best clones for specific localities.

The Federal Institut für Forstgenetik und Forstpflanzenzüchtung, in Schmalenbeck near Hamburg, has a collection of more than 300 selected clones from Europe and America. The best clones, as determined by nursery performance, will be tested in plantations.

In the Niedersachsischen Pappelmuttergarten in Harsefeld, the State Forest Service has a collection of more than 200 clones, derived from selected local ortets, seedlings from controlled crosses, and some exotic clones. Small numbers of trees of each of these clones are tested in Lower Saxony for comparison with the best registered types. New clones that are as good as or better than the best clones in local use are then propagated in larger numbers. This is a continuing program to obtain better clones and to replace those that may fall prey to unusual environmental conditions, diseases, or insects.

Between 1947 and 1952 the Research Institute of the German Poplar Society sponsored trial plantings of 18 poplar cultivars in approximately 150 cooperative plantations scattered throughout western Germany. During 1951 and 1952 the South German Branch of the Society established another 150 cooperative test plantings in Bavaria. The total number of trees in each planting varied from 100 to 200 and included 10 or 20 trees of each poplar cultivar. Planting stock (1- or 2-year-old trees) was purchased from certified commercial nurseries.

Because these were primarily demonstration plantings, their experimental design will provide only empirical clonal comparisons. The published objectives are (1) to demonstrate the economic possibilities and techniques of poplar culture; (2) to demonstrate choice of correct sites and soils in river bottoms, uplands, forests, and fields; and (3) to compare the most promising poplar cultivars under different environmental conditions.

In Baden, Dr. Friedrich Bauer (formerly Oberlandforstmeister, now at the Forestry Institute of the University of Freiburg) correlates his selections with the site and soil on which the elite ortets (fig. 7) are growing. He has made selections of excellent phenotypes from good poplar sites, dry sites, extremely heavy soils, wet peaty soils, and climatically unfavorable upland sites. These selections are propagated in 10 small state nurseries in Baden, each selection being propagated on sites and soils as similar as possible to the site on which the ortet was found (fig. 8).

Soil specifications include depth of water table, fertility, pH near the surface, and difference in pH between surface and lower soil level. Baden state foresters who order cuttings are required to provide standardized information, by numbers and symbols according to a guide sheet, on their proposed poplar planting sites. The guide sheet covers geographic location, elevation—for climatic information, site information on soil-water relations, soil structure, fertility, depth, and pH. On the basis of this information, clones from ortets selected from similar sites and soils are provided for planting. Statistically controlled clonal tests had not been established to compare the selected clones on similar sites or on a series of different sites and soils.

Photo by F. BAUER

FIGURE 7.—One of Dr. Bauer's selected ortets in the Rhine bottom lands of Baden, Germany. The branches have been removed to produce sucker growth suitable for cuttings.

In the Füllbroch State Forest, Dr. Bauer had an interesting 15-year-old test of clones derived from crooked parent trees. The ramets had been carefully trimmed and pruned every year to produce straight stems, but the trees were still crooked.

Several specimens of burly native *P. nigra* were observed in the Rhine bottom-land forests of Baden. These are called "Maser Pappel" in Germany and the wood is referred to as "Mappa Holz" by local furniture manufacturers in Baden. The wood brings a high price for face veneer, the price depending on the degree and regular distribution of the burl. The average burly log was said to bring about $700 per thousand board-feet. There apparently has been no selection of the best burly trees for clonal propagation.

Photo by F. BAUER

FIGURE 8.—One-year-old rooted cuttings of selected clones in one of the state poplar nurseries in Baden, Germany.

Many private growers and nurseries in Germany—too many for individual mention—are selecting and propagating elite trees. The Harff poplars (fig. 9)—selected and propagated under the supervision of Dr. Bruno Schmitz-Lenders, who has worked with poplars for many years—the Ruskamp poplars, and the Moos poplars are well known in western Germany.

Sweden.—The search for and selection of natural triploids and "plus" trees of the native aspen was an important part of the

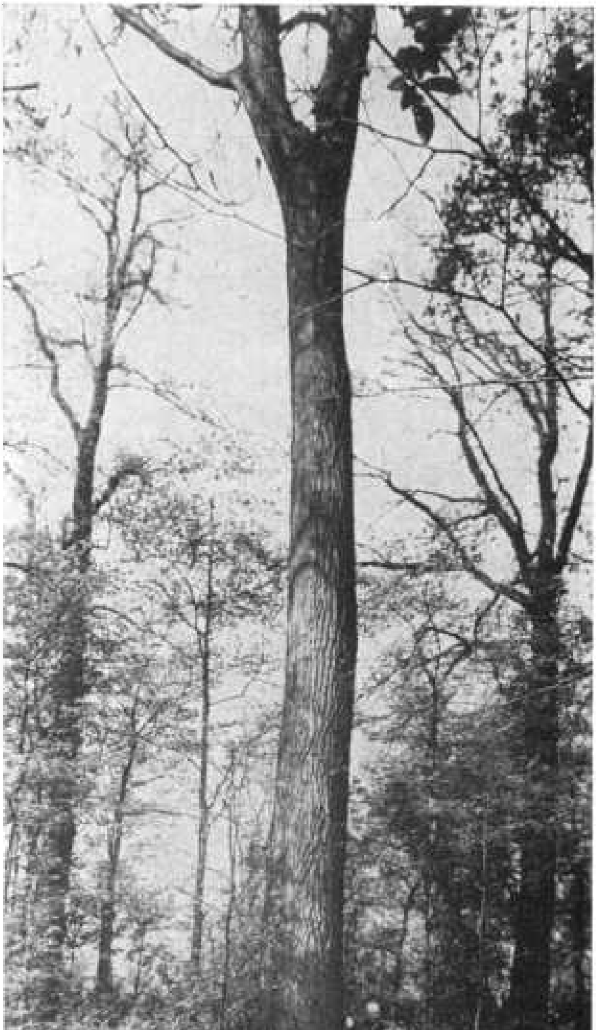


Photo by SCHMITZ-LENDERS

FIGURE 9.—Fifty-year-old Harff poplar on excellent bottom land along the river Erft, District of Cologne, Germany. Its d. b. h. is 45½ inches, total height 140 feet, total volume without bark (to 2.75-inch top) 494 cubic feet, including approximately 400 cubic feet of veneer and saw logs.

early work of the Swedish Tree Breeding Institute. The growth rate of these natural triploids, one clone of which was observed at the forest estate Satra, is higher than that of the diploids. The small stand at Satra, about 60 years old, is considered to be of clonal origin (through root suckers) from a single ortet. Clonal propagation of triploids and of diploid "plus" trees has not been started on a commercial scale. The selected trees have been used for intraspecific and interspecific breeding.

It is too early to compare the yield of Aigeiros hybrids with that of the aspen hybrids, but observations on roadside trees growing on upland sites in Sweden and Norway warrant the prediction that on good sites Aigeiros hybrids and hybrids between Aigeiros and Tacamahaca poplars will grow faster than the aspen hybrids. Such roadside trees have already been subjected to some degree of selection for adaptability to specific environment. Selection and breeding with these types has lagged in Sweden and Norway because sites suitable for their culture are limited and because the match industry in these countries prefers aspen.

Great Britain.—A collection of poplars for clonal tests was begun by the Forestry Commission in the middle 1930's under the direction of W. H. Guillebaud, but the war interrupted this work while most of the collection was still in the nursery. Poplars have received increasing attention since the end of the war. Large-scale field trials of the most promising clones in the collection of the Forestry Commission Research Branch, which were started in 1948 by T. R. Peace, are being expanded in various parts of England, Scotland, and Wales. Some of these are British selections, but the majority are the best clones from other countries of Europe and from America. All clones are subjected to artificial inoculation tests for resistance to bacterial canker.

Belgium.—The Dongelberg experimental plot established by Professor Poskin is apparently the oldest clonal test in this country. This test planting was established with commercial stocks used in Belgium. On the basis of sex and time of leafing, Professor Poskin believes there are at least eight clones of *P.* 'Robusta' in this plantation. There are also several clones of 'Regenerata,' most of which, but not all, are susceptible to a disease that closely resembles, and may be, bacterial canker.

The best clones from all countries are being tested at the Institut de Populiculture of the Union Allumettière in Grammont. The most promising clones in nursery trials are tested in plantations. This work is too recent for any conclusive results.

In 1952 the Direction Generale de Eaux et Forêts established an arboretum at Egenhoven-Bos, near Louvain, with five ramets each of clones that appear promising for commercial use in Belgium.

France.—Between 1949 and 1955 the Direction Generale de Eaux et Forêts established 15 poplar "forest arboretums" throughout France. These plantings total 156 acres and contain 11,200 trees. The trees are under regular observation and measurement.

Previous to 1952 the Department had also established poplar nurseries at Blois and in southern France to provide certified cutting stock. It is not clear whether all the stocks in these nurseries represent pure clones derived from cuttings from single trees or whether they were derived from cuttings taken from several ortets that have the same taxonomic characteristics. In a letter dated June 1, 1956, Dr. J. Pourtet stated that a new poplar nursery, representing pure clones, will replace these earlier nurseries.

The National Forest Research Station at Nancy is making selections of native *P. tremula* in which they recognize two races, a mountain race and a plains race. The races are reported to differ in the ratio of leaf length to width, in the lenticels, and in the character of the bark. Selections of superior straight-boled trees are being made in both races.

Switzerland.—Clonal selection and testing was started in Switzerland by the Federal Forest Experiment Station, located in Zurich. In 1950, Dr. Fritz Fischer established a poplar arboretum at Giritz near Koblenz with Swiss selections and some of the best clones from other countries. Field tests have also been started or are planned in other localities such as Lac de Neuchatel, Noville, and in the vicinity of Bellinzona.

In 1954 the Forest School in Zurich took over the work with Aigeiros poplars and with hybrids within this section for bottomland planting. The Federal Forest Experiment Station is now handling the selection and testing of Tacamahaca poplars and their hybrids, including intersection hybrids, for planting on upland sites.

Spain.—Selection of elite ortets for local use has been a common practice of the growers in the poplar regions of Spain. This is being continued by the government foresters responsible for poplar reforestation and by the Forest Research Institute. Favorable local environments for natural hybridization and survival of seedlings have provided some excellent phenotypes for selection. There is also good *P. alba* in southeastern Spain. An excellent specimen of this species was observed in a 25- to 30-year-old plantation of Lombardy-type poplars near Hostalrich. This tree, the only white poplar in the plantation, was 22 inches in d. b. h. and 100 feet in total height, and it had almost 60 feet of clear trunk.

In addition to selections for vigor, disease resistance, and tree form, selections are now being directed toward good phenotypes that are growing on dry sites. The Spanish foresters are also interested in *P. euphratica* Olivier, which is reputed to grow on alkaline soils. Unfortunately this poplar does not root from cuttings.

Since 1950 many of the best clones from Germany, France, The Netherlands, Italy, Morocco, Syria, and the United States, and clones derived from selected Spanish ortets, have been propagated at the Institute for Forest Research in Madrid. Selections include burly poplars for furniture face veneer. After preliminary observation and selection in the 20-acre experimental nursery, the most promising clones are tested in plantations throughout the country.

Controlled Breeding

Denmark.—Poplar breeding in Denmark has been done almost exclusively with the aspens. As a result of Dr. C. Syrach Larsen's demonstration of hybrid vigor in crosses between *P. tremula* and *P. tremuloides,* the experimental poplar nursery of the Danish Match Company at Hellestrup has been converted to a breeding station for the commercial production of F_1 hybrid aspens. An estimated 150,000 two-year hybrid aspen seedlings were being produced here in 1952. This was insufficient to meet the increasing demand.

Mass pollination is carried out in two greenhouses with lighting facilities for additional artificial illumination to hasten blooming and fruiting. One house is heated for early work in February, the other is unheated for work later in the season. These breeding houses have small pollination chambers arranged along one side for special small-scale pollination work, but the open benches are used for the mass pollinations.

Approximately one-fourth of the annual seed production has been obtained from early pollinations on some 400 grafted plants (in pots) of 15 selected female clones of *P. tremula.* Three-fourths of the hybrid seed production has been on large flowering branches 3 to 4½ feet long, cut from native *P. tremula* trees growing in various parts of Denmark. The flowering branches are brought into bloom in pails of water on the greenhouse bench and are pollinated by hand dusting. In the past most of the *P. tremuloides* pollen has been obtained from Canada.

The fruiting catkins are collected before they are fully open and are placed in glass-covered boxes in which the catkins are spread out one layer deep on screens until they open. The seed is cleaned in a small, screened, rotating drum with a fan to blow the seeds through the wire screen. The cotton stays inside the drum.

The Hellestrup Nursery maintains a record of the parentage of each seed lot and a record of where the hybrid seedlings are outplanted. The growth and development of the individual progenies will be checked to select the best parents for future hybridization.

A large number of *P. tremuloides* clones and seedlings of selected trees from eastern and western Canada, collected by Dr. Larsen, have been planted in the arboretum at Hellestrup. These will be used as parent stocks as soon as they come into bloom.

Sweden.—Aspen breeding has been one of the projects of the Swedish Tree Breeding Institute in Ekebo and the branch stations in Brunsberg and Sundmo since its founding in 1936. The experimental breeding has included intraspecific crossing of "plus" trees of *P. tremula,* polyploidy breeding, and species hybridization. The Institute had also mass-produced *tremula* × *tremuloides* hybrids for commercial sale when this did not interfere with research. In 1951 they produced and sold about 20,000 one-year hybrid seedlings.

The progenies derived from crosses between "plus" trees of *P. tremula* have not been as rapid growing as the aspen hybrids. For this reason production of commercial planting stock from mass-produced seed of "plus" trees of *P. tremula* has been overshadowed by the demand for F_1 hybrids of *tremula* × *tremuloides*. There has been little demand for the mass production of triploid *P. tremula* (obtained by crossing *diploid* × *tetraploid*) apparently because of the variability of the seed progenies. The seedlings range in vigor from those that equal the hybrid aspens in growth rate to very poorly growing, almost dwarf individuals that are graded as nursery discards. Triploid species hybrids, between diploid *P. tremuloides* and tetraploid *P. tremula*, are particularly promising. Selected fast-growing and disease-resistant triploid clones will undoubtedly find a ready market when commercial vegetative propagation is started.

The Swedish Match Company maintains Mykinge Försöksgård, an experimental area near Jönköping, in which some of the Ekebo aspen progenies are being field tested. A planting of *P. tremula* × *tremuloides* hybrids made in 1943 with 1-year seedlings on an area logged in 1941 clearly demonstrates their early vigor. Although this site was covered by a dense stand of root suckers when the hybrids were planted, the native aspens were completely suppressed by 1950. In the 1947 plantation of 1-year-old seedlings of *tremuloides* × *tremula*, *tremula* × *tremuloides*, and crosses between selected diploid *tremula* parents, the most uniformly vigorous progenies were the *tremuloides* × *tremula* hybrids; the direction of the cross seems to make little difference in vigor.

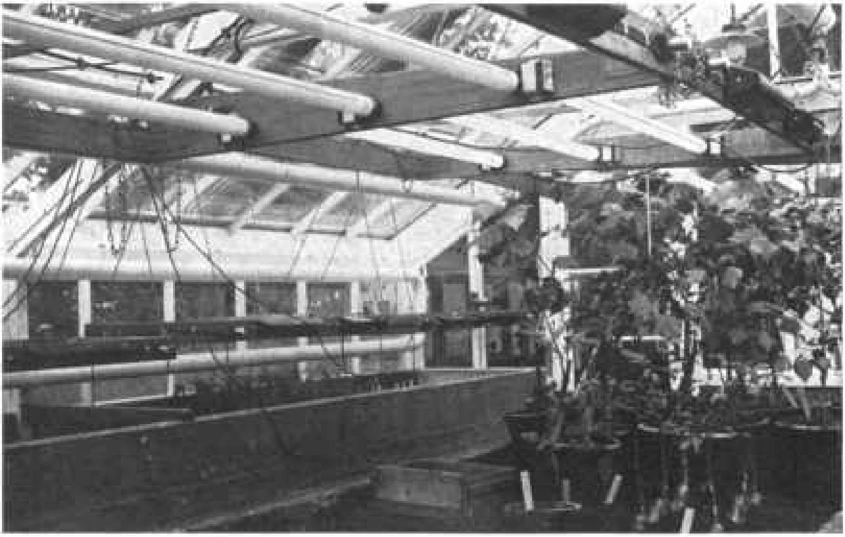
It is too early to predict the adaptability and disease resistance of these new hybrids. Test plantings to date indicate that their early growth rate is extremely promising. Frostcrack and sunscald observed on some of the hybrids indicate the need for continued testing for climatic hardiness. At present the chief risk with these hybrids appears to be disease, which will be discussed under that heading.

In 1950 the Match Company built greenhouse and nursery facilities at Mykinge, similar to those in Denmark, for the commercial production of aspen hybrids; the initial production goal was 200,000 hybrid seedlings per year. The hybridization work is started in February in greenhouses equipped to provide additional light to hasten the development of flowers and seed. The seed ripens and is planted approximately 3 weeks after pollination.

The Netherlands.—Poplar breeding is a major project of the Forest Research Institute in Wageningen, under the direction of Dr. H. van Vloten. The breeding techniques used at the Institute stem from, and are basically similar to, the methods used for experimental poplar breeding in Denmark and Sweden.

Male branches, in water, are placed in small glass-partitioned chambers in a sun porch of the laboratory building and the pollen is permitted to shed. Female branches are bottle grafted on 1-year-old rooted cuttings in pots. During the growing season these pots are plunged outdoors, but the plants are lifted periodically to prevent the roots from growing out into the soil. Kept rootbound, the plants—aspens particularly—will bloom for several successive years. On Leuce poplars, pollinations are also made on flowering branches that are kept in water until the seed matures.

Before and after pollination the female grafts and flowering branches are given artificial illumination between 5:30 p.m. and 7:30 a.m. to hasten flowering and seed maturation (fig. 10).



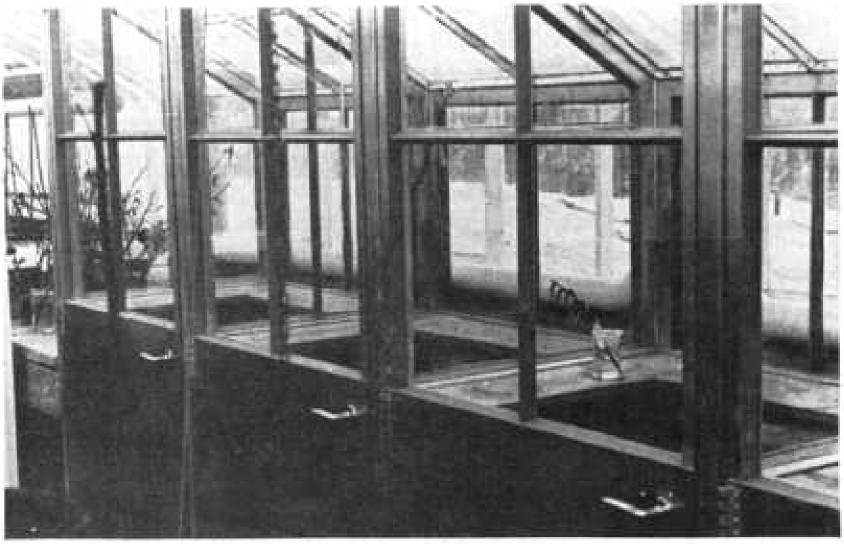
BOSBOUWPROEFSTATION T. N. O. photo

FIGURE 10.—Control-pollinated bottle grafts maturing seed on greenhouse bench at the Forest Research Station, Wageningen, The Netherlands. These potted plants are given additional artificial illumination during the night to hasten seed maturation.

Special pollination chambers, constructed of glass and aluminum and slightly larger than a telephone booth, are arranged along the sides of the greenhouse (fig. 11). They are heated by steampipes along the wall and are connected at the top to an exhaust ventilating system. The temperature of the chambers is maintained at 20° to 22° C. If the temperature rises too high, the ventilator is turned on and cool greenhouse air is drawn into the bottom of the chambers.

Several female parents are brought into a chamber just before the first flowers are receptive and are pollinated each day as the successive flowers in the maturing catkins become receptive. Pollen from one tree only, or from a single clone, is used in each chamber. When the pollinations are completed, the female catkins are washed with a fine water spray and the potted plants are returned to the greenhouse bench. Each pollination chamber is thoroughly washed down before another set of pollinations is started.

The control-pollinated seeds are planted individually on thin blocks of pressed peat that are thoroughly soaked in water before use. After planting, the blocks are kept in a glass-covered greenhouse bench. The germinated seedlings are lifted from the peat blocks after about 7 days and are transplanted to seed pans or flats that contain a thin surface layer of heat-sterilized soil. This method, seen only in The Netherlands, is said to eliminate loss



BOSBOUWPROEFSTATION T. N. O. photo

FIGURE 11.—Pollination chambers in the greenhouse of the Forest Research Station, Wageningen, The Netherlands.

from damping-off. The seedlings are given artificial illumination between 5:30 p.m. and 7:30 a.m. until they are potted and placed in coldframes.

Many progenies from crosses in the Leuce and Aigeiros poplars were growing in the nursery in 1952. The poplar breeders in The Netherlands, as in all other countries, were faced with the problem of finding land for plantation tests of the large numbers of seedlings that are relatively easy to obtain from controlled breeding.

Great Britain.—The earliest controlled breeding work with poplars was done by Augustine Henry in 1912 and 1914. His best-known poplar hybrids are the clonal mixture that he named *P.* ×*generosa,* F_1 hybrids between *angulata* × *trichocarpa.* There has been no recent controlled breeding with poplars in England.

Germany.—Poplar breeding on a comprehensive scale was started by Dr. W. Wettstein in 1930. Although this project was a casualty of World War II, a plantation of Wettstein's hybrids—now more than 17 years old—near Frankfurt includes some excellent individuals that have been selected for clonal testing.

The most extensive controlled-breeding program in West Germany is centered at the Federal Forest Genetics Research Station in Schmalenbeck near Hamburg. Although emphasis has been on the breeding of the Leuce poplars, work has also been started on Aigeiros poplars. Controlled breeding with the Leuce poplars includes breeding with triploid aspen, intraspecific crosses between selected phenotypes, interspecific hybridization, and since 1954 a breeding project with triploid *P.* ×*canescens.* A major concern is to decide how large a progeny should be outplanted for future selection and to find sufficient suitable land for plantation tests.

Limited controlled breeding has been done by other German workers. At Harsefeld, in Lower Saxony, Forstmeister H. Lücke has made some crosses and has been attempting to produce polyploids by colchicine treatment. Prof. Rohmeder, in Munich, has progeny from a cross between *P.* 'Marilandica' (female) and 'Italica' (male).

Austria.—Since the end of World War II Dr. W. Wettstein, at the Federal Forest Research Station in Hadersdorf (Vienna), has been breeding Leuce and Aigeiros poplars. Breeding and selection for photoperiodic response is considered particularly important because early spring budding and delayed fall dormancy are the most serious hazards at the higher elevations in Austria. Controlled breeding is done on flowering branches brought into the greenhouse and pollinated during January and February—the method devised by Wettstein in his early work in Germany. Approximately 10,000 seedlings were produced in 1956, including crosses with pollen from Spain and Korea.

Belgium.—The Poplar Experiment Station of the Belgian Match Company, established and specially designed for poplar breeding, has excellent laboratory and greenhouse facilities, including pollination chambers, and a good nursery site. The breeding techniques used by Dr. C. Muhle Larsen, Director of the Station, are essentially the same as those described for The Netherlands. The breeding work is still in its early stages. The major objectives are intraspecific and interspecific breeding to obtain improved clones for commercial use, and basic genetic information on various taxonomic and physiological characteristics.

France.—In the poplar nursery of the Match Company in Saintine, Mr. Chardenon is growing 27 seedlots of American poplar species for future breeding work. They have also been experimenting on the grafting of flowering scions of Aigeiros hybrids from old trees on rootstocks in small pots. These have been treated in the same manner as aspen grafts in Denmark, Sweden, and The Netherlands. The oldest grafts were 3 years old in 1952 and all had failed to bloom after the first year. They have also grafted scions of black poplar hybrids on willow as a possible method for getting partially incompatible grafts that might bloom at an early age.

Intraspecific and interspecific breeding with aspens and white poplars was started in 1954 by the National Forest Research Station at Nancy. The aspen hybridizations include crosses with pollen of *P. tremuloides* and *P. grandidentata* from Canada.

Italy.—A limited amount of controlled breeding is done every year at the Institute for Poplar Research at Casale Monferrato with Italian pollen and pollen from other countries. Tetraploid pollen has also been used. Exceptional conditions that favor natural hybridization throughout the Po Valley have made available seed and seedlings in almost unlimited quantity from parents that have been subjected to severe natural selection resulting from the prevalence of epidemic diseases. Consequently, only about 2 percent of the clones under test by the Institute have been obtained from controlled pollinations. Most of the clones have been derived from naturally pollinated seed collected from superior phenotypes. Several seedlings, from seeds received from our lower Mississippi region, are considered to be very promising. In 5 years, one of these (clone 72/51) had grown to a diameter of 13 inches at 3.3 feet above the ground.

Spain.—Controlled breeding with Aigeiros hybrids ×*P. nigra, tremula* × *alba, tremula* × 'Bolleana,' *tremula* × *nigra,* and *alba* × *nigra* has been started since 1953 at the Forest Research Institute in Madrid. Breeding is directed toward rapid growth, improved wood quality for veneer, lumber and pulp, and disease resistance. All progenies derived from controlled breeding are tested in the nursery in Madrid and the most promising are then used in field tests.

Significance for the United States

The possibilities for selection of natural hybrids are limited in the United States because exotic species or hybrids have seldom been used in commercial plantations. Exotic species have been planted in botanical gardens, arboretums, and—to a very limited extent—as shade trees. Although the older European hybrids have been extensively planted as street and shade trees, male clones were used almost exclusively because the female trees produce objectionably large amounts of cottony seed.

Natural hybridization has undoubtedly occurred where such European hybrids have been planted within the pollination range of our native poplars. But the germination and survival of such hybrid seed and seedlings would depend on a combination of favorable site conditions that are seldom present in residential areas where poplars are planted as shade trees.

Our native species, *P. deltoides, P. trichocarpa,* and *P. tremuloides,* three of the best timber poplars in the world, merit intensive racial studies and clonal selection and testing. Select clones can be used for planting until tested hybrids are available, but their principal value will be as parents for controlled breeding and hybridization.

The best of the European and Asiatic poplar species, those that have proved to be resistant to European diseases and insects, should be introduced and tested in different regions of the United States for possible use in practice and future breeding. They should be imported by means of seed, not cuttings; it is impractical, if not impossible, to sample adequately the inherent variation within an exotic species by the importation of cuttings.[3] If possible, seed should be obtained from 5 to 10 trees selected at random in each of a sufficient number of localities to sample the entire range of a species. This would provide information on possible racial variation as well as on individual variation.

Clonal tests must be set up in comparable, statistically sound, field designs under a wide variety of environmental conditions be-

[3] Poplar cuttings can be imported only through the Division of Plant Introduction and must be grown in quarantine at the Plant Introduction Garden for 1 or 2 years before they are released.

fore individual clones of native species or new hybrids can be recommended for commercial planting. The excellent growth and form of the selected ortet, substantiated only by nursery performance of the ramets, is not an adequate clonal test.

A central clonal nursery, a "clone bank," is needed to supply the demand for certified cuttings for nationwide tests. Only clones that have been adequately tested and found superior in at least the locality of their origin—and only the very best foreign clones, including those with figured wood—should be accepted and grown in such a central clonal nursery.

We need many demonstration poplar plantations, similar to those established by the German Poplar Society, to bring the poplars best adapted to a region or locality to the attention of farmers and landowners.

Controlled breeding and hybridization with our best native species should be started or expanded in the South and West because we do not yet have the possibilities for extensive natural hybridization. Large progenies of known parentage can be obtained easily through controlled breeding. Such progenies should be outplanted for selection of the best ortets for clonal tests after 10 to 15 years.

Aspen hybridization deserves special attention where the native aspen is at present commercially important or where it is better adapted to reforestation than other native species. If aspen hybrids prove to be as promising in this country as in Europe, it is quite certain that their mass production as F_1 hybrids would also be economically feasible in the United States.

NURSERY PRACTICE

European poplar nurseries are invariably on good agricultural soils, and most nurserymen practice a rotation that allows an interval of 2 to 5 years between successive poplar plantings. Organic manuring, direct or by cover crops, and the use of mineral fertilizers where necessary, is standard practice. Irrigation is considered essential in many nurseries. Spraying for insects and nursery diseases is practiced in all countries. Crooked trees are often staked because only straight stems can be certified for sale where certification is in effect. Where leaders are lost or damaged, laterals may be tied to vertical splints to obtain straight stems.

Pruning of nursery stock is not uniform in any country. The most common practice is to prune to a single whip by removing all side branches just before or immediately after the trees are dug for sale.

A traditional and common practice in some parts of Germany and France is to remove all side branches except three or four of the strongest laterals of the current year's growth. These lateral branches are cut back to short stubs 2 to 8 inches long (called Zuchtruten in Germany), which may be removed in the second year after planting. This heavy pruning is advocated to hold back top growth during the first year in order not to overtax the temporarily reduced root system. Some of the most progressive German nurserymen prune trees for roadside planting as above, but prune trees for forest planting to only one-third or one-half their height.

In The Netherlands, 1-, 2-, and 3-year stock is generally pruned progressively during the last year in the nursery to avoid retarding growth and to obtain rapid callusing. The trees are pruned to one-fourth their height in early spring, to one-third in June, and to about one-half in the fall before they are dug for sale. Some nurseries in France, including the Cacor State Poplar Nursery, are pruning their trees progressively during the growing season to approximately one-half or two-thirds of the stem height. Pruning stumped trees to one-half their height is recommended and practiced in Italy and in England.

Aigeiros Poplars

The black poplars, cottonwoods, and their hybrids are commercially propagated by cuttings and less commonly by sets. Cuttings are usually 10- to 15-inch lengths of dormant 1-year-old stems. Sets are dormant whips, 4 to 10 feet or more in length—most frequently 6 to 8 feet, taken from nursery stools, pollarded trees, or the top branches of felled trees. They are usually 1 or 2 years old, but may be older where they are taken from the upper branches of mature trees. Although sets are most often used directly for outplanting, a few nurseries produce 1-year-rooted stock from 1-year-old sets that are 3 to 6 feet long and are planted 10 to 18 inches deep.

Throughout most of the poplar regions of Europe, cuttings are obtained from stools, spaced 3.3 by 3.3 feet to 4.5 by 6.5 feet apart, that are usually cut back to 2 to 12 inches above the ground. Some growers prefer higher stools (up to 3 or 4 feet) for easier cultivation and handling. The current growth, cut back to the stool each winter, is used for cutting stock.

Stooled plants, with their many stubs, tend to accumulate such facultative parasites as *Valsa* and *Dothichiza,* and also boring insects. The buildup of diseases and insects in stools varies from nursery to nursery, depending on the cultivar, climate, site, and nursery practice. This has led to wide differences of opinion about the effective life of a stool planting; estimates range from 4 to 15 years or more. Loss of vigor of the stools is generally attributed to the annual harvesting of the shoots rather than to facultative parasites. In all cases that came to my attention, the early decline in vigor was most probably due to the inroads of *Valsa, Dothichiza,* wood and bark borers, and other diseases or insects.

In Baden, Germany, Dr. Bauer is testing the possibility of maintaining healthy stools by very careful trimming of pollards 3 feet high to promote rapid callusing of smooth, rounded heads without projecting stubs (fig. 12). In some of the Baden poplar nurseries the weaker shoots are removed from the stools in early summer to force the stronger shoots into better height and diameter growth.

Photo by F. BAUER

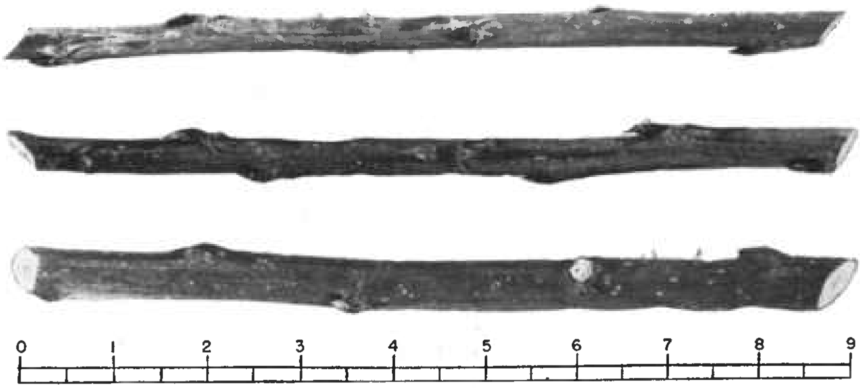
FIGURE 12.—Production of cuttings on 3-foot-high pollards in one of the state poplar nurseries, Baden, Germany. The current growth is removed annually for cuttings or sets. The tops of the stools are very carefully trimmed to promote rapid callusing of smooth, rounded heads without projecting stubs.

There has been much emphasis in Europe on how cuttings should be made, stored, and planted. Many nurserymen and poplar experts claim that a good cutting must be cut at an angle, not transversely; that the upper cut must be immediately above a bud; and that the cuttings must be made with a sharp knife because pruning shears make inferior cuttings.

Cuttings (figs. 13, 14) are generally made during the winter, tied in small bundles, and stored in moist sand in a storage cellar, heeled-in in light soil, or buried in pits until planting time. Some growers insist that cuttings should be stored vertically with the butt ends up. There is difference of opinion as to whether cuttings should be callused before planting.

Length of cuttings varies from 9 to 15¾ inches, with 9¾ to 11¾ inches the most common length where cuttings are planted flush with, or very slightly below, the surface of the soil. As soon as there is sufficient growth, all but one shoot is removed and the soil is hilled-up slightly over the top of the cuttings. This deep planting, presumably to decrease the possibility of disease infection (a doubtful control measure) and to favor growth of the top bud, is widespread but not universal.

Many nurseries in France plant the longer cuttings, 11¾ to 14¾ inches long, with two or more buds above the ground. The Raverdeau Nursery and the match company nursery at Saintine have been planting 13¾-inch cuttings with 3 or even 4 buds above



Great Britain Forestry Commission photo

Figure 13.—Type of cuttings recommended by the Forestry Commission of Great Britain.

Photo by Fernando Jaime Fanlo

Figure 14.—Poplars at the end of their second season's growth from cuttings, in the state poplar nursery at Castelnov on the Martin River, Province of Teruel, Spain. Average height at the end of the first year was 9 feet.

ground. In June the cuttings are pruned to one good shoot, usually one from a lower bud. On cultivars like *Populus* 'Regenerata,' which have a tendency to spreading growth, the young shoot is tied to the top of the cutting to obtain straight-stemmed trees.

Nursery spacing of cuttings varies greatly. Where the rooted cuttings are lifted and replanted at the end of 1 year, close spacing is the rule. In Italy they are planted 3 to 4 inches apart in rows spaced 32 to 40 inches. In northern Europe, cuttings may be spaced as close as 6 to 8 inches in rows 19½ inches apart. In The Netherlands the 1-year rooted cuttings are then lined out 3.3 by 3.3 feet and are grown for 1 or 2 years at this spacing. Spacings of 15½ by 31½ to 40 inches are used in northwestern Germany for the production of 2-year stock without transplanting. In France the spacing for cuttings that will be dug as 2-year-old trees is usually 15½ to 19½ inches by 3.3 feet.

Disease conditions have been so serious in Italy that stool plantings are now seldom used for the production of cuttings. The recommendation of the Poplar Research Institute at Casale Monferrato that stumped trees be used for outplanting has been widely accepted. The stumped-tree system eliminates the hazard of infected stock from diseased nursery stools and saves the nursery space and labor required to maintain stool plantings.

Stumped plants are produced by cutting back 1-year-old trees to a short stump with two or three buds, close-pruning the roots, and replanting the stumps in nursery rows. The stumped plants (fig. 15) are planted level with the ground and are spaced 16 to 24 inches in rows 5½ to 7 feet apart. When the stumps have sprouted and the new shoots are 10 to 12 inches high, they are pruned to one shoot and are hilled to cover the stump.

Cuttings are made from the stems of the 1-year-old trees from which the stumped roots are obtained. The cuttings are planted with their tops at ground level, and after growth has started the soil is slightly hilled around the shoots to cover the top of the cutting. Cuttings are spaced 3 to 4 inches in rows 32 to 40 inches apart; or to conserve space, they may be planted in single rows between the rows of stumps.

At the end of the year, the 1-year rooted cuttings are dug, cut back, and replanted as stumped trees and cuttings. The rooted trees are dug and sold as 2+1 stock (2-year root, 1-year top) if they have grown to sufficient size; otherwise they are left another year to produce 3+2 stock up to 24 feet in height. The demand is heavy for large trees because their use usually brings the grower a better financial return.

Some Italian planters who raise their own nursery stock on extremely fertile soils use the largest of their 1-year-old trees (8 to 10 feet tall) for outplanting and get satisfactory results. Large 1-year trees are also sold by commercial nurseries where there is a heavy demand for planting stock, but this practice is not recommended by the Poplar Institute.

GREAT BRITAIN FORESTRY COMMISSION photo

FIGURE 15.—Stumped 3+2 (3-year root, 2-year top) ready for outplanting. Kennington Forestry Commission Nursery, England.

Leuce Poplars

Populus alba, the European white poplar, is usually propagated from cuttings or sets in the same manner as the Aigeiros poplars.

The gray poplar *P.* ×*canescens* represents a confusing mixture of natural hybrids between *P. alba* and *P. tremula*, and undoubtedly includes many generations of crosses between hybrids and backcrosses to both parents. The rooting ability of these hybrids varies, but few clones root well enough for commercial propagation from cuttings. Where there is demand for the gray poplars they have usually been propagated from root suckers, root cuttings, or by layering rooted stems in a shallow trench with the tip exposed. By this method most of the buds develop shoots that root around the bud and can then be cut into separate plants at the end of the growing season.

W. Gröhn, a nurseryman in Halstenbek, Germany, stated that he had good success in rooting gray poplars by grafting short willow cuttings to the base of the poplar cutting before planting. Both the willow cutting and the poplar cutting produce roots. When the trees are dug, the willow cutting is simply broken off, leaving a well-rooted poplar.

P. tremula, the European aspen, is usually grown from seed. In the very few places where aspens are propagated vegetatively, the commercial nurserymen use root suckers, root cuttings (fig. 16), or layers, as for the gray poplars.

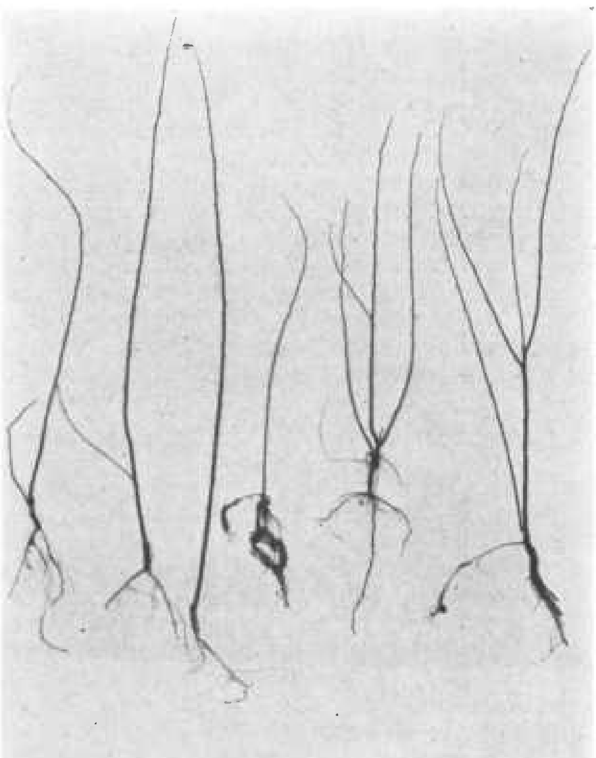


Photo by W. WETTSTEIN

FIGURE 16.—European aspen propagated from root cuttings. Short pieces of root are planted vertically or horizontally. Wettstein, in Austria, reports up to 60 percent rooting, with great variation between individual trees.

Aspens and gray poplars can also be successfully rooted by the "RS-cutting" method developed by C. Muhle Larsen. In late February pieces of root 2 to 4 inches long are placed in moist peat moss, lightly covered, in a greenhouse or hotbed. By the end of March, the root pieces have produced softwood shoots. Aspen is more prolific than gray poplar; one 4-inch length of aspen root produced 38 shoots. The 1- to 2-inch shoots are removed during April and May and are rooted in clean gravel in the greenhouse, hotbed, or coldframe.

The *P. tremula* × *tremuloides* hybrids are grown from mass-produced hybrid seed. At the Hellestrup nursery in Denmark, the hybrid seed is sown in outdoor beds on 2 to 3 inches of thoroughly composted soil that has been steam sterilized in the beds at 100° C. for ½ hour with portable equipment. Damping-off has not been serious. Sowing is at approximately 1 gram of seed per 4 square meters (44 square feet) of bed. At this density of sowing they can expect approximately 1,000 one-year-old seedlings.[4] The seed is covered lightly with composted soil and the beds are covered with glass for about 1 month. Past practice was to shade the beds during summer, but in 1952 the nursery experimented without shades to obtain stouter seedlings.

The 1-year seedlings are transplanted during the fall and early spring to nursery rows spaced 12 inches apart with 24 inches between every third and fourth row. This spacing is adapted to the tillers used for cultivation. The nursery is on a soil that has high pH and is underlain with chalk.

At Mykinge Försöksgård, Sweden, mass production of hybrid aspen begins in early February. The seed is sown on sphagnum moss litter in greenhouse seedbeds about 3 weeks after pollination. By early June the hybrid seedlings, 2 to 4 inches high, are ready for transplanting to outdoor beds. All seedlings are lifted in the fall and stored indoors in sand during the winter. The largest 1-year seedlings are sold in the spring and the smaller trees are planted in transplant rows to be sold as 1–1 stock.

Significance for the United States

In general, the excellent nursery practice used for the production of poplar planting stock in Europe is applicable to poplar culture in the United States.

Care and precision in making cuttings (angle of cut, knife vs. shears) and in storage of cuttings are not necessary. Between 1928 and 1932, in our work with poplar in the Northeast, we found that we could obtain practically 100-percent survival (without increasing the hazard of disease infection) by cutting bundles of whips into cuttings on a fine-tooth circular saw. We have stored cuttings successfully in all positions—horizontally, vertically, with tops up and tops down; in moist sand; in peat moss; and in sawdust at temperatures from 20° to 34° F., sufficiently low to prevent the production of roots or bud bursting before planting. We have

[4] It has been estimated that 540 grams of hybrid seed will produce approximately 400,000 one-year seedlings and 200,000 salable 1–1 seedlings. The smallest seedlings are discarded.

also found that callusing does not increase the rooting or growth of clones selected for good rooting ability.

Cuttings 10 to 12 inches long are the most practical for nursery planting in the United States.

Nursery spacing of 12 to 18 inches by 2 to 3 feet is generally sufficient for the production of 1-year-old rooted cuttings, 18 to 24 inches by 3 feet for stumped 2+1 stock, and 2 by 6 feet for stumped 3+2 stock.

Planting cuttings just deep enough to leave two buds exposed is preferable to planting level with the ground because this permits easier machine cultivation with a minimum of injury to the cuttings early in the season. There is no sound evidence that deep planting will prevent disease or produce straighter trees. Treatment of cuttings with an effective fungicide will give much better control of disease than deep planting, and straightness of stem depends primarily on the inherent nature of the clone. Some clones must be pruned early to a single stem; others produce a straight stem without pruning.

The Italian practice of using stumped trees for outplanting and of producing cuttings from the 1-year-old trees deserves strong recommendation.

The careful hand labor in making cuttings and the cost of splinting and staking in the nursery to produce straight trees cannot be justified in this country. Extremely crooked trees should be discarded; slightly crooked trees of inherently straight-stemmed clones will straighten up after outplanting.

Vegetative propagation of white poplars and aspens by present European methods, which are barely feasible economically even in Europe, cannot be recommended for commercial use in this country. It should be possible to produce *P.* ×*canescens* hybrids that will root from cuttings under nursery conditions by back-crosses to *P. alba* parents that have good rooting ability.

Hybrid aspen seedlings could be produced commercially in the United States by the method used in Denmark, but minor modifications would be needed to permit use of our standard nursery equipment.

SITE AND SOIL REQUIREMENTS

Aigeiros Poplars

These poplars are generally considered bottom-land species, and relatively few foresters or growers in the past have dared to recommend or try commercial culture on upland sites. But in all European countries, and in America, Aigeiros hybrids have been freely planted on upland sites as shade or roadside trees. In Spain particularly, European black poplars of both pyramidal and spreading types have been grown for centuries along roadsides seemingly too dry for their survival. Growth is very slow but the trees survive for many years under extremely adverse conditions.

Where soil depth, fertility, pH, and moisture conditions are adequate, the growth of Aigeiros poplars on such upland sites is as good as on bottom lands. And conversely, on bottom-land soils of low fertility, low pH, or poor aeration, the poplars grow as poorly as on infertile or dry upland soils. European poplar plantations clearly demonstrate that the limiting soil factors for profitable poplar culture are depth, fertility, pH, moisture, and aeration.

Soil depth

The Aigeiros poplars require soils 2 to 3 feet deep or more for their maximum growth. In general, the minimum depth on which reasonably satisfactory growth was observed in European plantations was approximately 18 inches. There were occasional exceptions, along rivers where the water was reported to be rich in nutrients, where growth was very good on such relatively shallow soils. The soil depth available for the growth of poplars may be limited by bedrock, hardpan, heavy clay, or stagnant ground water. Moving, well-aerated ground water in river bottoms or on slopes does not limit soil depth for the growth of poplars.

Soil fertility

Research on the fertility requirements of poplars has been started in many places, but the work is too recent to provide an accurate measure of the fertility level required for profitable poplar culture. Observations on many European plantations indicate that the most profitable growth rate requires a level of soil fertility equal to that needed to grow a profitable corn crop in the United States. The excellent growth of poplars on river sandbars does not contradict their need for fertile soils. Such trees are utilizing the fertility of the river water.

The effect that soil fertility has on growth rate of poplars was strikingly apparent in a 7-year-old plantation of clone *Populus* 'I–214' in the Po Valley in Italy. This planting was established on a river bottom site with a soil gradient, along the rows, from fertile sandy silt to coarse gravel. Here the same clone varied from 15 inches d. b. h. on the fertile silt to 6 or 7 inches d. b. h. on the less fertile gravel. There apparently was not sufficient variation in pH, permeability, and depth of the water table on this relatively flat site to account for these growth differences.

Soil pH

Liming experiments on a well-drained upland site at the Forschungsstelle für Flurholzanbau in Reinbek, Germany, have demonstrated that on their soils the critical pH for poplar is 4.5 to 5.0. These experiments were based on the growth of nursery stock on land cleared of a beech forest where the pH was originally 3.5 to 3.8. Below pH 4.5, growth was extremely poor; at pH 5.0 growth was fair: but for maximum growth the site required liming to approximately pH 6.0.

Low pH is seldom a limiting factor in the commercial poplar regions of Europe because most of these river-bottom soils are above pH 5.5. The threshold of pH 4.5 to 5.0 is strongly indicated but not confirmed on the relatively few sites with low pH where poplar has been planted in Europe. Unfortunately, heavy soils and poor drainage complicate the interpretation of poor growth on practically all such acid sites.

For example, the clonal test plot of the Netherlands Land Reclamation Society near Zwolle is on polder land where the depth of the water table is kept constant at approximately 20 inches. The soil is a highly organic sandy clay (30 to 50 percent clay) on peat. The soil is 20 inches deep at one side of the test plot and grades to a depth of 12 inches at the other side. The pH varies from 4.2 to 5.2. Although the soil is considered moderately heavy, there appears to be little water movement and inadequate aeration. Growth of the certified Netherlands clones is extremely poor and all clones are infected by bacterial canker. On this site it was not possible to separate the effects of low pH and poor aeration.

Soil moisture and aeration

The Aigeiros poplars require a moist soil during the entire growing season, or a water table within reach of the roots. There are examples of good plantations on sites with light, relatively dry soils where the summer water table is reported to be 12 to 15 feet deep. On upland sites, the best growth was observed more often on medium heavy soils, apparently because their water-holding capacity is better than that of light-textured soils.

Soil aeration during the active growing season is essential. The Aigeiros poplars will grow well on sites that have high ground water if the topography and a light soil permit free water movement to provide aeration. Heavy impervious soils on wet sites, and light permeable soils with a stagnant water table that does not drop below 18 inches during the growing season, are unsuitable.

The Chautagne plantations near Aix-les-Bains, France, present an excellent example of the poor growth of poplar on wet sites where there is insufficient ground-water movement to provide adequate aeration. Approximately 1,700 acres of marshy land below the outlet of the lake were purchased by the government in the late 1930's, drained, and planted with poplar. The soils, pH 7.0 to 8.0, vary from deep silty clay alluvium to stratified layers of peat alternating with thin layers of clay and silt. The drainage ditches originally installed were too shallow and too widely spaced. Much of the area carried a heavy growth of reed (*Phragmites communis*) in 1952.

Three-year-old rooted trees were originally planted at 13- by 16.5-feet spacing without site preparation and without cultivation after planting. The stock was mostly *P.* 'Robusta' with a limited mixture of other cultivars of the 'Virginiana,' 'Regenerata,' and 'Serotina' types. The growth of all cultivars on the poorly drained silty clay soils has been unsatisfactory, and on the peat soils without site preparation most of the poplars have failed to survive. 'Robusta' has shown itself the most poorly adapted to these wet sites. Small "bleeding" spots on the stems, resembling trunk scab, were abundant in these plantations.

In 1950, three experimental plots were laid out in the 1939 plantation on deep, moderately heavy, silty clay, and were given the following treatments: (1) control, (2) calcium nitrate fertilizer applied annually, and (3) thinning to half the stand by cutting out every other tree. Annual increase in circumference 2 years after treatment indicated no significant benefit from fertilizer or thinning. This tends to confirm the conclusion that the principal deleterious factor in these plantations was insufficient soil aeration due to poor drainage.

It was planned to improve the drainage on these sites by increasing the number and depth of the drainage ditches. To make the peat soils (peat with alternating thin layers of silt and clay) more permeable and so to provide better drainage, these areas were to be plowed 2 to 3 feet deep and permitted to lie fallow for 2 years before planting.

There are examples in France, Germany, and the Low Countries of attempts to establish poplars on poorly drained sites by planting the trees on mounds from 6 to 10 feet in diameter and from 2 to 3 feet in height. The author did not see any plantings of this kind where the poplars continued to grow satisfactorily for more than 6 to 8 years. Mounding the soil in a continuous bank along the drainage ditches (Rabattenpflanzung) was observed to be effective on heavy soils where the drainage ditches were not more than 20 to 25 feet apart and the mounds were 1½ to 2 feet high and 4 to 6 feet wide.

Poplars grow poorly on the banks around the rice fields in northern Italy, which are flooded from April to September. Apparently these banks are not wide enough to provide sufficient well-aerated growing space for the poplar roots.

Site-indicator plants

The study of ground-vegetation types as indicators of site quality for the Aigeiros poplars has received considerable attention in Germany.[5] Many of the species recognized in Germany as indicators of good, medium, poor, or nonpoplar sites are native to the United States, have become naturalized or occur locally as adventive escapes that are not sufficiently widespread to be considered naturalized. With one exception (*Impatiens*), all species in the following lists are found in the United States.

Indicators of the best poplar sites.—The most productive bottomland sites are highly fertile, well drained, and well aerated, and

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[5] Hesmer, H. (editor). *Das pappelbuch.* Deut. Pappelverein. 304 pp., illus. Bonn. 1951.

Rüskamp, Gustav. *Lohnender pappelanbau.* 88 pp., illus. Dülmen (Westfalen). 1952.

the ground water is within easy reach of the poplar roots. They are usually characterized by the predominance and lush growth of several of the following species:

Circaea alpina L.	enchanters-nightshade	Indigenous
C. canadensis Hill	do.	Do.
Deschampsia caespitosa (L.) Beauv.	tufted hairgrass	Do.
Galium aparine L.	cleavers, goosegrass	Do.
Geum rivale L.	water or purple avens	Do.
G. urbanum L.	large-leaf avens	Adventive
Glechoma hederacea L.	gill-over-the-ground	Naturalized
Impatiens noli-tangere L.	touch-me-not, jewelweed	[6]
Stachys silvatica L.	hedge-nettle	Adventive
Urtica dioicia L.	stinging nettle	Naturalized
U. urens L.	dog nettle	Do.

[6] Listed because our native species are usually indicators of good poplar sites.

Indicators of good poplar sites.—Lowland meadows with a high water table are usually good poplar sites if some of the following species are abundant. These plants indicate good aeration and a summer water table at least 18 inches deep:

Ajuga reptans L.	creeping bugleweed	Naturalized
Athyrium filix-femina (L.) Roth	lady-fern	Indigenous
Circaea alpina L.	enchanters-nightshade	Do.
C. canadensis Hill	do.	Do.
Filipendula ulmaria (L.) Maxim.	queen-of-the-meadow	Adventive
Humulus lupulus L.	common hop	Indigenous
Lysimachia vulgaris L.	garden loosestrife	Naturalized
Myosotis scorpoides L.	forget-me-not	Do.
Ribes nigrum L.	European black currant	Adventive
Scutellaria galericulata L.	marsh scullcap	Indigenous
Solanum dulcamaria L.	bitter nightshade	Naturalized

On upland sites where the water table is below the effective reach of tree roots the following species are indicators of sufficient soil moisture and fertility for good poplar growth:

Circaea alpina L.	enchanters-nightshade	Indigenous
C. canadensis Hill	do.	Do.
Geum rivale L.	water or purple avens	Indigenous
G. urbanum L.	large-leaf avens	Adventive
Impatiens noli-tangere L.	touch-me-not, jewelweed	([6])
Lamium maculatum L.	spotted dead-nettle	Adventive
Stachys sylvatica L.	hedge-nettle	Do.
Stellaria holostea L.	greater stitchwort	Do.

[6] Listed because our native species are usually indicators of good poplar sites.

Loam to loamy-sand soils with deep ground water can be good poplar sites. Some loess-loam soils in northwestern Germany have produced exceptionally high yields of poplar. The following species indicate safe and productive sites:

Asperula odorata L.	sweet woodruff	Adventive
Galium sylvaticum L.	baby-breath, Scotch-mist	Do.
Stellaria holostea L.	greater stitchwort	Do.

Indicators of poor poplar sites.—Where loam to loamy-sands with deep ground water are poorer in structure and deficient in bases they are less suitable for poplar. Sites that will support only moderate to poor growth of poplar are characterized by a decrease in the above plants and increasing predominance of the following species:

Anthoxanthum odoratum L.	sweet vernalgrass	Naturalized
Holcus lanatus L.	velvetgrass	Do.
H. mollis L.	German velvetgrass	Adventive
Lonicera periclymenum L.	woodbine	Do.
Rubus ideaus L.	raspberry	Naturalized

Sites not suited for poplar.—Common occurrence of the following plants indicates sites that should not be planted to poplar. These plants indicate that the soil is too wet for adequate aeration because of a high stagnant water table, is too heavy and poorly drained, or is deficient in bases:

Carex acutiformis Ehrh.	sedge	Naturalized
Corynephorus canescens (L.) Beauv.	clubawngrass	Do.
Deschampsia flexuosa (L.) Trin.	wavy hairgrass	Indigenous
Eriophorum angustifolium Honckeny	narrow-leaf cottongrass	Do.
Festuca ovina L.	sheep fescue	Naturalized
Iris pseudacorus L.	yellow iris	Adventive
Milium effusum L.	millet-grass	Indigenous
Molinia caerulea Moench	moorgrass	Adventive
Phalaris arundinacea L.	reed canary-grass	Indigenous
Phragmites communis Trin.	common reed	Do.
Pteridium aquilinum (L.) Kuhn	bracken	Do.
Sphagnum acutifolium Ehrh.	sphagnum moss	Do.
S. cuspidatum Ehrh.	do.	Do.
Vaccinium myrtillus L.	whortleberry	Do.
V. vitis-idaea L.	mountain-cranberry	Do.

Leuce Poplars

The natural range of the European aspen (*P. tremula*) extends from Italy to northern Sweden, and there is evidence for the existence of races that may differ in their site requirements. The variation between northern and southern races in their response to differences in day length is particularly evident.

Aspen has long been an important component of the native forests for the Scandinavian match industry; yet it is only in recent years that aspen has begun to be planted in these northern countries. Plantation culture of aspen in Europe is still in the experimental stage. Since they can be grown commercially on sites that are too dry or too infertile for profitable culture of Aigeiros poplars, the aspens and their hybrids (including *P.* × *canescens* types) can be used to extend the range of profitable poplar culture. It must be noted, however, that plantations of the so-called "Polish" aspens in Holland and of the hybrid aspens (*tremula* × *tremuloides*) in Denmark indicate that even aspens will make their maximum growth on fertile, moist, but well-drained soils.

The *P.* × *canescens* or gray poplars (the *alba* × *tremula* complex) have been planted throughout Europe, usually as shade trees and windbreaks but seldom for timber production. In northwestern Germany they are preferred for planting near the coast because they can withstand a coastal climate with its wind and salt spray better than other poplars.

The natural range of *P. alba* has not been clearly defined. In localities in southern Europe where the white poplar is abundant and reproduces naturally, it reaches its best development on well-drained fertile bottom lands. Its optimum site requirements are apparently similar to those described for the Aigeiros poplars. Although the white poplar has been widely planted in Europe as a shade and ornamental tree on upland sites, there is no conclusive evidence that for profitable culture it is better adapted to drier or poorer soils than the European black poplar (*P. nigra*).

Significance for the United States

The natural distribution of the European and American Aigeiros poplars along river courses may have been responsible for the traditional notion that these poplars are exclusively adapted to bottom-land sites. This is true for natural regeneration by seed. Bare soil, free from sod and weed growth, and continuous moisture at the soil surface for several weeks at the time of seed germination, are essential for germination and seedling survival. Such conditions are most frequent on river bottom lands that are subject to annual or periodic overflow. They are too infrequent on upland sites to bring the poplars out of the river valleys by natural seeding. But poplar culture is not based on the uncertainty of seed reproduction in such situations; plantations are established with rooted trees or cuttings.

The Aigeiros poplars can be grown commercially on upland soils, but research is needed to provide practical criteria for evaluating sites suitable for their profitable growth in the United States. Such research should include a study of the reliability of common native plants as indicators of site quality.

The guidelines outlined in this section, based on European experience and research, can be safely applied to poplar planting until more specific information is available in the United States. It is safe to assume that most of the indicator plants associated with good and poor poplar sites in Europe would be indicative of approximately the same biological conditions, favorable or unfavorable to poplar, when grown in this country. It is possible, however, that some of these plants may not require the same depth of soil necessary for the best growth of hybrid poplar. Soil depth should be checked on all sites considered for poplar culture.

The European aspen has much the same site requirements as our American aspens. The American species can be used to extend profitable poplar culture in the United States to sites that are not suited for commercial plantations of Aigeiros poplars.

We have only preliminary evidence of racial variation in American poplar species. The evidence of considerable racial differences in the European species indicates the immediate need for intensive racial studies of our important native poplars.

The gray poplars (*alba* × *tremula*) might be used to excellent advantage in breeding for rapid-growing hybrids adaptable to drier upland sites. Crosses between the European *alba* and our American aspens also offer possibilities for obtaining types with hybrid vigor that would grow on drier and less fertile sites than Aigeiros hybrids require.

With the exception of batture lands of our largest rivers, fertile, well-drained soil for profitable poplar culture is seldom available in large contiguous areas. But on almost every farm there is some acreage that meets the requirements for excellent poplar growth and that is not being used for agricultural purposes. For example, poplars can be grown around barns and farm buildings; they can serve as shade trees and can eventually be cut for timber. With a succession of younger trees to replace those that are harvested, such plantings would have a continuous aesthetic and monetary value. Farm roads and fence rows offer areas for the growing of poplar. Fertile farmland that is too wet in the spring for cultivation, but is sufficiently well drained during the growing season, is normally used for hay or grazing. Planted to widely spaced poplars, such land could produce both timber and grass.

OUTPLANTING

Site Preparation

Intensive soil preparation is commonly practiced only where the land is cropped between poplar rotations or intercropped during the early years after the poplars are planted. Under such conditions the land is plowed, harrowed, and fertilized for whatever crops that are to be grown.

Alder- or brush-covered sites are always cleared before planting, either completely or in wide strips; but there is usually no additional soil preparation. A typical example was observed in France where a match company had cleared an area carrying a dense stand of alder in strips 10 to 13 feet wide on 26.5 feet centers, and had planted the poplars 26.5 feet apart through the centers of these strips. The strips will be weeded for several years by cutting the new alder sprouts. The alder between the strips will be cut for fuel after 5 years, and again after 15 years.

Planting Stock

Unrooted cuttings and sets

The use of unrooted cuttings for outplanting was not observed in any of the poplar regions in Europe. Cuttings are the cheapest type of planting stock, but they require site preparation equivalent to plowing and harrowing and they must be cultivated for at least 1 year. They could be used successfully where the poplars are established on land on which cultivated crops are interplanted for several years. No convincing reason was advanced anywhere in Europe for the exclusive use of sets or rooted trees under such conditions.

Sets are used to only a limited extent in most of Europe, but there are a few localities where they are planted almost exclusively. Sets are always pruned clean of even the smallest side branches.

They are outplanted almost exclusively on sites that have a high water table because it is generally considered essential that the butts be in the ground water. Nevertheless, the author saw a few examples of excellent results with 1- and even 2-year-old sets planted above the water table in soil that was rather wet until early summer.

The oldest clonal tests of the Netherlands Land Reclamation Society were established with one row of rooted trees and one row of sets for each clone. After 20 years there was practically no difference in form or growth rate between the trees derived from these different planting stocks.

In Germany, in Westphalia and the Lower Rhine, 3- and 4-year-old sets, 10 to 15 feet long from pollarded trees, have been used with good results. In the Rhine bottom lands of Baden, sets are being used with excellent results on favorable sites. Here 1- or 2-year-old sets 6 to 8 feet long are used; they are peeled a few inches at the base, and are planted deep enough so that the peeled butt is in the ground water. On the steep face of a strip-mine bank in Horrem, Dr. Müller planted sets to a depth of about 3 feet in the winter of 1950-51. For this sandy fill, survival at the end of the first year was excellent and the growth was fair (fig. 17).

The Forest Inspector for the region of Venice, Italy, told the author that in the spring of 1952 he planted branches (sets) from large trees to a depth of more than 12 feet to reach ground water on a dune site where rooted trees had failed repeatedly. He said that in September of the same year survival of these long sets was better than 90 percent.

In the region of Hostalrich, Spain, the use of sets (plantones) is traditional and apparently the general practice. They are always planted with the butts in the ground water, and survival and growth is excellent. *Populus alba,* occasionally planted in this region, is also grown from sets.

There are some excellent 30- to 35-year-old poplars with breast-high diameters up to 23 inches on the Pratt Estate in England that were said to have been planted as sets in openings in a bottom-land hardwood stand.

Rooted planting stock

Rooted trees are most generally used for outplanting in all European countries, but there is considerable diversity in the age and size of planting stock even in the same locality. Trees less than 5 feet high are seldom used: the demand is predominantly for larger sizes. Rooted stock is of two types: rooted cuttings and stumped trees. Both are graded and priced either by height or by circumference. The grades commonly used in Italy are 8 to 11 cm. (3 to 4.2 inches), 11 to 15 cm. (4.2 to 5.8 inches), and more than 15 cm. in circumference at 1 meter (3.3 feet) above the ground.

Rooted cuttings.—Rooted cuttings are nursery-grown trees that have not been cut back to the ground, so root and top are therefore the same age. They are outplanted as 1-, 2-, and 3- and occasionally 4-year-old trees. In northern and middle Europe 2- and 3-year-old stock up to 12 feet high is most frequently used, although large 1-year-old rooted cuttings are planted with very good results on favorable sites.

For roadside and windbreak plantings the older 3-year and even 4-year trees have a better chance for survival because of their larger size and sturdier stems. In southern Europe, where poplars are grown on nursery soils of high fertility, 1-year-old rooted trees, 8 to 12 feet in height are used to some extent for outplanting; but, in Italy particularly, most planters prefer the larger, heavier-rooted, and stronger-stemmed 2- and 3-year stock.

Photo by R. MÜLLER

FIGURE 17.—One season's growth of unrooted sets on the steep face of a strip-mine bank in the lignite district west of Cologne, Germany.

Stumped trees.—Stumped trees are rooted cuttings that have been cut back to two or three buds at the end of the first year, root-pruned, replanted and grown 1 or 2 years longer in the nursery. The root is therefore 1 or 2 years older than the top. (See Nursery Practice, p. 33.) Stumped trees have been most extensively used in

Italy, and their use is recommended in England and is increasing in other countries.

In Baden, Germany, the State Forest Service has used stools from which cuttings are normally taken as stumped trees to fill failures in plantations. Roots 2 to 5 years old with 1-year shoots are used, depending on the age of the plantation where fill-ins are required.

Pruning of planting stock

Planting stock is generally top- and root-pruned at the nursery. Depending on the size of the tree, roots are ordinarily cut back to 6- to 12-inch lengths. The degree of top-pruning (described under Nursery Practice) varies from none to complete removal of all side branches and sometimes even to cutting back of the leader.

Observations in many young plantations indicate that severe pruning may retard early growth. The first- and second-year growth of some 20 clones that were planted without pruning in the poplar arboretum near Koblenz was remarkably better than that observed on any heavily pruned stock established by comparable methods on similar sites in central and northern Europe.

Spacing

The spacing of poplars in rows and particularly in plantations is one of the most controversial aspects of European poplar culture. The traditional conviction is that the cultivated poplars are biologically unlike forest trees in that they cannot be grown in forest stands. But from a biologist's standpoint it is poplar culture that differs basically from general forest practice because poplar plantations are usually monoclonal stands composed of genetically identical ramets. There is thus a complete lack of the genotypic variation that exists in a natural stand or in a plantation established with seedlings.

Row spacing

Poplars, except the aspens, are extensively planted in single or double rows along public roads, farm roads, field boundaries, and fence rows. Double-row planting, two relatively close-spaced rows with the trees staggered in the adjacent rows, is less common than single rows.

Many experts and growers recommend that poplars planted in single or double rows should be spaced widely enough apart to avoid contact between mature crowns, or should be thinned as soon as the crowns touch. This criterion permits very close planting of narrow-crowned trees such as the Lombardy poplar, and necessitates relatively wide spacing of broad-crowned types. This practice tends to ignore completely the probability of deleterious root interactions between adajacent trees. There is evidence that the growth of poplar may be more seriously influenced by the soil volume available for free development of the individual root system than by top competition for light.

Row plantings can be found in Europe at almost every conceivable spacing from practically open-grown trees to spacings as close as 3 feet. There is little evidence of seriously retarded growth vigor where closely spaced row plantings are on deep, fertile soil and the tree roots are not limited in their lateral extension by deep ditches or other obstructions. Retarded growth was observed in closely spaced row plantings on shallow soils—where depth was limited by the water table or infertile or impervious subsoil—and where the sidewise extension of roots was curtailed by water-filled ditches.

Close spacing of trees in rows, or double rows, does have a serious effect on log quality for lumber and veneer. Insufficient room for normal concentric crown development results in leaning trees that produce crooked logs with eccentric boles. Such trees may also have a large amount of tension wood, which further degrades their value for high-quality lumber and veneer.

Plantation spacing

There is relatively little argument about the spacing of aspens. They are traditionally considered to be forest trees than can be grown at relatively close spacing. The biological factors that affect closely spaced monoclonal plantations are not operative in aspen plantings because seedling stock is generally used for outplanting. In the Scandinavian countries the aspen hybrids are usually spaced approximately 10 by 10 feet with alder or other filler trees. The somewhat higher cost of the hybrid planting stock apparently has a bearing on plantation spacing.

Throughout Europe, plantations of Aigeiros poplars and their hybrids are established at almost every conceivable spacing, including square spacings of 5.0, 6.6, 9.8, 13.3, 16.4, 19.7, 23 and 26.3 feet, and rectangular spacings of 13.3 by 32.8 feet, 23 by 32.8 feet and 26.3 by 29.5 feet. There is wide divergence of opinion on plantation spacing, at the local as well as at the international level. Unfortunately the arguments for close or wide spacing are often seriously confused by failure to distinguish between the biological and economic aspects of the problem. Present planting distances are largely the product of tradition and of observations on the growth of poplar cultivars that are assumed to be genetically identical and are growing on sites that are assumed to be similar.

There are two rather adamant schools of thought on planting distance in Germany. The advocates of wide spacing (20 by 20 feet to 26 by 26 feet) argue that poplars should be planted at their final (crop-tree) spacing to produce high-quality logs for veneer and lumber, and pulpwood from the tops and branches. Such wide planting eliminates the hazard of stand degradation because of delayed thinning due to negligence, labor shortage, or lack of good markets for pulpwood. Spacing as close as 6.5 by 6.5 feet, with early and regular thinning, is urged by those interested in pulpwood production; but the relatively high establishment costs and the low value of the first thinnings for pulpwood tend to discourage such practice. Studies in The Netherlands indicate that the pulpwood value of a 6- to 8-year-old tree is less than the per-tree establishment costs.

The most commonly recommended spacings in Europe are from 20 by 20 feet to 26.5 by 26.5 feet. In Italy, there is increasing use of the 25.5-feet triangular spacing (trees staggered in adjacent rows) recommended by Prof. Piccarolo, and this spacing is gaining in favor in some other countries. Although the demand for pulpwood was the principal stimulus for the early interest in poplar culture in Italy, the expansion of markets for other uses has affected the trend in spacing. In 10 to 14 years, with wide spacing, the Italian grower can produce trees with 70 to 75 percent of their merchantable volume salable for lumber and veneer, and 25 to 30 percent marketable as pulpwood.

In Austria, Dr. Wettstein recommends spacing the poplars 13 by 20 feet where they are planted in mixture with other light-demanding species. For pure plantings of poplars where there is a pulpwood market, he is considering 6.6 by 6.6 feet, with early thinnings to 13 by 13 feet and a final spacing of 26 by 26 feet. Thinnings in 6-year-old experimental plantations established at the 6.6- by 6.6-feet spacing have yielded 1,120 cubic feet per acre of pulpwood, approximately 12 cords.

In widely separated parts of Europe, spacing 16.4- by 16.4-feet has given excellent yields without thinning. In Baden, Dr. Bauer recommends this spacing with filler trees at the same interval. The recommendation is justified by past experience; this planting distance with fillers has been widely practiced in the bottom lands of Baden for many years. The 16.4- by 16.4-feet spacing has also been in general use in southeastern Spain, where the plantations are intercropped during the first 4 or 5 years. The recommended 15- by 15-feet planting distance in England is not based on firm local experience, but it falls within this middle spacing range.

Planting

There is more agreement on planting methods than on almost any other aspect of European poplar culture. Correct and careful planting is strongly emphasized everywhere. Depending on the size of the stock, planting holes are made 16 inches to 3 feet in diameter or 16 to 24 inches square, and 16 to 24 inches in depth. The use of tractor-mounted soil augers to dig planting holes 12 to 24 inches in diameter is being tested in several countries. They are highly efficient where the soil is not too rocky.

Use of organic or mineral fertilizers, mixed with the soil in the planting hole, is strongly recommended but is not yet common practice. It depends on the fertility of the soil and the affluence of the landowner. Fertilizer is usually applied as a "small" or "large" handful. On land that is intercropped for the first few years, the fertilizer is applied as a part of the crop culture. Manure or mineral fertilizers are seldom used where poplar plantations are on meadowland that is cut for hay or used for grazing. Such lands are most often river bottoms subject to annual overflow, where fertilization is seldom necessary.

Some poplar foresters recommend annual or periodic fertilization on sandy soils of low fertility. Research on this problem has been started in Germany, but there is at present very little information to guide the grower as to the kind and quantity of fertilizer required.

Liming is considered essential for soils with a low pH and is widely practiced in some regions. The lime is broadcast, applied around the tree, or mixed with the planting soil.

In many places where large planting stock is used, and particularly where newly planted trees are subject to strong winds, soil is heaped in a conical mound around the tree. The height and diameter of such mounds varies from place to place. Conical mounds 3 to 4 feet in diameter and 1 foot high at the tree are recommended in England. Poplars planted on sites exposed to high winds are mounded somewhat higher.

First-Year Plantation Care

The intensity of protection and culture during the first year after planting varies from none to seemingly unnecessary extremes. On windy sites poplars are sometimes individually staked. Where leaders are broken, a lateral may be tied upright to a splint to avoid crook.

Where necessary, the poplars are protected against rabbits by guards made of roofing paper, asphalt paper, or hardware cloth. Occasionally barbed wire on 3 posts, or even rail fences 5 to 6 feet square, are built around each tree for protection against deer and cattle. The costs are said to be justified by the income derived from hunting leases or grazing values.

Cultivation

All poplar experts now agree that grass and weeds inhibit the growth of newly planted poplars. The most intensive cultivation is applied to plantations on land that is used for agricultural crops during the first 3 to 5 years after planting. This is the most common practice in Italy and Spain (fig. 18) and is practiced to some extent in France—particularly in the south, in the lower Rhine Valley in Germany, and in Belgium and The Netherlands. The stumps are removed after a poplar rotation and the land may be replanted immediately to poplar or it may be used several years, sometimes as much as 5 to 10 years, for agricultural crops before poplars are planted again.

On some estates in the Po Valley, agricultural crops are often interplanted primarily to cover the establishment, fertilizer, and early cultural costs of the plantation. After 3 to 5 years, when the yield of crops under a poplar plantation is reduced approximately 50 percent, the land is put into grass for hay and pasture. Such clean culture and fertilization results in extremely vigorous young plantations and produces high yields on 12- to 20-year rotations in southern Europe.

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FIGURE 18.—Newly planted poplars in the Genil River Valley near Granada, Spain. Agricultural crops will be grown for several years under the poplars.

On noncultivated land, or where the land is also used for hay and grazing, only the most progressive growers hand-cultivate an area 3 to 6 feet in diameter around each tree during the first year or two after planting. Examination of the stumps of many felled poplars in the Parisian Basin, where they are generally grown on grasslands, showed 3 to 5 extremely narrow rings immediately after planting.

The most important single factor responsible for the retarded growth of the Parisian Basin poplars is undoubtedly the deleterious effect of sod on newly planted trees. In view of the value of poplar timber and the susceptibility of poorly growing poplars to disease, the saving in labor costs and the small amount of grass that would be lost by cultivation or mulching around each tree is not adequate compensation for such drastic curtailment of early growth.

Mulching

A mulch heavy enough to eliminate weeds and grass is fully as effective as cultivation. At Mykinge, Sweden, a 10-year-old experimental plantation of very poorly growing Aigeiros hybrids on a brushy and soddy site was heavily mulched with straw in 1950. The effect of the late mulch was already apparent in 1952. The growth rate had increased and the foliage color was much improved.

It is not necessary to mulch the entire plantation area. In Great Britain, Peace and Jobling have found a marked early growth response, on almost every kind of site, to mulching an area 3 to 4 feet in diameter around each tree. Mulching individual trees to maintain growth after planting is an old practice but it has never become general even in restricted localities. It is now recommended in Great Britain and is beginning to be more widely recommended and used on the Continent.

Significance for the United States

Fitted land, plowed and harrowed as for agricultural crops, is necessary for plantation establishment with unrooted cuttings, and it will also provide maximum growth conditions where sets or rooted trees are used. Normally such site preparation is possible only on cleared land.

On cut-over forest land or on land too brushy for plowing, minimum site preparation will require cutting the brush at least 4 to 6 feet around each planted poplar. Strips are most desirable, and where these are made by machine they should be at least 10 feet wide. If possible, the planting strips should be rototilled or treated with other machinery, such as a weed-hog or a heavy disk, to break up the root mat.

There is no sound justification in the European plantings, except those on the most windy sites, for severe pruning to whips—with or without short lateral stubs. The stubs actually provide entry for such diseases as *Valsa* and *Dothichiza*. Well-rooted unpruned trees have survived excellently and have made very good growth with careful planting on good sites.

One-year-old rooted cuttings should be planted in holes 12 to 18 inches in diameter, depending on the size of the roots, and 15 to 18 inches in depth. For 2+1 stumped trees the holes should not be less than 18 inches in diameter so that the roots need not be cut back too severely.

The application of approximately ½ to 1 pound of commercial fertilizer per tree, mixed with the soil at the time of planting, will greatly stimulate early growth. How much benefit may be derived from liming a short distance around each tree on soils with a low pH is still questionable. Where the soil pH is between 5.0 and 6.0, broadcast liming to bring the pH up to at least 6.0—and preferably to 6.5—will have a more lasting effect.

Mounding is beneficial where the newly planted trees are subjected to strong winds, but its value under less exposed conditions needs further investigation. Roots usually form in these mounds and if the mounds are eventually washed away these roots become exposed and may be subject to injury and infection by fungi.

Dormant unrooted cuttings have been used successfully to establish plantations of hybrid poplars by the U. S. Forest Service's Northeastern Forest Experiment Station. But it cannot be too strongly emphasized that they will be successful only on tilled land, and that they must be kept free of grass and weeds at least during the first year after planting.

The use of unrooted sets for outplanting on sites that have a high water table or on soils that remain moist all summer deserves wider testing. For best results, the sets should be vigorous shoots not less than 6 feet long, and they should be planted at least 24 inches deep, preferably with the butts in the ground water. One-year-old whips are preferred but 2-year-old stems are being used successfully in Europe.

Rooted trees provide the greatest assurance of successful establishment where the land cannot be plowed and harrowed or given adequate soil preparation. One-year-old rooted cuttings are suitable for outplanting if they are 5 feet or more in height. Two + one stumped trees that have been dug and root-pruned at the end of their first growing season in the nursery will give better results on difficult sites than 1-year-old rooted cuttings.

Pruning to half the height of the tree has proved best for successful establishment and vigorous early growth. Progressive pruning during the last year in the nursery has the important advantage of smaller branch wounds and complete healing before the trees are outplanted. This can be recommended as the best practice on the basis of European experience.

In row plantings, where no thinnings are contemplated, hybrid poplars should be spaced 15 to 25 feet apart. Where the tree roots can spread laterally, the spacing depends mainly on the crown width of the clone and the size to which the trees are to be grown. Twenty-five feet is a safe distance if these factors are not known at the time of planting.

The traditional European notion that poplars cannot be grown in closely spaced forest stands is based on experience with single-clone plantations. Monoclonal plantings at close spacing deteriorate rapidly if they are not thinned before the growth rate is seriously retarded by the density of the stand. Single-clone plantations can be successfully matured with an original spacing of 4 by 4 feet, *provided they are thinned early and frequently*. Such close spacing is desirable to provide early ground cover where plantations are established with cuttings. Close spacing is also useful on low sites that are subject to overflow and where it is advisable to speed up the deposition of silt.

Plantation spacing of 15 by 15 feet, or thinning to this final spacing, can be recommended as biologically sound for the culture of Aigeiros hybrids on good soils. Mixtures of hybrids can be established at closer spacing without undue risk of stand retrogression due to delayed thinning. There is no evidence in Europe about the growth and development of random mixtures of many clones in closely spaced plantations. The possibilities of clonal mixtures are discussed under "Management and Silviculture."

If dormant cuttings are used for the establishment of a plantation, the plantation *must* be kept free of weeds during the first year by machine or hand cultivation. For satisfactory early growth it is also necessary to keep a weed-free area, 4 to 6 feet in diameter, around rooted trees or sets during at least 1 and preferably 2 years. The deleterious effect of grass and weeds on newly planted poplars may continue for 4 to 5 years depending on the fertility of the site and the depth of the soil. The grass and weeds may be eliminated by cultivation or by applying a heavy mulch, such as hay, straw, sawdust, or wood chips. Mulched trees should be fertilized.

Site preparation on cut-over forest and brush land will be possible at reasonable cost with machinery (brush cutters, rototillers) developed in recent years. Where such machinery is not available or is too expensive, site preparation can be reduced to cutting the brush for a distance of 6 feet around each widely spaced planting hole.

Cuttings provide the cheapest type of planting stock but require the most intensive site preparation and cultivation after planting. They can be cultivated with minimum expense if they are check-planted to permit machine cultivation in two directions. The use of cuttings can be recommended for the farmer or landowner who has machinery available for fitting the land and cultivating the plantation during the first year.

Sets are cheaper than rooted trees but their use is limited to sites that have abundant moisture during the entire growing season. The cheapest rooted stock will be 1-year-old cuttings. The cost of 2+1 or even 3+1 stumped trees should not be excessive in nurseries that are equipped with tree diggers designed to handle large nursery trees.

The most profitable plantation spacing will depend on many factors; and among these the markets available to the grower must be considered. At the present time thinnings are a low-value product salable primarily to the cellulose industry, and therefore close planting usually will be advisable only where a market for such wood is available.

Close spacing will add relatively little to the cost of establishing plantations with cuttings; but the cost, or the time required, for thinning young plantations must be considered. A spacing of 8 by 8 feet should eliminate the need for thinning before a plantation of mixed clones reaches merchantable pulpwood size.

Since the production of high-quality logs for veneer or lumber requires proper pruning even in forest stands, plantations for such products can be established at a final crop-tree spacing of 15 by 15 feet. Where the land is to be used for poplars and grass, the distance should be increased to 25 by 25 feet.

The cost of planting rooted trees must be considered in deciding the plantation spacing distances. If a soil auger mounted on a tractor is available for digging the holes, the cost of planting 100 to 200 trees per acre would not be excessive. The cost of ½ to 1 pound of fertilizer per tree, and the cost of liming, is a reasonable establishment cost for hybrid poplar.

MANAGEMENT AND SILVICULTURE

Leuce Poplars

Management

The European aspen is normally associated with other broadleaf and coniferous species; but, like the American aspen, it also grows in pure stands after catastrophe, particularly fire. No instances of aspen management were observed in western continental Europe. In the Scandinavian countries aspen is generally managed extensively, seldom intensively, in mixture with spruce, birch, or both. Investigations and publications on the silviculture and management of native aspen stands have been sponsored by the match industry in Norway and Sweden, and interest in more intensive management has increased greatly in recent years. Aspen is considered a liability by some foresters managing Scotch pine in Scandinavia because it is the alternate host of *Melampsora pinitorqua.* This rust disease can cause high mortality in Scotch pine seedlings and serious crooks in the leaders of older trees.

In spruce-aspen stands in Sweden and Norway the aspen is maintained in the stand during the later years of the longer conifer rotation as scattered codominants or intermediates, or through a succession of root suckers that replace trees lost through suppression. Any merchantable aspens in the spruce-aspen stand are harvested with the conifers. In the second rotation, the aspen becomes the dominant species by natural regeneration mostly from root sprouts. When there is advanced spruce reproduction or seed trees in these stands, relatively little sivicultural work is required to develop a fully stocked spruce understory for the spruce-aspen third rotation.

Managed stands of European white poplar were not observed or mentioned in western Europe. This poplar forms such dense natural stands by prolific root suckering in the river valleys of southern France that it is difficult to estimate the extent of regeneration by seed. In one such stand the largest trees were 12 to 15 years old, 10 to 13 inches in d. b. h., and 60 to 70 feet in total height. Stem form resulting from early natural pruning was excellent.

Thinning

The natural aspen stands in Scandinavia, both pure and in mixture, are maintained at a relatively high density by light thinnings started soon after the aspen has reached merchantable size. Although there is little uniformity in the length of the cutting (thinning) cycle, the following tabulation,[7] based on relatively even-aged, naturally regenerated stands in Norway and Sweden, indicates the general effect of intermediate cuttings on the density of the aspen:

		Trees per acre		
Age (years):	*Stands (number)*	*Aspen (number)*	*Spruce, birch, or both (number)*	*Total (number)*
20	1	680	93	773
30–39	5	333	134	467
40–49	6	230	142	372
51–56	3	161	301	462

[7] Data derived from the following reports:

Anonymous. *Sätra bruk.* Särtryck ur programmet för Svenska Skogsvardsföreningens 26:te exkursion till Skaraborgs län 9–11 juni 1938. 16 pp., illus. Stockholm. 1938.

Barth, Agnar. *Aspen. Dens kultur og behandling for kvalitetsproduksjon.* Fra ingeniør F. H. Frølichs fond for aspeskogbrukets fremme Nr. 1. 87 pp., illus. Oslo. 1942.

The high average of "other" trees in the three 51- to 56-year-old stands represents higher original stocking. The 20-year-old stand was a mixture of aspen and birch. Mixed stands of aspen-spruce or aspen-spruce-birch normally carry a higher proportion of the associated species.

Aigeiros Poplars

Management in forest stands

It is the traditional concept in Europe that Aigeiros poplars cannot be managed in typical forest stands. There is abundant evidence that single-clone plantations of the commercially planted poplars cannot be matured profitably without careful and regular thinning if planted closer than 16 by 16 feet on the best sites, or closer than 26 by 26 feet on average sites.

There is no evidence in Europe on management of a random mixture of many poplar clones of different parentages in closely spaced (forest) plantations. But there are many examples of successful management of poplars in bottom-land hardwood forests.

In Schleswig-Holstein, Germany, hybrid poplars were planted into openings in a young beech-oak stand on an excellent well-drained alluvial soil. The poplars at 56 years of age averaged 20 to 21 inches in d. b. h. (maximum 30 inches) and 100 to 110 feet in total height. The peeled volume of the largest trees was estimated to exceed 200 cubic feet. The trees were clean boled for 40 to 60 feet—evidence of an early and continuously dense stand. On the Rhine bottom lands in Baden the highest quality and most profitable poplar stumpage is grown in mixed forest stands with native hardwoods.

The poplars near Yvonaud, Switzerland, are in mixed stands with alder and other native bottom-land species. At 50 to 60 years the average height of the poplars is more than 100 feet with a reported volume (poplar) of more than 9,000 cubic feet per acre. A poplar-birch mixture approximately 50 years old in the same locality showed similarly excellent growth of the poplars. The local foresters were not certain about the history of the birch, which was younger than the poplar. It may have been interplanted later, or it may be sprout regeneration from birch planted with the poplar. In the community forest of Noville, 2-year-old rooted poplars were successfully established in openings left by removal of mature oaks.

Poplars have also been used to convert coppice to high forest. In France for example, *Populus* 'Robusta' and 'Serotina' had been planted in strips cut through an old coppice stand of oak, beech, hornbeam, and other species on a silty sand in which the water table was reported to vary in depth from 2 to 3 feet. After 25 years the original coppice species had disappeared almost completely under the poplar canopy.

Near Emendingen, Germany, hybrid poplars were planted into small openings in a bottom-land stand containing ash up to 43 years old, oak up to 90 years old, and described as coppice with standards. The poplars, at 32 years, had grown up through the ash and oak and stood 15 feet or more above the forest canopy. Growth of the poplars had been fairly vigorous: the best trees had reached 24 inches in d. b. h.

Filler trees

Filler trees are interplanted to fill the gaps between widely spaced poplars on land that is not utilized for intercropping, hay, or pasture. They are occasionally used in row plantings. The use of filler trees is most common in the Rhine Valley of Germany, less common in France and the Low Countries where poplar plantations are frequently used for hay and forage and more occasionally for crops.

Where there is a market for fuel or specialty uses such as turnings, the filler trees often provide an early monetary return from the plantation, and in some localities they are planted primarily for this reason. But filler trees perform a far more important biological function: they provide the early ground cover needed to eliminate grass and weeds and to protect and improve the forest floor. They also function as trainers for the widely spaced poplars. Good poplar silviculture requires early and regular pruning; and shading of the pruned poplar stems by the interplanted species prevents or at least greatly reduces epicormic branching, which is often prolific on trunks exposed to full sunlight.

Black alder (*Alnus glutinosa* (L.) Gaertn.) and white or speckled alder (*A. incana*) are most frequently used for interplanting (fig. 19). The black alder is usually preferred; but in plantations on strip-mine banks at Hermülheim, Germany, the white alder, interplanted at 5 by 5 feet, has been found superior to the black. Black alder is reported to grow more slowly on these mine banks and fails to provide a sufficiently early ground cover at this spacing. Alder, because of its nitrogen-fixing nodules, is generally considered beneficial to the growth of poplar; however, there is still some doubt on this point.

The Research Institute of the Germany Poplar Society, in Brühl, was investigating the possibilities of a number of species for interplanting with poplar. They planned to interplant a 3-year-old poplar plantation with blocks of red oak, beech, black alder, black locust, hornbeam (*Carpinus L.*), and linden at a 5 by 5 feet spacing in the spring of 1953.

At Albalate, Spain, a poplar plantation at 13- by 13-feet spacing was interplanted with *Pinus canariensis* (fig. 20). After 5 years the poplars averaged between 45 and 50 feet in height. They will be removed at commercial maturity, probably at the end of 12 years, to leave a coniferous stand.

Where there is a market for thinnings, filler trees (particularly alder) are generally planted at close spacings of 3.3 by 3.3 feet to 5 by 5 feet because the necessary early and repeated thinnings are profitable. Present practice on state lands in Baden is to plant alder, ash, and willow at the same spacing as the poplars, 16.5 by 16.5 feet, to eliminate the need for early thinnings. If these filler trees grow into the crowns of the poplars, they are headed back at heights of 20 to 35 feet.

Plantation cultivation, fertilization, and irrigation

Cultivation of the entire plantation area during the first 3 to 5 years after planting was observed only where the land is also used for agricultural crops. Hand cultivation for a distance of 3 to 5 feet around the young trees has been practiced by a few growers in all regions.

Established plantations are seldom fertilized except where crop fertilizers are applied annually during the early years of intercropping. Experiments on annual and periodic application of fertilizers and lime have been started on the strip-mine banks in northwestern Germany.

In Italy, southern France, and Spain, poplar plantations are regularly irrigated on sites where irrigation is required.

Photo by G. HOUTZAGERS

FIGURE 19.—Twenty-year-old plantation of *Populus* 'Marilandica,' at St. Oedenrode, The Netherlands, with coppice understory of alder.

Photo by FERNANDO JAIME FANLO

FIGURE 20.—A poplar plantation underplanted with *Pinus canariensis*, on river-bottom land at Albalate del Arzobispo (Teruel), Spain. The plantation was established in 1946; the photo was taken in October 1954.

Thinning

Single-clone plantations can seldom be retrieved successfully where vigor has been seriously reduced because of too close spacing; the occasional exceptions are on particularly excellent sites with deep soils. Degenerate plantations resulting from failure to thin at the proper time can be seen in every poplar region of Europe. It is primarily for this reason that poplar foresters recommend planting distances wide enough to eliminate the need for thinning.

Initial spacing and earliness and frequency of thinning depend on local land use and local market conditions. Close spacings, when the plantation is thinned frequently and at the proper time, provide a higher total yield per acre than wide spacings because they produce additional wood in small sizes from the thinnings without reducing the growth rate of crop trees. But close spacing is practical only where thinnings can produce a profit, and this is impossible in many parts of Europe. For example, in The Netherlands the estimated establishment cost per tree has been more than the pulpwood value of an 8-year-old tree, the maximum age at which a first thinning must normally be made in a 6.5- by 6.5-foot planting.

European recommendations for thinning poplar stands are derived from general observations, growth studies, and thinning experiments in plantations at various spacings. There is considerable difference of opinion because the comparisons have been based on commercial plantings established under different conditions. Differences due to clones carried under a single cultivar name, site and site preparation, condition of planting stock, year of planting, planting methods, culture, and other biological variables are hopelessly confounded in such comparisons. The most common basis for thinning recommendations is to thin without making overly large holes in the canopy as soon as the crowns touch.

The most generally accepted final spacing for mature stands is 20 by 20 feet to 26.4 by 26.4 feet. In the Po Valley, triangular spacing of 24.5 feet is said to provide the most profitable yields. On the deep alluvial soils along the Rhine in Baden, common practice has demonstrated that a final spacing of 16.5 by 16.5 feet is biologically and financially sound. The plantations spaced at 5 by 5 feet in southern Spain are usually thinned to half the number of stems at the middle of the 12- to 14-year rotation (fig. 21 and fig. 22).

There is also some difference of opinion about whether release should be uniform around the entire crown of the residual trees or whether release can be "sidewise." This is important where the original planting distance is relatively wide, because in regularly spaced plantations removal of every other tree—a 50-percent thinning—is necessary to free the residual crowns on all sides. With initial spacings of 10 by 10 feet or wider, a 50-percent thinning in a stand without filler trees opens the stand to an undesirable degree. A lighter thinning allows more gradual release but produces irregular openings that tend to produce crooked trunks and eccentric crowns. Both conditions may affect the wood quality through the formation of tension wood.

Mixed stands of poplar with filler trees or volunteer species usually receive silvicultural thinnings to favor the poplars as crop trees. In Baden the filler trees are often topped at 20 to 30 feet to eliminate interference with the poplar crowns and still maintain full ground cover and shade on the poplar trunks to prevent epicormic branching.

Pruning

Proper pruning is essential even in closed stands for production of the highest quality logs, particularly for veneer. Although there is general agreement on what constitutes good pruning, this is probably the most frequently mishandled cultural treatment. Local traditions and uses are often responsible for extremely bad pruning practices.

The severest pruning was encountered in the Mediterranean region of France and Italy, where the native black poplars, and

Photo by FERNANDO JAIME FANLO

FIGURE 21.—Nine-year-old poplar plantation at Bordils (Gerona), Spain.

particularly the Lombardy types, have been put to multiple uses for centuries. The poplars are usually pollarded high and pruned annually, or severely pruned as standards, for fagots; and during dry summers when forage is scarce, the leaves and young shoots may be stripped for fodder.

Pruning to small feather-duster tops every year or two, with abundant production of watersprouts, is common where fuel is scarce. Examples of 60- to 80-foot poplars stripped of all branches to the current year's leader are not uncommon. In the region of Naples, where pollarded poplars used as vine supports (fig. 23) also provide fuel and lumber, the most fertile soils support a 3- and occasionally a 4-story culture: poplars, grapes, sometimes dwarf fruit trees, and an annual crop or forage.

Examples of excessive pruning can be found also in other poplar-growing regions of continental Europe. Where there is a local shortage of fuel, the immediate need for fagots overshadows any enhanced timber value. Even where fagots are not a primary

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FIGURE 22.—Merchantable thinnings from 5- to 6-year-old plantations in the river-bottom plantings at Oliete, Spain.

consideration, farmers frequently prune too high if the poplars shade cultivated fields.

Local labor costs largely determine the frequency and carefulness of pruning on community and larger private ownerships. On such properties the best pruning practices were observed where there is a limited market for fagots and labor is cheap in relation to the value of high-quality poplar logs. Where there is a good market for fagots, pruning is often too severe.

Where labor costs are relatively high there is also a tendency toward less gradual pruning to provide some heavier branch wood for sale and to reduce the labor costs (fig. 24). Such delayed pruning leaves large knots that heal poorly; the removal of 6 to 10 whorls may reduce growth; and on widely spaced trees such pruning almost invariably induces a heavy crop of watersprouts. The result is often a decrease rather than an increase in log quality.

Pruning is done in many ways and with various tools. Climbing the trees and pruning with a hand ax is still a common practice, but the use of ladders and pole tools is increasing. Climbing irons are said to be commonly used in southern France—with detrimental effects on log quality.

The best pruning was observed in Germany, The Netherlands (fig. 25), Belgium, and northern France. The pruning practice of the Belgian Match Company is typical of good plantation management. Eight to 10 years after planting, the trees are pruned to one-third of their height, between 10 and 15 years to half their height, and after 15 years the pruned stem is increased to its final length of approximately two-thirds the total height.

The trees are not pruned regularly each year; for example, a 21-year-old plantation near Boussu was pruned for the fifth and the last time at 19 years. The crowns are also thinned to three or four branches per whorl between the 8th and 15th years to reduce the number of knots in the crown section and to "give the trees more air and light." Such crown thinning was not observed in other parts of Europe.

Photo by T. R. PEACE

FIGURE 23.—Poplars used for vine supports with continuous intercropping. Vicinity of Naples, Italy.

The following rules for pruning poplars, taken from *Das Pappelbuch* (see footnote 5, p. 40), would be accepted by most poplar foresters throughout Europe as biologically sound; but many would question the economic applicability where the work must be done by hired labor.

- Start pruning in the 5th year after planting.
- From 5 to 10 years prune one whorl of branches annually.
- From 11 to 30 years prune one whorl every 2 years. At 30 years the final crown length should be 60 percent of the tree height on open-grown trees, 40 to 50 percent on plantation trees.
- Prune live branches from early spring, but not at freezing temperatures, until mid-August. Remove new watersprouts in July. Dead branches can be pruned at any time.
- Use chisel tools only for live branches up to 1.2 inches in diameter; for larger branches use pole saws and handsaws.

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FIGURE 24.—Twenty-year-old *Populus* 'Robusta' along a farm road. The trees are spaced 26.5 feet apart in the rows. Here pruning has been delayed too long. The local market for fagots tempts the grower to delay this work until the branches are large enough to pay the pruning costs. Holtwick, Germany.

NED. HEIDEMIJ. (ARNHEM) photo

FIGURE 25.—A row planting of *Populus* 'Robusta' along a secondary road in The Netherlands. These trees have been properly pruned.

Rotation

The rotation for Aigeiros poplars and their hybrids is extremely variable—from 12 to 60 or 70 years. The shortest rotations are practiced where wood is scarce and the climate and soils favor rapid growth. In the Mediterranean region of Spain and in Italy, plantations are often harvested 12 to 15 years after planting, but rotations of 18 to 25 years are recommended as most profitable.

Longer rotations—20 to 40 years, depending primarily on the site and growth vigor of the clone—are the rule in France, Belgium, The Netherlands, and where wood is scarce in Germany. The Raverdeau Nursery in the Parisian Basin favors a 20-year rotation for *P.* 'Robusta,' which is said to grow rapidly in the first 10 to 15 years; and a longer rotation for 'Serotina,' which surpasses 'Robusta' after 20 years.

Where Aigeiros hybrids are grown in mixed forest stands with native species, particularly in Germany, the rotation may be as long as 70 years. Such management produces large, clear logs of highest value for sliced and rotary veneer.

Natural regeneration

The Aigeiros hybrids are always planted. Regeneration by seed is not practical because many cultivars are male and the seed of female hybrids would not breed true. But when the tree is cut, most if not all of these hybrids produce root suckers wherever the surface roots are exposed. Although scarification with a drag or disk harrow before logging would provide exposed roots for prolific root suckering, regeneration of plantations by this means has not been given serious consideration in Europe. The most probable reasons are that a dense stand of root suckers would make intercropping or grass culture on the land impossible, and delayed weeding of such a dense single-clone stand could result in serious deterioration.

Significance for the United States

The management of American aspen can be recommended only in regions where there is a market for the wood and where climate and soils are unsuited for the more rapid-growing Aigeiros or Tacamahaca hybrids, or for more valuable native species. The possibility of managing aspen in mixture with spruce or other native species, as the European aspen is managed in Scandinavia, deserves study on favorable sites in our northern regions.[8]

There is abundant evidence in Europe that a single clone should not be planted in closely spaced plantations unless there is positive assurance that thinnings will be made at the proper time. But there is no evidence to indicate that random mixtures of clones of different parentages cannot be grown at close spacing.

Dense natural seedling stands of our native cottonwood and of the European black poplar, where they still occur, mature into excellent forest stands by natural thinning. There is, however, a basic biological difference between such a seedling population in which every tree is a different genotype, and a monoclonal stand in which all trees are identical genotypes. With very rare exceptions every tree in a seedling stand differs more or less from its neighbors in some or all of its physiological characteristics. Such genetic variation is completely lacking in a monoclonal stand.

Forest plantations should be established with mixtures of carefully selected and tested clones of as many parentages as possible. In such a stand there will be little chance that an individual tree will be surrounded by ramets of the same clone.

There is one such example in Maine where approximately 13,000 hybrid seedlings, representing 95 parent combinations, were planted at 6- by 6-foot spacing in 1927 and 1928. The seedlings were grouped by parentage and the plantations were never thinned. Many parent combinations have been partially or completely eliminated by climate, disease, and insects; yet there are some parentages in which survival is still better than 70 percent. Here the hybrid plantation has followed the same developmental pattern as a seedling stand of a native species. There has been sufficient genotypic variation between seedlings of even the same

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[8] Study of mixed aspen-conifer stands, chiefly balsam fir, is under way in the Lake States. Personal communication from Paul O. Rudolf, U. S. Forest Service, Lake States Forest Expt. Sta. 1956.

parentages to produce a stand of dominant, intermediate, and suppressed trees. Close spacing has not resulted in the uniform loss of vigor in all individuals with resulting decadence of the entire stand.

The interplanting of filler trees in poplar plantations is biologically advantageous. The best filler species for use in the United States would depend on local climate and site conditions. Commercially important species should be used where the objective is conversion to the filler species or the development of a mixed stand. Volunteer native species should be retained as fillers, particularly on cut-over forest land and brushland. At present the planting of alder and other commercially inferior species as filler trees cannot be recommended.

Hybrid poplars can be grown in forest stands with native species. Mixed stands permit wide spacing of the poplars and silvicultural thinnings to favor them as crop trees. Such stands will require relatively less cultural investment—particularly in pruning, will reduce the risk by the inclusion of species known to be adapted to the environment, but will tend to increase the length of the poplar rotation.

Close spacing, with early and frequent thinnings, will produce higher total yields of cellulose per acre than wide spacing without thinning. Wide spacing will usually be advisable where there is no market for thinnings. Row plantings are preferred to plantations with close spacing for the production of cellulose and quality logs, because they are less susceptible to deterioration from delayed thinning.

Pruning methods recommended in Europe are biologically sound. Growth rate can be maintained by gradual reduction of crown length over a period of 10 to 20 years after the trees are well established—6 to 8 years after planting. The advantages of pruning while branches are small to get clean pruning cuts and of pruning early in the growing season to get rapid healing are obvious. The effectiveness of paints to eliminate the risk of infection of wounds after winter pruning should be investigated.

Annual pruning can be recommended for the farmer or landowner who can do this work in slack seasons. Since winter pruning fits best into the workload of the American farmer, it may be done during this season in spite of the risk of infection by diseases and wood stains. Pruning for high-quality veneer logs should be started when the trunk reaches 6 or 7 inches in diameter, the size of the core to which peeler logs are turned, rather than at a specific age. On this basis pruning would start at an earlier age on a good site than on a poor site, and earlier on fast-growing hybrids than on slow-growing types.

DISEASES

Trunk, Branch, and Twig Diseases

Bacterial canker

This is the most serious disease of poplars in northwestern Europe and Great Britain (fig. 26). It was first reported as epidemic in The Netherlands on the local 'Brabantica' poplar, which came into high favor about 1860 and was grown extensively because of its excellent growth rate, good form, and desirable wood quality. As early as 1870 this cultivar was observed to be suffering from disease and by 1875 it was reported that very few healthy specimens were to be found.

GREAT BRITAIN FORESTRY COMMISSION photo

FIGURE 26.—Bacterial canker on *Populus* 'Eugenei' in a test planting for disease resistance in England.

Studies of the disease were reported in 1900 in Belgium, and in 1906 it was described as the most common type of canker in northern France. Bacterial canker became so serious in The Netherlands and in the adjacent Low Countries that it threatened the commercial growing of poplars. This led to the clonal selection work of Dr. Houtzagers during the 1930's and the compulsory certification in The Netherlands of clones that are resistant to this disease.

Bacterial canker is characterized by the initial appearance of small cracks in the bark, which exude a light-colored bacterial slime during the first year. Callus forms around the infected area as the disease progresses, and this produces the characteristic swollen nonhealing cankers. Trunk cankers may occasionally kill a tree rather quickly by girdling, but usually the numerous cankers that develop on the branches kill the tree gradually by reducing its living crown over a period of years (fig. 27).

The presence of slime is a definite diagnostic character in young cankers, but in old cankers slime is not always present. For this reason it is not possible to diagnose all older branch and trunk cankers with absolute certainty. In France, the author was shown 'Regenerata' poplars 20 to 25 years old, with unusually large cankers on the lower 15 feet of the trunks that were characterized by vertical slits in the bark. These have been assumed to be bacterial cankers.

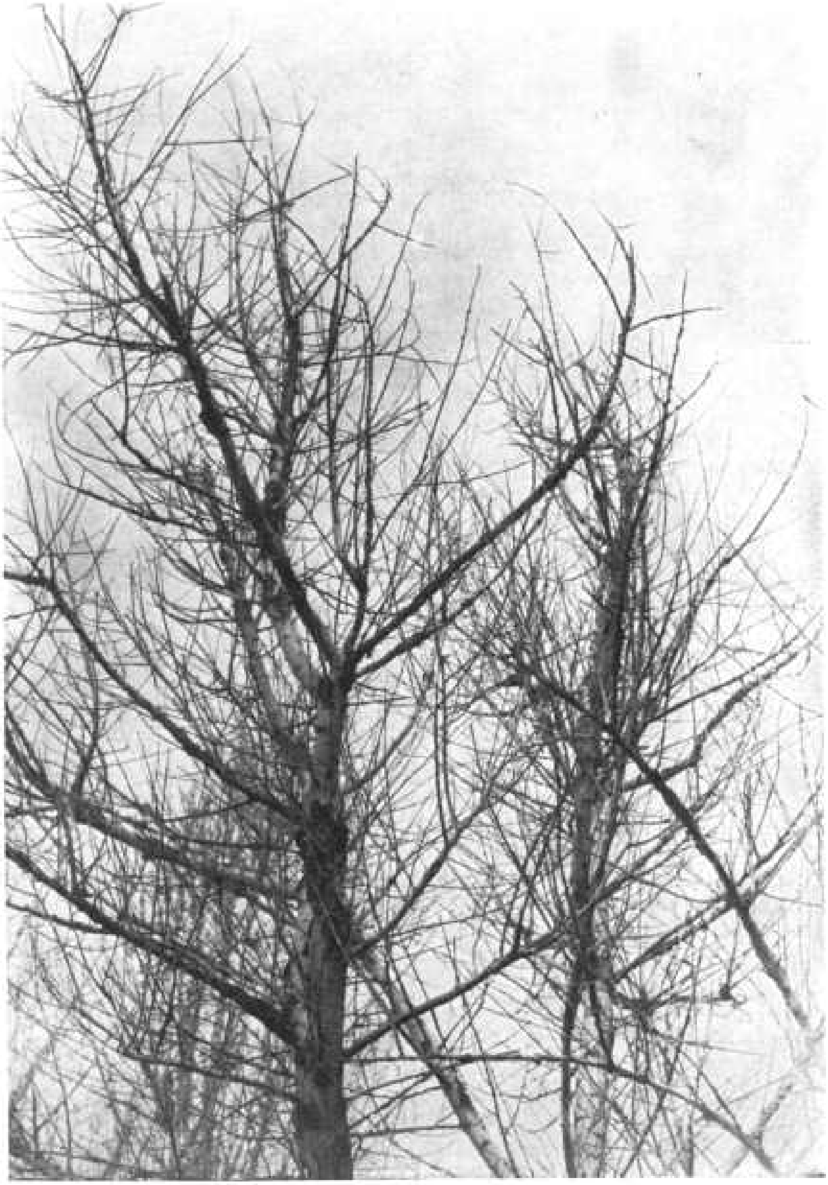
Typical bacterial branch cankers, as diagnosed from the ground, were present on some of the trees with trunk cankers, on others the branch cankers were lacking. A cautious investigator would not classify such cankers as bacterial without cultural evidence; they may have originated from other primary causes. M. Chardenon, of the French Match Company, suggested that climatic or other environmental conditions during a particular year or series of years might account for these unusual trunk cankers.

Bacterial canker has been investigated in several countries; the most intensive and continuous research was started in The Netherlands about 1936. It is now generally agreed that a bacterium, *Pseudomonas syringae* (v. Hall) E.F.S. f. sp. *populea* Sabet (synonym: *Ps. rimaefaciens* (Sm. et Towns) Koning), is responsible for at least the initiation of the disease. The evidence in The Netherlands indicates that the most susceptible period is in the spring, but this may differ from year to year as to exact dates. Although individual clones vary in degree of susceptibility in different years, their relative susceptibility as compared to other clones is usually the same from year to year.

Netherlands pathologists have found that the typical syndrome of bacterial canker is not induced by inoculation with pure cultures of the bacterium. Such inoculations produce infections and swellings that heal over in the first or second year. (These healed infections resemble, superficially, the trunk scab described on p. 75.) It is necessary to inoculate with the raw slime or, as Sabet reported from England, to supplement the inoculation of the pure bacterial culture with sterilized slime, to obtain a typical canker.

Bacterial canker is so serious in Great Britain that selection and inoculation tests have been under way for some years. Old multiclonal plantings where bacterial canker has been present for many years indicate that under conditions of natural infection some individuals are resistant. Disease-free ortets have been selected from such plantings for pathological tests.

The role of other bacteria and fungi that are usually associated



GREAT BRITAIN FORESTRY COMMISSION photo

FIGURE 27.—Branches and upper trunk of *Populus* 'Eugenei' heavily infected with bacterial cranker. Near Farnborough, Hants, England.

with this canker is in doubt. It is possible that the bacterial infection alone, without secondary pathogens, might not result in the serious losses associated with this disease.

It is now known that there are clones that are highly resistant to artificial inoculation, but it is not yet proved that there are any completely immune clones. There is some indication that the severity of bacterial canker, and possibly even susceptibility, may be intensified by poor growing conditions. The Zwolle clonal test of the Netherlands Land Reclamation Society is on a poorly drained peat soil. The growth of all clones is very poor and bacterial canker is much more prevalent and more severe than on two comparable plantings of the same clones on good sites in the central and southern Netherlands. Even clones that are highly resistant to artificial inoculation when tested on a good site show cankers in the Zwolle plantation in some years when climatic conditions favor the disease. It is reported that this is the only site in The Netherlands where trunk cankers have developed on *P.* 'Serotina.'

There is no information available as to the possible existence of distinct physiological strains of the primary pathogen (differing in pathogenicity) in various parts of Europe. Inoculum from the same regional source has always been used in the intensive inoculation studies carried out in The Netherlands on many clones over a long period of years.

The fact that bacterial canker has not been reported from southern France or Italy may indicate natural environmental control of the disease organism, the occurrence of a different syndrome, or absence of the carrier or carriers of the disease. It is improbable that there has been no opportunity for transport of the bacterium to southern Europe.

The problem of clonal susceptibility to natural infection has not been studied with sufficient precision to warrant sound conclusions. Such tests are necessary for new selections. A clone that is superior in all respects except its susceptibility to *artificial* inoculation might have other inherent attributes that would protect it from natural infection. For example, it is not known how bacterial canker is transmitted from tree to tree. If it is carried by insects, then susceptibility to natural infection would be correlated with the degree of clonal attractiveness to such insects.

Tacamahaca poplars and their hybrids are generally considered highly susceptible to bacterial canker, and for this reason there is a strong prejudice against this entire group. The prejudice is based on observations and tests of relatively few clones in comparison to the number of Aigeiros clones involved in the years of natural and artificial selection for disease resistance. Inoculation tests in Great Britain have now clearly indicated that there are clones of *P. trichocarpa, P. balsamifera,* and their hybrids, which are highly resistant to bacterial canker.

There are examples of Tacamahaca poplars within the natural range of this disease that are free of bacterial canker. Such cases may be purely accidental but they merit further tests. A row of healthy, 30-year-old 'Berolinensis' poplars on the old castle grounds in Schleswig, Germany, averaged 90 feet in height and approximately 26 inches in d. b. h. There was no excessive borer injury on the branches of these trees and no evidence of any disease. 'Berolinensis' is reported to be healthy in this locality.

Spring dieback

This disease—called Defogliazione primaverile, literally translated "spring defoliation"—almost eliminated profitable poplar culture in northern Italy and was a primary incentive for the establishment of the Poplar Institute at Casale Monferrato. There is much confusion over the scientific name of the fungus responsible for this disease. In Italy, *Pollaccia elegans* Serv. (perfect stage, *Venturia populina* (Vuill.) Fabr.) has been reported to be the pathogen on Aigeiros poplars, and a second species *Pollaccia radiosa* (Lib.) Bald. and Cif. (perfect stage, *Venturia tremulae* Adreh.) on *P. alba.*

In Spain, the perfect stage of the fungus responsible for dieback ("la defoliacion de primavera") is reported to be *Didymosphaeria populina* Unamuno. It is considered to be distinct from *D. populina* Vuill., *Venturia populina* Fabr., and *V. tremulae* Kleb.

Napicladium tremulae (Frank) Sacc. and *Pollaccia radiosa* (Lib.) Bald. and Cif. have been identified as the cause of this disease in northern Europe.

The disease kills the young leaves and new shoots in early spring, usually before the leaves have reached their full size. Young twigs girdled by insects may have the same appearance but are easily distinguished from spring dieback. The dead, blackened, immature twigs and leaves may remain on the trees as "flags" into the summer. Repeated defoliation can be serious enough to cause the death of the tree, but it is not always certain whether death is due to this fungus alone or to the invasion of secondary parasites.

During 1952 the author found only one locality in which heavy mortality might be ascribed to the primary effect of spring dieback. A 12-year-old plantation of *P.* 'Berolinensis' in Lolland, Denmark, was in critical condition after several years of heavy infection. It was impossible to determine whether the decline and heavy mortality was due entirely to repeated spring dieback or to a combination of dieback and other pathogens. There was no indication of typical bacterial canker on these trees, but they did have small brownish to black necrotic areas on the trunks much like the trunk scab of 'Robusta' in Germany. Since this plantation was on rather heavy and poorly drained soil it is possible also that site conditions may have been responsible in part for its early deterioration.

Clonal variation in susceptibility was apparent in this plantation. Although the stock had been presumed to represent a single clone, there appeared to be at least two clones. Among the rather wide-spreading trees that were heavily infected and dying there were a few more columnar individuals that were very lightly infected and appeared to be in good health.

In Sweden it is reported that in some years spring dieback drastically reduces the growth of young trees of *P. tremula,* particularly trees under 5 years of age. The disease is not considered to be of practical importance after the trees reach a height of about 20 feet. Severe spring dieback apparently has not been observed on the *tremula* × *tremuloides* hybrids.

Isolated cases of spring dieback, too light to have any effect on the growth of poplars, were observed in practically all European poplar regions. A few trees of 'Regenerata' and 'Robusta' in the poplar nursery at Schmalenbeck, Germany, had typical symptoms. Near Bellinzona, Switzerland, in a new planting of white poplars from Italy, some of the trees were heavily infected. Dieback was also present in Spain. In England it is thought to be associated with dieback of aspen.

Spring dieback is an arrant menace to poplar culture that fortunately can be eliminated by the breeding and selection of resistant clones. Selection of resistant hybrids has eliminated the danger of epidemic losses in Italy, at least until physiological strains of different pathogenicity are imported or develop in Italy. Constant vigilance is necessary because it is uncertain whether different species or races of this pathogen vary in virulence and pathogenicity.

Canker and stem dieback

Several fungi cause stem dieback or cankers, depending on the vigor of the tree or the part of the tree that is infected. Where small and weakly growing stems and branches are quickly girdled and killed, particularly during the dormant season, the syndrome is usually called bark necrosis, stem or branch dieback, or simply dieback. On larger branches or trunks where the infection is limited by callus formation around the dead sunken area, it is called canker. Such cankers usually increase in size by periodic advances of the pathogen and new callus formation.

Dothichiza populea Sacc. et Briard.—Stem dieback and cankers due to *Dothichiza* can be found in all parts of Europe. It has become so generally associated with dieback of poorly growing trees, particularly newly planted trees, that growers and foresters who are unfamiliar with the pathology of the poplars usually attribute all cases of stem necrosis to this fungus. In all countries, some examples of *Dothichiza* disease that were called to the attention of the author proved, on close inspection, to be due to *Valsa*.

The fungus is characterized by olive-colored tendril-like sporehorns that are exuded from the fruiting bodies through small ruptures in the dead bark during damp weather. It is particularly virulent on newly planted trees on unfavorable soils, where grass is inhibiting their growth, or where the trees have not been properly planted.

The European belief that *Dothichiza* is a facultative parasite, highly virulent only on young trees that are growing poorly because of other conditions, is supported by general observations but has not been proved by research. Observations in a few plantations pose the possibility that more virulent strains of this fungus may be present in some localities.

There is also evidence that *Dothichiza* can be serious on older established poplars. Many trees in an 18-year-old *P.* 'Robusta' plantation in the lower Rhone Valley had elongated and slightly sunken cankers on the upper trunks. Although both *Dothichiza* and *Valsa* were found in the tops of felled trees, *Dothichiza* was most abundant. This plantation, spaced 13 by 13 feet, was on a deep silt soil over coarse sand, and in dry summers the water table could drop to 12 feet. The last 10 years had been relatively dry; 1947 and 1949 were exceptionally dry years, with 70 rainless days in the summer of 1949. The detrimental effect on growth vigor of the prolonged dry weather may have been responsible for the prevalence of disease.

Bordeaux mixture and other fungicides are used for control of *Dothichiza* in the nursery and in newly established plantations. The most common way to protect new plantations against this disease is to maintain the trees in strong vigor by careful planting, fertilization, clean culture, and irrigation where necessary.

The Italian method of taking cuttings from 1-year-old stumped trees is spreading to other countries. This eliminates the danger of incipient disease in cuttings from old stools that have accumulated such facultative parasites as *Dothichiza* and *Valsa*.

Dothiorella spp.—*Dothiorella* has frequently been reported to produce much the same syndrome on poplars as *Dothichiza*. Severe damage by *Dothiorella populnea* Thüm. and *D. populina* Karst. was reported in the Provinces of Burgos and Leon, Spain, in 1942 and 1943. A plantation of fastigiate, columnar, and medium wide-spreading types at Carrion de los Condes, inspected by the author in 1952, was especially interesting for the variation in disease and insect resistance.

Although most of the fastigiate types had succumbed to *Dothiorella*, there were at least three clones in this plantation in 1952. Some of the remaining fastigiate trees were heavily infested with both gall aphid and a small leaf spot resembling *Septoria*. A few fastigiate individuals, with larger and darker green leaves than the infested trees, had practically no aphid galls or leaf spots. The columnar and wider-spreading types in this plantation appeared to be free of disease and insects and were making excellent growth.

Valsa spp.—*Valsa* species have practically a worldwide distribution and *V. sordida* Nitsch. (imperfect stage *Cytospora chrysosperma* (Pers.) Fries) is present everywhere in Europe. This fungus causes dieback and cankers that can be distinguished from *Dothichiza* in the field only if the fungus has fruited. The sporehorns of the imperfect stage (*Cytospora*) are bright orange in color. If the sporehorns are gone, *Cytospora* can still be recognized by the somewhat smaller bark ruptures through which the spores were exuded.

Although it is normally saprophytic on dead branches, *Valsa sordida* can assume a parasitic role on trees that are in poor vigor from other causes. In the poplar nursery in Saxony a large section of the stool planting on a poor site was reported killed by this fungus.

Valsa nivea (imperfect stage, *Cytospora nivea* Sacc.), which is normally saprophytic on native *Populus tremula*, was reported in 1955 [9] as a potentially serious parasite on *tremula* × *tremuloides*

[9] Persson, Arne. *Kronenmykose der hybridaspe.* Phytopath. Ztschr. 24 (1): 5572. 1955.

hybrids in southwestern Sweden. This fungus has caused repeated and severe dieback in the crowns of hybrid aspens at Sofiero and Ekebo (Lat. 56). The dieback was not found in plantations of the same age and parentages at Mykinge and Brunsberg, 151 and 390 miles north of Ekebo, respectively. Climatic differences are assumed to be responsible for lack of infection in the more northerly plantations.

The first symptoms became apparent in the Sofiero and Ekebo plantations on 10- to 14-year-old trees. The disease is reported to be just as common and severe on vigorously growing trees as on poorly growing trees, but the progenies of different parentages vary in their susceptibility to this fungus.

Nectria spp.—There have been reports of severe losses from *Nectria coccinea* Fr., *sanguinella* Wa., and *N. galligena* Bres. *major* Wa. in a few localities. These fungi were reported to be responsible for the widespread death of poplars in the Lower Rhine region of Germany some 25 years ago. Only isolated cases—usually branch infections—were observed in the course of these studies, and at present this disease is not considered serious in Europe.

Hypoxylon crustaceum (Sow.) Nke. and *H. atropurpureum* Fr. have been reported on *Populus tremula* in Norway, but poplar foresters did not consider these pathogens a serious problem in aspen management.

Trunk scab

This name is used here as most descriptive of a spot necrosis of the bark, which occurs in widely separated regions of Europe. The cause of trunk scab is not known; but from observations and limited investigations it appears to be of pathogenic origin. Intensive research will be required to determine whether trunk scab is caused by a single organism, or whether different pathogens produce similar syndromes in the same or in different localities.

It is possible that trunk scab represents the effect of primary invaders that, having limited pathogenicity, produce only local lesions that the tree can overcome in 1 or 2 years. Where such a primary infection is followed by secondary pathogens the syndrome could be quite different; for example, cankers typical of the secondary pathogen could develop.

Small necrotic areas, usually brown or dark colored, appear on the bark of the trunk and produce an exudate during the growing season. These circular to elliptical areas, ½ inch to 1½ inches in diameter, heal over after 1 or 2 years but new spots continue to appear each year, giving the trunk a scabby appearance. The disease degrades the wood by producing brown-stain spots under the healed lesions, with or without included dead bark.

The individual defect areas extend only a short distance horizontally and are somewhat longer longitudinally. Scabby logs produce low-grade veneer because of the regularly spaced series of stained areas or holes where dead bark was enclosed. This syndrome is called "Braunfleckengrind" in Germany; in France it is referred to as the "maladie des taches brunes" and also as the "disease of 'Robusta' in Chautagne"; and in Italy it is called "Batteriosi."

Trunk scab has been increasing in Germany since 1941. It was first observed on *P.* 'Robusta,' which appears to be most susceptible; but it also occurs on 'Regenerata,' 'Serotina,' and 'Berolinensis.' It affects trees on some of the best poplar sites. As early as 1950 the planting of 'Robusta' was prohibited in the state forests of North Baden and the Palatinate.

In France, trunk scab was observed only in the region of Chautagne. The forest pathologist at Nancy has isolated a number of bacteria and several fungi. Although the evidence points strongly to bacterial origin, he is of the opinion that *Phytophthora* should not be overlooked as a possible primary pathogen.

"Batteriosi" is a serious disease in Italy; it attacks even the most vigorous trees of highly susceptible clones. Fortunately there is clonal variation in resistance to this disease and susceptible clones, such as 'I–488,' are being replaced by resistant clones. Dr. Vivani of the Poplar Research Institute at Casale Monferrato has isolated several bacteria.

Trunk scab was also observed in plantations along the River Toradera near Hostalrich, Spain, and in a young plantation of *P.* 'Robusta' in the vicinity of Mons, Belgium. The 'Berolinensis' poplars on the Knutenberg Estate in Denmark, which were heavily infected with twig blight, also showed evidence of this syndrome.

Leaf Diseases

Leaf diseases, with the occasional exception of *Melampsora,* are usually of practical importance only in nursery plantings. The control of these diseases by spraying has become routine procedure in most progressive poplar nurseries in all countries. The spray schedule in the state poplar nurseries in Baden is typical of good European nursery practice. Bordeaux mixture is applied at approximately 6-week intervals. The first bordeaux spray is a 1-percent solution; later sprays are 2-percent.

Melampsora rust

Six species of *Melampsora* have been recognized in Europe: (1) *M. larici-populina* Kleb.; (2) *M. allii-populina* Kleb.; (3) *M. larici-tremulae* Kleb.; (4) *M. pinitorqua* Rostrup; (5) *M. Rostrupii* Wagner; and (6) *M. magnusiana* Wagner. The alternate hosts of the above species are *Larix* species (1,3), *Allium* species (2), *Pinus* species (4), *Mercurialis perennis* (5), *Chelidonium majus* and *Corydalis* species (6).

Melampsora is easily recognized by the bright orange-yellow spore masses on the underside of the leaves. Rust infection can completely defoliate young poplars by midsummer; and after a succession of heavy infestations for several years such trees may succumb to secondary pathogens.

The disease can be epidemic in older plantations. One such epidemic was observed in early September 1952 near Bellinzona, Switzerland, in a plantation of about 200 trees approximately 12 years old. This was obviously a mixture of at least two clones that differ in their resistance to *Melampsora* rust. Six trees in this stand were practically rust free; one tree with a broader habit of growth showed medium rust infection; and all of the remaining trees were so heavily infected that they were practically defoliated. It is not known whether this plantation had been heavily attacked in previous years, but such epidemic infection in several successive years would certainly result in severe growth retardation of a monoclonal plantation.

Fortunately *Melampsora* can be dismissed as a serious threat to poplar culture because there are many inherently resistant clones. For every region there are now clones that are highly rust resistant, but the same clones are not necessarily resistant in other regions.

Leaf blotch

Waterman and Cash have given this name to a leaf disease caused by *Septotinia populiperda*.[10] The fungus produces small brown spots on the young leaves; these spots usually increase rapidly in size, soon become gray at the center, and have an irregular but sharply defined margin. The imperfect stage of this fungus had been collected in Latvia and described in 1932 under the name of *Septogloeum populiperdum* Moesz & Smarods.

Leaf blotch is not considered a serious disease in Europe. Nurserymen, when questioned on its occurrence in the past, remarked that it was easily controlled by routine spraying with bordeaux.

Localized, light infection was seen in the poplar nursery at Keppel, The Netherlands, in mid-July. There had been leaf-beetle feeding earlier in the season and the leaf blotch appeared to be associated with the beetle injury. Spraying for beetle control had apparently controlled the spread of leaf blotch. A few infected leaves were observed in the state poplar nursery at Harsefeld, Germany, in the poplar arboretum in Giritz, Switzerland, and on some of the oldest leaves on an occasional tree of clone *P.* 'I–455' in a nursery at Fronte, Italy. This disease is considered unimportant in Italy because it has appeared only in nurseries and in late summer. Noticeable infections have not been found in plantations.

Septogloese

A leaf disease called "Septogloese" in Germany was first observed in 1947 and described by Johannes in 1950[11] as caused by the fungus *Septogloeum populiperdum* sp. n. (This name had already been applied in 1932 to the imperfect stage of the leaf blotch fungus by Moesz & Smarods.) Septogloese does not appear to be

[10] Waterman, A. M., and Cash, E. K. *Leaf blotch of poplars caused by a new species of Septotinia.* Mycologia 42: 374-384. 1950.

[11] Johannes, Heinrich. *Eine pappelsterben hervorgerufen durch den pilz Septogloeum populiperdum sp. n.* Deut. Pflanzenschutzdienst Nachrichtenbl. 2 (5): 67-69. 1950.

the same disease as the leaf blotch reported by Waterman and Cash; the symptoms are different.

On the current year's growth of nursery stools and newly planted cuttings, leaves infected by the septogloese disease are reported first to become mottled (etiolated), then translucent, the green color being maintained only immediately adjacent to the veins. After 2 to 3 weeks the margins of the leaves begin to curl strongly upward. The fruiting bodies of the fungus—small white pustules about 1 sq. mm. in area—appear on the leaves during wet weather. Leaf fall is earlier than normal. In the following spring, the buds, after normal swelling, fail to develop and the stems die back. Whether the death of the stem is due to the leaf fungus or to a secondary parasite such as *Valsa* was still under investigation at the time of this survey.

In the poplar nursery at Harsefeld, German poplar foresters did not consider specimens of leaf blotch with symptoms typical of those described by Waterman and Cash to be the same disease they recognize as septogloese. They stated that they had observed this leaf blotch occasionally on nursery stock.

Other leaf diseases

There are other leaf diseases in Europe that up to the present time have not been of practical importance. Among these are *Taphrina aurea* (Pers.) Fr., which causes blisters and some leaf distortion; and leaf spots caused by species of *Phyllosticta, Marssoniana, and Septoria.*

Root Diseases

Root diseases have not been known to cause widespread damage in the poplar regions of Europe. Localized cases of severe reduction in growth or of high mortality have been reported as due to infection of the roots by *Armillaria mellea* (Vahl) Fr., *Rossellinia necatrix* (Hart.) Berl., *R. amphisphaerioides* L., *R. quercina* Hart., *R. aquila* (Fr.) de Not., *Pholiota aegerita, Botrytis cinerea* Pers., and other fungi. The crown gall bacterium, *Pseudomonas tumefaciens* Sm. et Towns, also occurs on poplar in Europe. These root diseases are usually thought to become serious only on heavy or wet soils.

Unidentified Diseases

Small, elongated, and slightly sunken stem cankers of unknown origin had been observed for several years previous to 1952 in test plantings of hybrid aspens at Ekebo, Sweden. In a planting of two rows each of different interspecific and intraspecific crosses, the *tremula* × *tremula* progenies were free of infection, and there was also a difference in the amount of infection on two adjacent hybrid progenies of the same female with different male parents.

The variability of infection in the adjacent trees was indicative of, but not proof of, inherent variation in susceptibility because in previous years all diseased trees had been removed as soon as they showed evidence of cankers, thus reducing the probability of heavy and uniform exposure to infection. The same symptoms were observed on hybrid aspens in the experimental plots of the Swedish Match Company at Mykinge and of the Tree Breeding Station at Brunsberg. In these plantations, as at Ekebo, removal of diseased trees as soon as they were found had failed to eliminate the disease.

On a hybrid aspen at Brunsberg, a series of necrotic areas extended from an unidentified trunk canker at 6 feet above the ground to the base of the tree. These appeared to be infections from the original uppermost canker. The forester at Brunsberg stated that similar cankers are occasionally found on the native *P. tremula*.

There were dying Lombardy poplars in the vicinity of Stockholm, Sweden, with symptoms similar to the "vascular wilt" of this cultivar in the United States. Along the highway from Madrid to Burgos many columnar and fastigiate black poplars also exhibit this syndrome. There is evidence of clonal variation among these Spanish types not only in growth habit, but also in disease and insect resistance. Near Quintanar de la Mata, heavy infection of a leaf spot resembling *Septoria* was found on some trees whereas adjacent trees with somewhat different growth habit were free of infection.

In the arboretum at Horsholm, Denmark, a specimen of *P.* 'Bolleana' was in very poor condition; it had many dead branches and knobby swellings on the trunk that resembled the crown gall (*Pseudomonas tumefaciens* Sm. & Towns) reported by Cook on this poplar in the United States. The Asiatic Tacamahaca poplars in the arboretum appeared unhealthy, with many small dead branches and twigs. These Asiatic species seemed to be suffering from much the same condition—environmental or disease, or both—as in the botanical gardens in the northeastern United States.

A yellow mottling of the older leaves, locally called "mosaic," was observed in early September on nursery stock of *P.* 'Angulata' in northern Italy. It is said to occur only on young nursery trees and not on all clones, and is thought to be of physiological origin. It could be a deficiency symptom or a virus disease. "Mosaic" is not considered important.

Possible virus infections that result in premature leaf fall have been reported from Madrid, Spain. The symptoms have been described as similar to the virus diseases reported by Atanasoff on *P. balsamifera* in Bulgaria and by Perisic on "Canadian" poplar in Jugoslavia. Light green areas, which later become yellow and dry, appear along the veins of the leaves. There has been no experimental work in Spain to determine whether this "mosaic" condition is actually a virus infection.

A leaf spot that was similar to but not typical of leaf blotch was found in the state poplar nursery near Zaragoza. This apparently had occurred late in the season and by the end of September had affected relatively few leaves on the individual plants.

Wood Decay and Stains

Wood decay

Poplars are susceptible to numerous wood-decay fungi. These seldom attack trees under 40 years of age and rarely become serious on the best sites in trees less than 50 or 60 years old, the maximum rotation recommended in Europe. Since Aigeiros poplars are usually cut on a 12- to 35-year rotation, wood rots seldom cause appreciable economic loss.

Heartwood stains

Heartwood stains, in varying shades of dark brown, red, and orange, are common in all European poplar regions. The stained wood is sound; there is no decay and no evidence that the stain leads to eventual decay. It is uncertain whether the staining is of pathological or physiological origin. A dark-brown stain is the most frequent cause of log degrade in Great Britain. Some growers believe that it is correlated with variety or poor sites because it is often present in *P.* 'Serotina' and 'Robusta' and in trees on dry sandy soils or wet peaty soils.

Heartwood stain is common in the poplars grown in Italy. The color varies: in *P. alba* it is orange; in the Aigeiros hybrids it is red to dark brown. This problem is under investigation in several laboratories. At the Poplar Institute they have found that the bacterial count, pH, moisture content, and shrinkage on drying of the stained heartwood are higher than in normal white wood. No pathogen has yet been identified as the cause of staining. It commonly follows borer injury and is said to be more common on trees grown from cuttings than on seedlings.

In Italy logs used for pulpwood, lumber, or veneer for matches, core stock, and boxes are seldom downgraded because of stain. Where poplar is used for both bleached and unbleached groundwood pulp, the bolts are sorted and the unstained bolts are ground separately for unbleached pulp. Stained heartwood causes some manufacturing difficulties and waste in veneer use, but the shortage of suitable timber and the prevalence of stain has prevented industry from insisting on degrade.

For special uses, for face veneer, and for veneer and lumber in regions of Europe where other suitable species are available there is a severe degrade for stained heartwood. Industry is more interested than the grower is in research to eliminate this defect.

Significance for the United States

The history of poplar culture in Europe has demonstrated that disease can threaten the poplar culture of an entire region or even of an entire country.

It is apparent that climatic control of the pathogens limits their epidemic spread both in Europe and in the United States, but there may be racial or individual variation in the inherent virulence or pathogenicity of the disease-producing fungi and bacteria. It is possible also that extensive planting of a single disease-resistant clone may, within a relatively short time, lead to the development of new strains of the pathogen to which that clone is no longer resistant.

Fortunately, because of the extremely variable germ plasm available in the genus *Populus,* it should be possible to produce hybrid clones that will be resistant to introduced diseases or new strains of native diseases more virulent than those presently in existence. Bacterial canker in northern Europe and the spring dieback and rust diseases in Italy would have eliminated profitable poplar culture in those regions if it had not been possible to select new inherently resistant clones. Continued vigilance, breeding, and selection will be necessary in order that the appearance of new diseases, or more virulent strains of older diseases, may be met with new resistant clones.

Monoclonal plantations are biologically unsound, because every ramet of a single clone has all the weaknesses as well as the excellence of the original ortet. A new disease or a more virulent variant of an unimportant native disease could wipe out extensive areas of a single clone in one epidemic. Random mixtures of 25 or more clones of different parentage will provide biological assurance against extensive disease losses because in such a stand every tree will not be equally susceptible to a new disease, or to a more virulent form of the native pathogen, against which the clones had not been tested.

Bacterial canker has not yet been reported in the United States.

Spring dieback has long been recognized as common on our American aspens but it is not considered important on Aigeiros and Tacamahaca poplars. In 1956, Bruce W. Dance[12] reported that two different fungi are responsible for this disease on poplars in the United States and Canada. He concluded that the correct name of the fungus commonly found on aspen is most probably *Fusicladium tremulae* Frank (= *F. radiosum* (Lib.) Lind), perfect stage *Venturia tremulae* Aderhold. He has identified the fungus that has been reported only occasionally on Tacamahaca and Aigeiros poplars in the United States and Canada as *Pollaccia elegans* Serv. (= *Fusicladium radiosum* (Lib.) Lind var. *balsamiferae* J. J. Davis), perfect stage *Didymosphaeria populina* Vuill. (= *Venturia populina* (Vuill.) Fabricius).

Dothichiza, Valsa, and most European leaf diseases are present in this country, but it is possible that European forms may represent strains of different virulence than those in the United States. European experience indicates sufficient inherent variation to warrant the prediction that poplar clones resistant to practically all of these diseases can be produced by selective breeding.

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[12] Dance, Bruce W. *A leaf and twig blight of balsam poplar caused by Didymosphaeria populina Vuill., imperfect stage: Pollaccia elegans Serv.* Canada Dept. Agr. Forest Path. Lab. Interim Rpt. 70 pp., illus. 1956. [Processed.]

The best American poplar clones should be submitted to European poplar research stations for tests of their susceptibility or resistance to the most important European diseases. Clones resistant to European diseases should be brought into the United States and tested in different regions. They will be invaluable for planting and for breeding new resistant types if European diseases appear in this country.

Because of the serious risk of introducing new diseases or more virulent strains of native diseases, extreme care is essential in the importation of cuttings or nursery stock. Our present quarantine regulations prohibit the importation of cuttings or plants of poplars except through the Federal Plant Quarantine Station. Since other countries in this hemisphere do not have equally strict quarantine regulations, and because of the extensive introduction of European cutting stock into South America, we may expect that most European diseases will eventually reach this side of the Atlantic.

From the biological aspect, heartwood rots may be dismissed as of little importance; the rotation for poplar will be sufficiently short to eliminate any loss from wood rots. Heartwood stain, usually associated with so-called wetwood, is common in poplars in the United States. The dark-colored heartwood of *P. balsamifera* has been associated with bacterial infection, but in hybrid poplars we know little about the cause of stained heartwood.

It is the opinion of the author, based on observations during the past 30 years, that stains and wetwood are of pathogenic origin, that apparently various organisms are capable of producing similar symptoms, and that infection is probably through wounds, including the cut end of the original cutting. There is no conclusive research evidence available in Europe to invalidate this opinion.

It is apparent in all countries of Europe that poplars growing under adverse environmental conditions are particularly subject to disease. This is also true in the United States.

Trunk scab is a relatively new disease in Europe. Shade trees in the United States occasionally have small "bleeding" spots on the trunks, but since these poplars are not used for veneer it is not known whether this syndrome is associated with typical trunk-scab defects in the wood. It is possible that the American trunk-scab syndrome may become of considerable importance in some parts of the United States when hybrid poplars are grown extensively in commercial plantations.

The blanket indictment of the Tacamahaca poplars as highly susceptible to bacterial canker assumes a lack of individual variation for which there is insufficient justification. There are far too few clones of *P. trichocarpa*, *P. balsamifera*, and other balsam poplars in Europe to warrant the conclusion that there are no resistant Tacamahaca clones. The growth vigor of Tacamahaca hybrids, particularly when crossed with the Aigeiros poplars, justifies their continued breeding and selection.

The economic loss occasioned by epidemic diseases that kill trees or retard their growth is obvious. Heartwood stains and diseases such as trunk scab, which apparently do not interfere with the growth of the affected trees, are nevertheless of serious economic importance. Stained heartwood is entirely suitable for bleached pulp but it cannot be used for the production of unbleached groundwood pulp. When used for veneer, stained heartwood associated with wetwood results in manufacturing difficulties due to excessive shrinkage, splitting, and warping. Aside from the manufacturing difficulties, it is doubtful whether stained heartwood, because of its color, could find a profitable market in the United States.

INSECTS

Of the many insects that infest poplars in Europe, only those of major economic importance and the most common species of minor importance are discussed here.

Boring Insects

Borers, particularly *Saperda,* are no doubt the most generally destructive poplar insects in Europe. There is as yet no good evidence for inherent resistance of individual clones to borer injury. Usually trees in poor vigor are more heavily infested than those growing vigorously, but occasional observations on excellent sites indicate that there are exceptions. Some boring insects can kill the infested trees; some may be associated with the spread of poplar diseases; and all cause more or less serious log degrade.

Saperda carcharias (L.), the large poplar longhorn beetle, is distributed throughout Europe, but heavy infestations are usually localized. In some localities it is the most serious insect pest of poplars. Since the full-grown larvae are more than ¼ inch in diameter, the larval tunnels in the wood are of large size, and the deeply boring larvae cause very serious degrade of lumber. The burrows are often infected with bacteria and fungi, which cause discoloration and additional product degrade.

There is some evidence that isolated trees and trees in rows are more heavily attacked than trees in plantations or in mixed stands. There are reports from Germany that border trees in plantations with filler species that increased stand density were more heavily attacked than trees inside the stand. There is evidence in Italy that poplars on dry sites are particularly susceptible to infestation.

For control, the introduction of a suitable fumigant such as carbon disulphide or carbon tetrachloride into the burrow is most frequently recommended. In Italy, a large match with fumigant at one end (called Antitarlo) is widely used for borer control. When these matches are pushed into the gallery and sealed with wet earth, the moisture of the tree releases the fumigant. Sanitation, by removing and burning infected wood, is always recommended. Spraying at the time the adult beetles are flying is practiced in a very few nurseries. It is not a practical control in plantations except under conditions of extremely heavy infestation.

Saperda populnea (L.), the small poplar longhorn beetle, infests the branches of large poplars or the stems of small trees. The injury caused by this beetle is similar to that caused by our native *S. concolor* Lec., the poplar gall Saperda. The eggs are laid in the bark of small branches or in the leader; and, as the larvae work between the bark and the wood, the branch develops gall-like swellings. The larvae eventually burrow into the center of the stem. This insect is most serious on young, poorly growing trees where it may infest the small stem or leader and result in eventual breakage at the weakened point. How much this insect is involved in spreading various canker diseases is not known. It seems probable, however, that it is an agent in the spread of bacterial canker and perhaps other fungus cankers.

Cossus cossus (L.), the goat moth, normally attacks other broadleaf trees but occasionally causes considerable damage to poplars. It is widely distributed; but, like the insects mentioned above, it may be serious only in certain localities. The goat moth seems to prefer isolated or widely spaced trees. Full-grown larvae may be as much as 3½ inches long. The larval stage extends over 2 or 3 years, and during this period the larvae continue to make larger and larger oval-shaped burrows in the wood. For control of this insect in The Netherlands, the entrance holes are plugged with cotton soaked in melted paradichlorbenzene.

Zeuzera pyrina (L.), the wood leopard moth, is reported numerous in the south of England; it injures poplars and other broadleaf species by attacking stems of small diameter. During the first season the larvae form a circular burrow in the outer sapwood, and during the second year they burrow a 6- to 8-inch vertical tunnel in the inner wood. Small stems often break off at the point of injury. This insect is not considered serious on the Continent.

Aegeria apiformis (Cl.), the hornet clearwing moth, is locally numerous and destructive in many parts of Europe from England to Italy. The young larvae feed first in the bark and cambium at the base of the trunk and then burrow into the wood of the stem and large roots. Trees that have been heavily infested for several years have the outer layers of wood honeycombed with the larval burrows and such trees tend to die back from the top or sometimes are killed outright.

Sciapteron tabaniformis Rott., the dusky clearwing moth, has been responsible for damage in Germany similar to that of the horned clearwing moth. It is also considered a destructive poplar pest in Italy.

Phytobia carbonaria (Zett.), the poplar cambium borer, is of considerable economic importance in Europe. The larvae bore long irregular burrows in the cambium, which become infected with bacteria, discolored, and covered by new wood. New tunnels are formed each year during an infestation, so the infested logs show concentric rings of small brown spots of varying width that are referred to as "pith flecks." The frass-filled tunnels cause serious log degrade because they constitute weak points in the wood and make it unsuitable for the manufacture of matches or plywood. This insect is responsible for considerable economic loss in England.

Sternochetus lapathi (L.), the poplar and willow borer, is found in all of the poplar regions of Europe. It is usually associated with alder and willows but also attacks young poplars, and where infestation is heavy it can cause considerable damage. The hibernating insects resume feeding in the spring in the soft tissue of the inner bark and outer sapwood. Recently planted trees are particularly susceptible and are often killed by girdling.

Barypeithes pellucidus Boh. and *B. araneiformis* Schrank, short-snouted weevils, have been serious pests in nurseries where bracken compost was used. These insects infest the bark of young trees just above the ground level.

Cryphalus asperatus (Gyll.) infests the bark in the tops of poplars that are in poor vigor, often on trees attacked by other insects such as borers and defoliators. This insect may cause dieback and prepare the way for diseases in weakened trees.

Agrilus sexguttatus Brahm. This borer, related to the bronze birch borer, feeds in the cambium and weakens or kills the tree by partial or complete girdling. It has damaged large trees in Germany. The first sign of damage—discoloration of the outer leaves of the crown—is followed by early leaf fall and death of the tree.

Gypsonoma sp. Serious but very localized damage on young trees, particularly in the nursery, was observed in several localities. The insects feed in the buds before entering and hollowing the young shoots. In Germany this injury is laid to *G. acerina* Dup. In Italy, it is reported that there is more than one species of this insect on poplars. Since the insect overwinters in the soil it can be controlled by rotation of nursery areas with other crops.

Insects on the Leaves

Stilpnotia salicis (L.), the satin moth, is one of the most serious defoliators of poplars in southern Europe. The larvae first feed on the surface tissues but later consume all of the leaf except the midrib. This insect is periodically epidemic in Italy, locally or widespread. Heavy infestations usually result in complete defoliation. Normally defoliation is followed by the development of new leaves, in young trees by increased epicormic branching; since the growth rate is impaired, a succession of epidemic years results in serious damage.

Chrysomela populi L., the red poplarleaf beetle, and *C. tremulae* F., the aspenleaf beetle, are distributed over all of Europe. *C. populi* has caused serious defoliation in many localities from England to Italy. *C. tremulae* has been reported locally serious in Germany. The larvae skeletonize the leaves by feeding on the surface layers; and the adult beetles, which emerge during midsummer, cut irregular holes in the leaves.

Plagiodera versicolora (Laich.), the imported willow-leaf beetle, causes leaf damage similar to that described for *Chrysomela* spp.

Phratora spp. Three species of blue poplar-leaf beetles, *P. vulgatissima* (L.), *P. vitellinae* (L.), and *P. laticollis* Suffr., have been reported on poplars in Europe. These are small beetles ⅛ to ⅙ inch in length, of a blue-black metallic lustre with shades of bronze to green, particularly on the under side. Both the larvae and the adult beetles skeletonize the leaves. The adults cause additional damage by feeding on the very young shoots.

Epidemic infestations of leaf beetles in nurseries and recently established plantings are easily controlled by spraying. Heavy infestation in established plantations is apparently rare; no instances of serious plantation damage were brought to the author's attention.

Dicranura vinula (L.), the puss moth, has occasionally caused considerable defoliation of poplars in Italy and in England. The poplar kitten, *D. hermelina* Goeze, is of minor importance.

Cladus viminalis Fall, the poplar sawfly, and *Croesus septemtrionalis* L., the birch sawfly, occasionally cause local epidemic defoliation.

Hyphantria cunea (Drury), the fall webworm. At the 1952 International Poplar Commission meetings in Rome it was reported that the fall webworm, introduced into Yugoslavia from America, feeds on about 70 species of plants and is a very serious threat to poplar. It has two and possibly three generations per year in Yugoslavia. This introduced insect is spreading rapidly in Hungary and adjacent countries.

Leaf miners are distributed throughout all Europe but are generally considered of minor economic importance. There is no information on how damaging heavy infestations by *Phytagromyza populi* Kalt. (the poplar leaf miner), *Zeugophora scutellaris* Suffr., and other leaf miners may be to the growth and general health of poplars. In mid-August 1952 the author observed heavy infestations on *P.* ×*canescens* in the vicinity of Stockholm, Sweden, and on native aspen along the highway from Oslo, Norway, to the Swedish border. Infested trees were easily recognized by the gray appearance of the foliage.

Chalcoides aurata (Marsh.) and *C. helxines* (L.), flea beetles, are occasionally numerous enough in nursery plantings to require control by spraying.

Chaitophorus spp., poplar-leaf aphids. Two species, *C. populi* L. and *C. leucomela* Koch., are often found in large numbers on young leaves and shoots. Insects of the second species produce blisters on the leaves, and in England they are believed to be associated with infection by the fungus *Taphrina aurea*. Damage by leaf aphids is seldom serious.

Pemphigus spp., gall aphids. There are several species of aphids that are responsible for galls on the leaf blades or petioles. The most common of these belong to the genus *Pemphigus*. The leaf-gall aphid (*P. affinis* Koch.) produces galls on the leaf blades; *P. spirothecae* Passerini (the spiral-gall aphid) attacks the leaf petioles; and *P. bursarius* L. produces galls on the petioles and on the midrib of the leaf. In Spain, heavily infested columnar *P. nigra* types were growing in proximity to wide-spreading *P. nigra* trees that were practically free of these aphids. This probably indicates clonal differences in susceptibility.

Harmandia loewi (Rübs.), the poplar gall-midge, produces galls on the leaf petioles. Aspen is reported to be the favorite host.

Byctiscus spp. Two species of these leaf rollers, *B. populi* (L.) and *B. betulae* (L.), have been reported responsible for some injury to poplar in Germany and Italy.

Insects on the Bark

The poplar-bark aphid (*Pterochlorus salignus* Gmelin.) and the willow-bark aphid (*Melanoxantherium salicis* L.) are widely distributed on the bark of poplars. Vigor of the tree is drastically curtailed by very heavy infestation and it is also possible that these insects may be a link in the spread of bacterial or fungous diseases. A woolly aphid (*Eriosoma*) is sometimes very heavy on poplars in southern Europe.

Phleomyzus passerinii Sign., the woolly aphid of poplar, is a serious pest in Italy. Heavy infestations have necessitated felling thousands of young trees. Dr. Vivani's studies indicate inherent variation in susceptibility to this insect. Clones *P.* 'I–28' and 'I–65' are highly susceptible. Clones 'I–214,' 'I–455,' the cultivar 'Carolin,' and *P. alba* are reported to be "exempt from infestation."

Cimbex variabilis Klg. The male of this sawfly gnaws the bark of poplar shoots, forming deep spiral grooves that sometimes completely girdle the young stems. Where the leader is completely girdled it usually breaks off before the end of the year. Occasional injury by this insect was observed in most of the poplar regions of Europe.

Significance for the United States

There is observational evidence in Europe of possible clonal variation in susceptibility to scale insects, leaf-gall aphids, and leaf beetles.[13] There is practically no evidence of inherent variation in susceptibility to boring insects.

In sufficiently large numbers, borers that feed in the cambium, such as *Agrilus* species, can kill even the largest trees by girdling. Wood borers that live in the bark in their early stages (*Saperda*) seldom kill large trees, but small trees may break off at the point of injury. These boring insects are particularly damaging because their large burrows may be so numerous that the timber can be used only for cellulose.

Leaf-feeding insects seldom cause high mortality even under epidemic conditions unless such epidemic feeding is continued for several years. But these insects are important because heavy defoliation seriously retards growth and may weaken the trees to such a degree that they are highly susceptible to attacks by other insects and diseases. Leaf aphids seldom cause appreciable damage

[13] Research at the Northeastern Forest Experiment Station, U. S. Forest Service, has demonstrated inherent clonal variation in susceptibility to the Japanese beetle. (U. S. Dept. Agr. Yearbook 1949: 157.)

except in nursery plantings where they are easily controlled. Infestations of aphids and scale insects on the bark can be heavy enough to injure or kill plantation trees.

Several of the European poplar insects have been introduced into this country. The leopard moth (*Zeuzera pyrina*) is known to occur in the Northeastern States from Philadelphia to the northern border of Massachusetts. Although elms and maples are the favorite host plants in the United States, many other deciduous trees—including poplars—are attacked.

The horned clearwing moth has also been introduced into this country. It is widely distributed throughout the northern part of the United States and has been reported as the cause of severe injury to the large roots of poplars in the vicinity of Revere, Mass. There is also a native species of this insect that attacks poplars and willows; it is similar in appearance to the European species and is often mistaken for it.

The poplar and willow borer (*Sternochetus lapathi*) has become established from Maine west to Ontario and northern Wisconsin and south to Virginia. In recent years it has also been found in Washington and Idaho and it is said to be spreading to other areas. In the United States it attacks willow, alder, poplar, and birch. It has proved particularly serious to poplar and willow nursery stock and newly planted trees.

The short-snouted weevil, *Barypeithes pellucidus* Boh., is recognized as a strawberry pest in the United States.

The satin moth (*Stilpnotia salicis*) is now widely distributed in New England and the Maritime Provinces of Canada. It is also present in the Pacific Northwest and British Columbia west of the Cascade Range. It has been responsible for serious local defoliation of poplars in New England since it was first discovered in Massachusetts in 1920. The damage to poplars in New England is less serious than in southern Europe because in New England the insect produces only one generation per year.

Several European leaf beetles have also appeared in the United States: the European leaf beetles (*Chrysomela interrupta* F. and *C. tremulae* F.) and the imported willow leaf beetle (*Plagiodera versicolora* Laich.). The latter is now common in New England and extends into western New York and south to Virginia. Severe infestations in the United States, as in Europe, are not common; but when they do occur they cause considerable damage.

The European poplar sawfly (*Trichiocampus viminalis* Fall.) is now distributed from New Jersey through the Northeastern States into eastern Canada and west into British Columbia. Serious defoliation of shade and ornamental poplars has been reported.

The cottonwood leaf-mining beetle, *Zeugophora scutellaris* Suffr., has also been introduced into the United States.

In addition to the introduced pests we also have related native species of several important European poplar insects. The native poplar borer (*Saperda calcarata* Say) produces the same damage as the European longhorn poplar borer. *Saperda concolor* Lec., our native poplar-gall saperda, is similar in its attack on poplar to the European *Saperda populnea* L. We also have native cambium miners in the United States, which cause damage similar to that of the European poplar cambium borer (*Phytobia*) on many species, including poplars. The bronze birch borer, *Agrilus anxius* Gory, attacks poplars and aspens in the United States with the same effect as the European member of this genus.

The giant American sawfly (*Cimbex americana* Leach) has been reported as occasionally infesting poplars. Although the European puss moth has not been reported in this country, we have native species on poplar that are related to this insect. There are three native species of gall aphids (*Pemphigus*) that attack poplars in the United States. Our native scale insects can cause serious injury to newly planted trees; in 1950 the author saw a young plantation in Michigan where the poplars were dying back from extremely heavy scale infestation.

Control of boring insects whose burrows open through the bark is possible by the injection of fumigants. Insects that feed under the bark, without such openings, can be controlled by spraying with DDT or other suitable insecticides when the insects are moving. Sanitation—removal and burning of infested branches and trees—is a practical control measure. Heavy infestations of leaf insects in plantations can be controlled by modern spraying methods. Control of leaf miners and aphids will seldom be necessary in plantations.

It is apparent in Europe that under conditions of intensive poplar culture both defoliator and boring insects can cause serious economic loss by degrading the timber, by killing the trees, or by severely retarding their growth. Control by modern methods, using mist blowers and airplanes for spraying or dusting, should be economically feasible for poplar plantations. Spraying for the control of boring insects will require exact knowledge of the life cycle of the insects because the control must be applied when the mature insects are moving and laying their eggs.

DAMAGE BY OTHER AGENTS

Mistletoe

Poplars in north-central France are often heavily parasitized by mistletoe (*Viscum album* L.). 'Regenerata' is particularly susceptible, but other cultivars are also attacked. Mistletoe can be unbelievably heavy on branches, and it also occurs on the upper part of the trunks. It is said that mistletoe does not appreciably retard growth, but the trunk wood penetrated by the haustoria cannot be used for veneer or lumber. This represents a relatively minor loss.

Environmental and Climatic Damage

Environmental conditions that reduce growth vigor are often the primary cause of decadence. Abnormally dry weather, sites that are too dry or too wet, soils that are infertile or too acid, and other environmental conditions such as the inhibiting effect of sod, or crowding in plantings of a single clone, can condition the stand for further injury by insects and diseases. Borers and such facultative parasites as *Valsa* and *Dothichiza* may damage and kill many trees that have been weakened by adverse environment.

Poplars are susceptible to wind breakage, but on deep soils such damage is usually limited to the branches—rather than uprooting of the trees. Although recovery from mechanical injury is rapid on good sites, the broken branches provide possible entry points for fungi and bacteria. There is occasional local damage to tops and branches from the accumulation of snow, ice, or sleet. Local hailstorms can be extremely damaging. One- and 2-year-old plantations, on the Plaine de l'Orbe between Lake Neuchatel and Lake Geneva, were completely ruined by a hailstorm so severe that large branches of old trees were stripped of their bark.

Late spring frosts occasionally defoliate susceptible clones by killing the young leaves and shoots. Although there is seldom appreciable retardation of the current year's growth, there is no information about the extent to which such frost damage may facilitate invasion by insects, fungi, and bacteria. Frost damage can be avoided by the selection of frost-hardy clones.

Frost-crack on the lower trunk was observed in several countries. In some localities frost-crack damage is severe on susceptible clones—for example, on *Populus* 'Robusta' in northwestern Germany—but it is not generally serious throughout Europe.

Salt-spray injury is common on the Aigeiros poplars where they are used for windbreaks in maritime areas. *Populus* ×*canescens* is more resistant to such conditions and is used extensively in northwestern Germany and in Denmark for windbreaks in coastal areas.

Damage by Animals

Browsing damage by cattle and deer, and girdling by rabbits, are a menace in many parts of Europe where grazing and hunting are major sources of income from the land. Under such conditions each newly planted poplar is protected against cattle and deer by high woven-wire guards, by barbed wire loosely wrapped around the stem, or even by single-bar fences supported on 3 or 4 posts around each tree. Wire mesh or tar-paper guards are placed around each tree for protection against rabbits. Repellent sprays are sometimes used, but they are not generally considered reliable.

Significance for the United States

The environmental and climatic factors described as deleterious to poplars in Europe are equally damaging to poplars in this country. We have long recognized adverse site condition as the most important limiting factor for profitable poplar culture. For both biological and economic considerations, poplars should be planted only where site and climate are favorable for the maintenance of their normal growth rate.

The risk of wind, snow, ice, and hail damage must be considered in localities where trees in forest stands or in rows are subject to such injury. The rapid recovery of poplars from top breakage should be one of the factors included in the calculation of the economic risk.

Frost and frost-crack injury can be avoided by selection of clones tested for adaptability to the local climate.

On the basis of European experience, *P.* ×*canescens* cultivars should be selected for maritime exposures.

Poplars will require protection against animals, particularly deer and rabbits, where the animal population is high. Fencing, as practiced in Europe, will not be practical for extensive plantings under present conditions. The development of effective repellents offers the best possibilities for economical protection.

GROWTH AND YIELD

Aigeiros Poplars in Plantations

Comparable and precise data on growth and yield of Aigeiros poplars are rare in Europe. Variations among different clones designated under the same cultivar name, and inadequate information about planting stock, planting methods, and early care of plantations permit only empirical growth-and-yield comparisons among countries, cultivars, sites, spacings, and culture.

Excerpts from published data on yield of poplar in Spain, Italy, and Germany are presented in table 1. The close spacing and/or intensive culture on excellent soils are reported to produce average annual increments as high as 490 cubic feet per acre on 11- to 12-year rotations in Spain, and 500 cubic feet per acre on 25-year rotations in Italy. Average annual increment for 25-year rotations on site class I in Germany is reported as 392 cubic feet per acre; on site class III, as 120 cubic feet per acre.

Productivity of plantations examined by the author

More than 150 plantations were inspected by the author, but sufficient information for a reasonably accurate estimate of growth and yield was available for only 64 plantations (table 2). The ages listed in the table are the years since plantation establishment—1, 2, or 3 years less than the total age of the trees. Descriptions of site conditions and spacing for the individual plantations are given in the appendix, p. 119.

Summary by cultivar and country

The minimum, average, and maximum annual increments for cultivars and for countries, based on the 64 cases in table 2, are given in table 3. *P.* 'Marilandica' showed the lowest average annual increment. The fact that the 13 mixed plantings produced the highest average increment substantiates the biological soundness of clonal mixtures.

TABLE 1.—*Excerpts from published data on yield of poplar in Europe* [1]

Age (years)	Spain						Italy			
	Granada			Logrono			162 trees per acre		101 trees per acre	
	Trees per acre (average)	Total yield per acre	Average annual increment per acre	Trees per acre (average)	Total yield per acre	Average annual increment per acre	Total yield per acre	Average annual increment per acre	Total yield per acre	Average annual increment per acre
	No.	*Cu. ft.*	*Cu. ft.*	*No.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
6	1,240	2,401	400	324	2,801	476	1,358	226	1,100	183
7		3,015	430				1,686	241	1,436	205
8		3,658	457				2,058	257	1,829	229
9		4,287	476	324	3,658	406	2,472	275	2,272	252
10	840	4,873	487				2,929	293	2,772	277
11		5,416	492				3,430	312	3,358	305
12		5,887	491	324	5,487	457	3,965	330	4,073	339
13		6,259	481	324	5,259	405	4,494	346	4,687	361
14	660	6,516	465				5,009	358	5,402	386
15		6,588	439				5,502	367	6,130	409
16		6,602	413				5,973	373	6,873	430
20				253	7,802	390	7,674	384	9,660	483
25							9,288	372	12,518	501

Age (years)	Germany								
	Site class I			Site class II			Site class III		
	Trees per acre (average)	Total yield per acre	Average annual increment per acre	Trees per acre (average)	Total yield per acre	Average annual increment per acre	Trees per acre (average)	Total yield per acre	Average annual increment per acre
	No.	*Cu. ft.*	*Cu. ft.*	*No.*	*Cu. ft.*	*Cu. ft.*	*No.*	*Cu. ft.*	*Cu. ft.*
10	324	1,600	160	324	1,029	103	648	457	46
15	162	4,687	312	162	2,286	152	324	1,486	99
20	81	7,545	377	81	3,458	173	162	2,515	126
25	40	9,803	392	40	4,544	182	81	3,344	134
30	40	11,375	379	40	5,373	179	40	3,915	130
40	40	15,176	379	40	7,759	194	40	4,844	121
50	40	19,334	387	40	9,746	195	40	6,002	120

[1] Data derived from the following reports:

Anonymous. *VIII Sesion de la Comision Internacional del Chopo en España.* Ministerio de Agricultura, Patrimonio Forestal de Estado. 460 pp., illus. Madrid. 1955.

Piccarolo, Giacomo. *Il pioppo. norme pratiche di cultivazione.* Ramo editoriale degli agricoltori. 130 pp., illus. Rome. 1952.

Hesmer, H. (editor). *Das pappelbuch.* Deut. Pappelverein. 304 pp., illus. Bonn. 1952.

The figures for The Netherlands may be somewhat low because the stands on which data were obtained in this country were all *P.* 'Marilandica,' a relatively slow-growing clone.[14] The high values for Italy and Spain are a reflection of the favorable climate, long growing season, highly fertile soils, and intensive culture.

[14] They are, however, higher than the 6.5 cubic meters "average annual increase per hectare" (93 cubic feet per acre) reported by G. Houtzagers in 1937.

TABLE 2.—*Productivity of European poplar plantations*
(Volume estimates based on peeled wood to 2.75-inch top diameter)

NETHERLANDS

Case No. and cultivar [1]	Residual stand						Thinnings		Total	
	Trees per acre	Age	Average d. b. h.	Average height	Stand volume per acre	Average annual increment per acre	Age	Volume removed per acre	Volume	Average annual increment per acre
	No.	*Yrs.*	*Ins.*	*Ft.*	*Cu. ft.*	*Cu. ft.*	*Yrs.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
1. *P.* 'Marilandica'	68	21	15.4	81	2,501	119	------	------	2,501	119
2. Do	79	32	16.1	92	3,558	111	------	------	3,358	111
3. Do	55	35	18.7	95	3,344	96	------	------	3,344	96
4. Do	53	32	17.3	96	2,844	89	27	(1)	+2,844	+89
BELGIUM										
5. 'Regenerata'	100	16	12.2	72	2,115	132	10	972	3,087	193
6. Do	80	21	13.4	79	2,201	105	10	272	------	------
							11	457	------	------
							17	400	3,330	158
7. 'Robusta'	------	18	------	------	2,415	134	(1)	(1)	+2,415	+134
GERMANY										
8. *P.* ×*canadensis*	------	56	24.4	121	[2] 5,059	90	------	------	5,059	90
9. Do	------	56	33.8	125	[2] 9,932	177	------	------	9,932	177
10. Unnamed	83	10	8.7	51	672	67	------	------	672	67
11. Do	63	11	11.8	54	1,015	92	------	------	1,015	92
12. Do	53	32	20.5	107	4,201	131	------	------	4,201	131
13. Do	115	12	11.8	75	2,444	204	------	------	2,444	204
14. Do	115	16	16.5	89	5,259	329	------	------	5,259	329
15. Do	53	23	23.2	98	5,016	218	------	------	5,016	218
16. 'Robusta'	260	12	9.4	62	3,115	260	(1)	(1)	+3,115	+260
17. Do	132	13	9.4	71	1,729	133	------	------	1,729	133
18. Do	337	15	[3] 9.4	[3] 69	4,287	286	------	------	4,287	286
19. Do	146	25	16.5	95	7,102	284	------	------	7,102	284
20. Do	162	17	12.6	72	3,658	215	------	------	3,658	215
21. Do	700	13	5.1	48	1,972	152	------	------	1,972	152
22. Do	214	13	6.3	48	900	69	------	------	900	69
23. Do	------	14	7.7	54	1,572	112	10	43	------	------
							13	257	1,872	134
24A. Do	223	14	11.4	62	3,773	270	(1)	(1)	+3,773	+270
24B. Do	223	14	7.1	52	1,258	90	(1)	(1)	+1,258	+90
25. Do	135	17	9.4	69	1,715	101	14	527	2,242	132
26. 'Regenerata'	42	24	19.7	82	2,529	105	------	------	2,529	105
27. Do	115	28	------	------	3,450	123	------	------	3,450	123
28. 'Regenerata Harff'	------	54	[4] 47	[4] 148	10,260	381	------	------	10,260	190
29. Do	------	55	[4] 47	[4] 148	10,260	374	------	------	10,260	187
30. Do	------	31	28	112	[5] 6,040	390	------	------	6,040	195
31. 'Marilandica'	45	37	22.8	102	4,216	114	(1)	(1)	------	------
							32	1,715	+5,931	+160
32. Unnamed	28	41	26.1	125	3,973	97	(1)	1,043	5,016	122
	15	57	33.3	140	3,947	69	(1)	2,715	7,705	135
33. Do	20	60	34.2	135	5,277	88	(1)	(1)	+5,277	+88
34. 'Marilandica'	26	57	30.4	125	5,073	89	(1)	(1)	+5,073	+89
35. 'Regenerata'	40	41	22.4	125	4,344	106	(1)	(1)	+4,344	+106
36. *P.* ×*canadensis*	71	22	15.3	100	3,643	166	(1)	1,143	4,786	218
37. Do	34	50	------	------	10,003	200	------	------	10,003	200

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TABLE 2.—*Productivity of European poplar plantations*—Continued

GERMANY—Continued

Case No. and cultivar[1]	Residual stand: Trees per acre	Residual stand: Age	Residual stand: Average d. b. h.	Residual stand: Average height	Residual stand: Stand volume per acre	Residual stand: Average annual increment per acre	Thinnings: Age	Thinnings: Volume removed per acre	Total: Volume	Total: Average annual increment per acre
	No.	*Yrs.*	*Ins.*	*Ft.*	*Cu. ft.*	*Cu. ft.*	*Yrs.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
38. *P.* ×*canadensis*	32	60	39.4	138	11,432	191	------	---------	11,432	191
39. *P.* ×*canadensis* mixture	140	17	13.0	89	4,301	253	([1])	543	4,844	285
40. Do	121	18	11.8	85	3,044	169	([1])	([1])	+3,044	+169
41. Do	101	28	16.5	95	4,930	176	([1])	([1])	+4,930	+176
42. Do	101	38	18.1	102	6,202	163	([1])	4,001	10,203	268
FRANCE										
43. *P.* 'Virginiana'	83	13	14.6	75	2,572	198	------	---------	2,572	198
44. 'Robusta'	83	20	18.5	82	4,373	219	------	---------	4,373	219
45. 'Serotina de Champagne'	83	14	8.3	49	612	44	------	---------	612	44
46. 'Regenerata', 'Robusta'	87	24	11.8	66	1,629	68	------	---------	1,629	68
47. 'Virginiana'	42	28	19.3	98	2,815	100	------	---------	2,815	100
48. Do	75	45	22.0	126	8,088	180	------	---------	8,088	180
49. 'Robusta'	81	20	14.6	105	3,544	177	------	---------	3,544	177
50. Do	253	18	9.0	70	3,044	169	------	---------	3,044	169
51. 'Italica' mixture	------	25	--------	--------	4,501	180	------	---------	4,501	180
52. Do	269	20	11.0	59	4,087	204	------	---------	4,087	204
53. 'Regenerata', 'Robusta'	112	20	13.8	75	3,144	157	------	---------	3,144	157
SWITZERLAND										
54. *P.* ×*canadensis* mixture	------	55	--------	--------	9,289	169	([1])	([1])	+9,289	+169
ITALY										
55. *P.* 'I-214'	115	5	8.0	50	770	154	------	---------	770	154
56. Do	115	7	6.0	53	486	69	------	---------	486	69
57. Do	115	7	10.0	59	1,386	198	------	---------	1,386	198
58. Do	115	1	15.0	98	4,930	448	------	---------	4,930	448
59. Mixture of clones	130	16	16.0	112	6,859	429	------	---------	6,859	429
60. 'I-214'	128	6	8.0	65	1,128	188	------	---------	1,128	188
61. 'Monilifera' mixture	162	9	9.0	98	3,087	343	------	---------	3,087	343
62. Mixture of clones	115	17	17.7	108	7,174	422	------	---------	7,174	422
SPAIN										
63. Unnamed	253	5	8.3	49	1,872	374	------	---------	1,872	374
64. Mixture of clones	162	11	10.0	70	2,229	203	------	---------	2,229	203

[1] One or more thinnings were made but data were not available on age of thinning or volume removed.
[2] Volume estimates based on 40 trees per acre.
[3] These values are for inside trees only; border trees average 14.2 inches in d. b. h. and 79 feet in height.
[4] Measurements of the best trees; volume estimates based on 20 trees per acre.
[5] Volume estimate based on 40 trees per acre.

TABLE 3.—*Summary of poplar growth by cultivar and country*

Item	Cases	Annual increment per acre [1]		
		Minimum	Average	Maximum
Cultivar:	*No.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
'Marilandica'	6	+89	+111	160
'Regenerata'	5	105	+137	193
'Virginiana'	3	100	159	198
'Robusta'	15	69	+182	286
Unnamed	9	67	+176	374
P. ×*canadensis*	5	90	175	218
'Regenerata Harff'	3	187	191	195
'I-214'	5	69	211	448
Mixed plantings	13	68	+236	429
Country:				
The Netherlands	4	+89	+104	119
France	11	44	154	219
Belgium	3	+134	+162	193
Switzerland	1	----------	169	----------
Germany	37	67	+171	329
Italy	8	69	281	448
Spain	2	203	288	374

[1] Based on the annual increments listed in table 2.

An owner of three poplar estates of approximately 100 acres each in the Seine Valley in France has obtained the following yields:

Soil:	*Rotation (years)*	*Total yield per acre (cu. ft.)*	*Average annual increment per acre (cu. ft.)*
Very best	25	6, 300	252
Good and deep	25	4, 650	186
Good but shallow (average)	30	1, 860	62

These figures are not inconsistent with the average for the 11 French plantations listed in table 3; but the 252 cubic feet of annual increment on the very best sites on these estates in the Seine Valley does exceed the maximum for the 11 plantations listed in the table. It is not so high as the maximum for Germany.

Comparisons of site, culture, spacing, and age

Site.—The broad site classifications "good" and "poor" are based on the author's observations, including soil borings where necessary and feasible, and information provided by the local foresters or owners. Enough information was available for classing 38 cases as good and 7 cases as poor (table 4). The difference in average productivity was 106 cubic feet per acre per year. Statistically, this was highly significant.

Culture.—To gage the effects of culture, 32 stands that were given at least 1 year of cultivation or intercropping after planting, or were established on sites with a forest floor, were compared with 24 stands in which the poplars were planted in grass without cultivation (table 4). The difference in average annual increment, 32 cubic feet per acre, was not statistically significant.

Grass retards the growth of newly planted poplars during the first years after planting. This inhibiting effect is particularly serious because the weakly growing trees are highly susceptible to adverse climatic conditions, diseases, and insects. On deep soils the trees that have escaped serious injury usually recover their normal growth rate after 3 to 5 years. It is most probable that these growth-and-yield data are not sufficiently precise for evaluating this early reduction in productivity because they are confounded with other unknown or unmeasurable environmental factors.

Spacing.—For comparing the effect of spacing on productivity, the data were grouped into three classes based on the average growing space available per tree: (1) less than 269 square feet (approximately 16.4 by 16.4 feet); (2) 269 to 538 square feet; and (3) more than 538 square feet (approximately 23.3 by 23.3 feet). Comparisons of the average annual increments of these spacing classes are listed in table 4.

The difference in average annual increment between spacings of less than 269 square feet and more than 538 square feet is statistically significant. The difference between 538 square feet and 269 to 538 square feet falls just short of statistical significance.

The average annual increment for spacings of more than 23.3 by 23.3 feet is 64 and 54 cubic feet per acre less than with closer spacings. This loss of more than 25 percent in productivity reflects incomplete use of the total available growing space.

Age.—The age comparisons for Italy and Spain were analyzed separately (table 4) because of the short rotations in these countries. The difference of 155 cubic feet per acre per year in favor of the 10- to 19-year-old plantations indicates the soundness of Italian and Spanish recommendations for rotations of 20 to 25 years.

The data for all cases except Italy and Spain (table 4) show the average annual increment of three age groups to be as follows:

Years:	*Average age*	*Cubic feet per acre per year*
10–19	14. 5	173+
20–29	23. 3	167+
29+	46. 2	149+

Although the differences among these age groups are not statistically significant on the basis of these data, these figures do suggest that the maximum volume productivity in the observed plantations was reached some time between the 14th and 23d years. Although there is a further decrease in average annual increment between the 23d and 46th years, this is not large enough to preclude the profitable production of large, high-quality timber. The high price of large high-quality veneer logs in Europe will provide a good profit on longer rotations.

TABLE 4.—*Comparisons to show effect of site, culture, spacing, and age*

Item	Cases	Average annual increment per acre	Difference between means; computed value of t; value of t needed for significance
SITE			
	No.	*Cu. ft.*	
Good sites	38	205	Difference=106 cubic feet/acre t=2.82 [1]
Poor sites	7	99	t (for P=0.01)=2.69
CULTURE			
Forest, or early cultivation or intercropping	32	+191	Difference=32+ cubic feet/acre t=1.27
Poplars in grass	24	+159	t (for P=0.05)=2.00
SPACING: GROWING SPACE			
269 to 538 square feet	26	+201	Difference=10+ cubic feet/acre t=0.34
Less than 269 square feet	18	+191	t (for P=0.05)=2.01
269 to 538 square feet	26	+201	Difference=64+ cubic feet/acre t=1.99
More than 538 square feet	13	+137	t (for P=0.05)=2.02
Less than 269 square feet	18	+191	Difference=54+ cubic feet/acre t=2.25 [2]
More than 538 square feet	13	+137	t (for P=0.05)=2.04
AGE			
Italy and Spain:			
Less than 10 years (average 6.5 years)	6	221	Difference=155 cubic feet/acre t=2.06
10 to 19 years (average 13.8 years)	4	376	t (for P=0.05)=2.26
All cases except Italy and Spain:			
10 to 19 years (average 14.5 years)	21	+173	Difference=6+ cubic feet/acre t=0.23
20 to 29 years (average 23.3 years)	15	+167	t (for P=0.05)=2.04
10 to 19 years (average 14.5 years)	21	+173	Difference=24+ cubic feet/acre t=0.99
More than 29 years (average 46.2 years)	20	+149	t (for P=0.05)=2.02
20 to 29 years (average 23.3 years)	15	+167	Difference=18+ cubic feet/acre t=1.01
More than 29 years (average 46.2 years)	20	+149	t (for P=0.05)=2.04

[1] Significant at 1-percent level.
[2] Significant at 5-percent level.

Aigeiros Poplars in Row Plantings

There are thousands of row plantings in Europe (fig. 28 and fig. 29). In the poplar regions of France and Italy it was possible to inspect 10 to 20 such plantings in a day's drive. Unfortunately, information sufficient for comparative evaluation of their productivity was seldom available. Data on 23 of the more than 300 row plantings examined by the author are presented in table 5. A description of the plantings is given in the appendix, p. 123.

Estimation of productivity of row plantings on a per-acre basis is impractical; therefore volume and average annual increment have been estimated on the basis of 100 feet of row.

TABLE 5.—*Productivity of European poplar in row plantings*

(Volume estimates based on peeled wood to 2.75-inch top diameter)

Case No. and cultivar	Spacing	Age	Average tree: Diameter breast high	Average tree: Height	Average tree: Volume	Average tree: Average annual increment	100 feet of row: Trees	100 feet of row: Volume	100 feet of row: Annual increment
	Ft.	*Yrs.*	*Ins.*	*Ft.*	*Cu. ft.*	*Cu. ft.*	*No.*	*Cu. ft.*	*Cu. ft.*
65. *P.* 'Heidemij'	15	35	31.5	90	171	4.9	6.7	1,146	32.7
66A. 'Serotina'	7	15	11.8	66	19	1.3	14.3	272	18.1
66B. Do	7	16	12.0	69	20	1.3	14.3	286	17.9
66C. Unnamed	7	17	16.1	75	38	2.2	14.3	543	31.9
67. 'Robusta'	16	13	12.6	66	21	1.6	6.3	132	10.2
68. Do	21	13	13.4	69	24	1.8	4.8	115	8.8
69. Do	13	15	11.0	69	17	1.1	7.7	131	8.7
70. Do.[1]	33	18	18.5	79	52	2.9	3.0	156	8.7
70. *P. alba*	33	18	11.4	66	18	1.0	3.0	54	3.0
71. 'Robusta'	20	18	15.0	82	35	1.9	5.0	175	9.7
72. Do	26	18	17.3	75	44	2.4	3.8	167	9.3
73. Do	23	19	13.1	77	24	1.3	4.3	103	5.4
74. Do	20	20	15.4	79	36	1.8	5.0	180	9.0
75. 'Serotina'	20	20	15.7	75	36	1.8	5.0	180	9.0
76. Do	21	22	17.7	75	46	2.1	4.8	221	10.0
77. Unnamed	23	23	18.5	100	63	2.7	4.3	271	11.8
78. Do	33	38	26.0	100	122	3.2	3.0	366	9.6
79. Do	49	60	43.2	131	426	7.1	2.0	852	14.2
80. Mixture of clones	28	23	22.0	82	75	3.3	3.6	270	11.7
81. 'Serotina'	13	19	17.7	79	47	2.5	7.7	362	19.1
82. 'Robusta'	25	29	25.2	110	127	4.4	4.0	508	17.5
83. Do	25	28	21.3	90	74	2.6	4.0	296	10.6
84. 'Regenerata'	25	28	23.2	90	89	3.2	4.0	356	12.7
85. 'Serotina' [2]	[3] 16	27	14.6	82	34	1.3	6.3	214	7.9
	[4] 16	27	15.7	82	38	1.4	6.3	239	8.9

[1] Mixed planting of *Populus alba* and 'Robusta'. The data on *P. alba* are included for comparison of its slower growth rate with that of 'Robusta'; they are not included in the computations or comparisons in the text.

[2] 4-row planting, rows 20 feet apart.

[3] Trees in inside rows.

[4] Trees in outside rows.

Average, minimum, and maximum yields

These data should be used only for empirical comparisons. They are too meager to warrant rigorous statistical analysis.

The average annual increment for all cases is 13.8 cubic feet per 100-foot row, and the average age is 22.5 years. This is an

NED. HEIDEMIJ. (ARNHEM) photo

FIGURE 28.—Row planting of *Populus* 'Marilandica' in The Netherlands. The crooked stems are characteristic of this cultivar. Much timber in The Netherlands is grown along the roads and highways.

Photo by G. HOUTZAGERS

FIGURE 29.—Roadside planting of *Populus* 'Heidemij' on the new Northeast Polder, The Netherlands, underplanted with alder to be managed as coppice. The alder had been cut a year before the photograph was taken.

average total yield of 310 cubic feet (approximately 3.4 cords) per 100-foot row in 22.5 years. Minimum production (case 73) is 103 cubic feet (approximately 1.1 cords) per 100-foot row in 19 years. Maximum productivity (case 65) is 1,146 cubic feet (approximately 13 cords) per 100-foot row in 35 years.

Comparisons of cultivar, age, and spacing

Cultivars.—The average annual increment per 100-foot row for the cultivars represented in these row plantings is as follows:

Cultivar:	*Cases (no.)*	*Increment (cu. ft.)*
'Robusta'	10	9. 8
Mixed clones	1	11. 7
'Regenerata'	1	12. 7
'Serotina'	7	13. 4
Unnamed	4	16. 9
'Heidemij'	1	32. 7

TABLE 6.—*Productivity of aspen stands on good sites in Sweden*

Type of stand	Stands	Average annual increment of aspen per acre	Trees per acre [1]			Basal area per acre [1]		
			Aspen	Asso-ciates	Total	Aspen	Asso-ciates	Total
33- and 34-year-old stands of aspen and—	*No.*	*Cu. ft.*	*No.*	*No.*	*No.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*
Spruce	2	75	2,660	1,582	4,242	92	31	123
Spruce, birch, alder, ash	2	56	2,725	542	3,267	76	12	88
43- and 44-year-old stands of aspen and—								
Spruce	2	91	1,734	877	2,611	106	9	115
Spruce, birch, alder, ash	2	69	1,600	220	1,820	79	7	86
51- and 52-year-old stands of aspen and—								
Spruce	1	101	1,213	3,315	4,528	106	22	128
Spruce, birch, alder, ash	1	71	1,025	1,870	2,895	72	18	90

[1] Figures for number of trees and basal areas are the totals for the residual stand plus trees removed in intermediate cuttings. Trees lost through natural mortality are not included.

Age.—The average productivity per 100-foot row for each of four age groups is as follows:

Average age (yrs.):	*Cases (no.)*	*Average annual increment (cu. ft.)*	*Total volume (cu. ft.)*
16.5 (13–19)	11	13.4	221
24.7 (22–29)	9	10.9	269
36.5 (35–38)	2	21.2	774
60	1	14.2	852

Spacing.—The average annual increments per 100-foot row for three spacing classes are as follows:

Average spacing (ft.):	*Cases (no.)*	*Increment (cu. ft.)*
12 (7–16)	8	17.5
23 (20–28)	12	10.5
38 (33–49)	3	10.8

The d. b. h., height, and volume data for the average tree do not indicate any trend toward reduction in growth rate due to the closer spacings in these row plantings. The larger number of trees per 100-foot row is primarily responsible for the higher average yield of the 7- to 16-foot spacings. The effect of close spacing on log quality—crook, lean, eccentric growth—has been discussed in an earlier section.

Native Aspen in Scandinavia

The intensity of aspen management varies widely in Sweden and Norway. The following yields are frequently cited [15] as overall averages for aspen at 50 years of age:

Site class I: Total production—2,860 cu. ft./acre (57 cu. ft./acre/year).
Site class II: Total production—2,144 cu. ft./acre (43 cu. ft./acre/year).

The productivity of well-managed stands in southern Scandinavia is much higher than these overall averages. The native aspen stands in Skaraborg shire, between latitudes 58° and 59° (the latitude of northern Manitoba), are considered to rank among the best in Sweden. The information in table 6, based on sample areas on sites rated as good for aspen, is from a forest estate located between Vener Lake and Vetter Lake in Skaraborg.

The average annual increments, from 56 to 101 cubic feet per acre (0.62 to 1.1 cords), reflect intensive management. The consistently higher yields of aspen in association with spruce—in contrast to the lower yields in mixture with spruce, birch, alder, and ash—is particularly noteworthy. Since the sites are rated as good, the differences in yields between stands of practically identical ages might be predicated on differences in stand density, species composition, or both.

Differences between stands of similar ages in the number of aspens per acre are hardly sufficient to account for the higher yields and larger basal areas in the aspen-spruce association. The number of trees and the basal areas of the associated species are consistently lower in the aspen-spruce-birch-alder-ash association. There is, therefore, little or no justification for attributing the poorer growth of aspen in association with spruce, birch, alder, and ash to unfavorable stand density or to the tree size of the associated species. It is possible, if not probable, that species composition—the individual or collective effect of birch, alder, and ash—is responsible for the lower aspen yields.

Significance for the United States

Aigeiros poplars.—There is no doubt whatever that with intensive management we can obtain, and perhaps even surpass, the present European yields of Aigeiros poplars under similar climatic and site conditions. This will not necessarily require such extremely intensive culture as agricultural intercropping. We have one of the most productive natural poplar species, the American cottonwood, distributed throughout the eastern United States from Canada to the Gulf of Mexico. And we have under test many hybrids potentially as productive as any in Europe.

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[15] Barth, Agnar. *Aspen. Dens kultur og behandling for kvalitetsproduksjøn.* Fra ingeniør F. H. Frølichs fond for aspeskogsbruketš fremme Nr. 1. 87 pp., illus. Oslo. 1942.

The fast-growing Aigeiros cultivars that are in general use in Europe today stem from hybrids between the American cottonwood and the European black poplar. The cottonwood (*P. deltoides*) is the more productive of these two parent species. It produces its highest yields on the batture (overflow) lands of the lower Mississippi River Valley. In fully stocked natural stands, annual yields of 4 to 5 cords—approximately 360 to 450 cubic feet—per acre have been reported [16] as not uncommon. The average yield of fully stocked natural stands on these batture lands has been estimated to be 5,000 cubic feet at 20 years, 250 cubic feet per acre per year. The following yields per acre have been estimated for fully stocked natural stands on good sites in the Mississippi Delta region:[17]

At 5 years: 6 cords (approximately 540 cubic feet) (108 cubic feet/acre/year).
At 10 years: 24 cords (approximately 2,160 cubic feet) (216 cubic feet/acre/year).
At 15 years: 50 cords (approximately 4,500 cubic feet) (300 cubic feet/acre/year).

These estimates are for unmanaged stands. Managed stands, properly and regularly thinned, would exceed these yields. The use of élite native clones, selected for rapid growth, would further increase the productivity of this species in managed plantations. And the fact that most European hybrids exhibit hybrid vigor provides a sound basis for predicting that hybrids, bred and selected for our southern environments, would exceed the productivity of the fastest growing native clones in the optimum range of this species.

The yield of cottonwood is somewhat lower in the northern part of its range and on sites that are less fertile and drier than river-bottom lands subject to periodic overflow. Under such environmental conditions the European hybrids may be better than the natural species. The best European cultivars should be introduced, through strict plant quarantine, for the reasons mentioned in earlier sections. They would require at least 10 to 15 years of well-designed field testing before they could be safely recommended for commercial planting in this country.

There is no indication that the European cultivars will be more productive, at least in the northern half of the United States, than the best of the hybrids now under countrywide test by the Northeastern Forest Experiment Station. These hybrids were originally selected for survival and growth under New England's climatic conditions. The growth of the best hybrids in the original test plantations, established in 1927 and 1928 in western Maine, justifies the prediction of a minimum total yield of 40 cords (3,600

[16] Williamson, A. W. *Cottonwood in the Mississippi Valley.* U. S. Dept. Agr. Bul. 24, 62 pp., illus. 1913.

[17] Bull, Henry, and Muntz, H. H. *Planting cottonwood on bottom lands.* Miss. Agr. Expt. Sta. Bul. 391, 18 pp., illus. 1943.

cubic feet) of pulpwood per acre in 15 years (240 cubic feet per acre per year) with reasonably good plantation management on suitable upland soils.

Under intensive management on the best soils the yield could be much more. Open-grown hybrids on excellent sites in Massachusetts and Pennsylvania have reached 22 inches d. b. h. in 11 years. In row plantings, spaced 25 feet, the yield of such hybrids in 11 years would be approximately 240 cubic feet (or 21.8 cubic feet per year) per 100-foot row. This is comparable to the best growth of Aigeiros cultivars in European row plantings.

The higher average yield of clonal mixtures in European plantations strengthens the case against monoclonal stands.

Aspen.—Within its commercial range, the timber form and productivity of our quaking aspen (*P. tremuloides*) is fully as good as that of the European aspen. Studies in the Lake States have shown that at 50 years on good sites a yield of 47 cords per acre (84 cubic feet per acre per year) may be expected for unmanaged stands. The results of thinning experiments indicate that intensive management could raise the average annual increment on good sites well above 100 cubic feet per acre in less than a 50-year rotation.

Species hybridization, and possibly also racial hybridization, can be expected to provide new types of greater productivity than the native species.

Effect of associated species.—There is practically no experimental evidence on the possible inhibiting effect of associated species of forest trees on the growth of poplars. All poplar species and hybrids are classified as very intolerant to shading. Nevertheless, we have an experimental area on which root sprouts of hybrid poplars have survived for periods of 4 to 7 years under the complete shade of loblolly pines planted 2 by 4 feet apart. These poplars outgrew and overtopped the loblolly when the pines were between 10 to 18 feet in height. This indicates far greater tolerance to shading than is generally accorded to poplars; and, most significantly, it indicates absence of any seriously deleterious root interactions between the poplars and the pines.

On the other hand, during the past 30 years the author has observed plantings on equally good sites where the growth of poplars was severely retarded by brush and hardwood sprout growth that was mowed periodically to prevent overtopping the poplars. Since the poplars had full sunlight, the growth-retarding effect was apparently due to inimical root interactions. Experiments to provide answers to this problem are basic to any future recommendations for the management of Aigeiros species and hybrids, and of aspen, in mixture with other species.

On suitable soils hybrid poplars can be managed to produce a greater volume of wood per acre, and larger individual trees, in a shorter period of time than any other timber tree in the United States. Large-diameter, knot-free, high-quality veneer logs can be produced in 15 to 25 years. We have no other timber tree that can equal this combination of growth and wood-quality potential. But from the economic aspect such production must have commercial use and reliable markets.

On the basis of present utilization, covered in the next section, it is safe to predict that in areas where an adequate supply can be maintained, the demand for poplar logs will keep pace with greatly expanded production. The problem of marketing small local production has been discussed in the introduction.

The establishment of hybrid poplar plantations and their management for maximum quantity and quality production will require a somewhat higher investment than plantations of biologically less exacting timber species. But the yields on relatively short rotations will be sufficiently high to warrant the expectation of profitable dividends on the added investment.

For industrial and nonfarmer ownerships, poplar production will necessitate a cash investment that will require the maximum use of mechanical equipment to reduce to a minimum the use of hand labor. For the farmer, the investment in poplar production will usually represent the use of machinery available on the farm, his own supervision and labor, and the labor of his regular farmhands. This will seldom interfere with agricultural activities because most of the work with poplars can be handled as off-season jobs.

CHARACTERISTICS OF THE WOOD

The anatomical characteristics of some species of poplar are sufficiently distinct for reasonably accurate identification, but the wood of individual Aigeiros hybrids cannot be identified by this means. Yet there is evidence of differences among the wood of the various cultivars in their use requirements, the qualities and properties important for their conversion and use for veneer, lumber, pulp, and particularly for specialty products. These differences are due both to inherent variations and to the effect of environmental conditions under which the trees were grown.

Trees of the same cultivar are reliably reported to have different wood qualities, depending on the rate of growth, spacing, and possibly other environmental conditions. Research is under way in several European laboratories to evaluate the technical qualities and properties of the cultivars in common use. These studies are complicated by the fact that the same cultivar name may be applied to several clones, by the complex nature of some wood qualities, and by the effect of environmental factors that cannot be accurately measured and correlated with wood quality.

The following characteristics and qualities apply, in general, to the wood of the poplars grown in Europe. The wood is light in weight, light-colored—unless heartwood stain is present, free of resins, usually straight grained, and normally uniform in texture and workability because there is little difference between sapwood and heartwood and between spring and summer wood. In comparison with many other timber species it is a low-strength wood, but its toughness and strength properties are relatively high in proportion to its light weight.

Poplar holds nails and screws well, and its resistance to splitting by nails makes it a good box wood. It can be glued readily except where tension wood (gelatinous fiber) is present. Because of its white color it can be easily stained, and it takes paint and varnish well. It is generally odorless, though a Spanish report states that the wood of *Populus alba* "supplies good building material" but is not "valued for packing because it imparts to the goods a disagreeable smell."

Poplar wood is soft (easily dented) ; it does not splinter and it is easily veneered without previous steaming. It is a poor fuelwood because of its low density and fast burning. Nevertheless, in localities where fuel is scarce there is an excellent market for branch wood, prunings, and fagots.

The sapwood is preferred to heartwood for many uses. For this reason there is often a better market for fast-growing wood than for slow-growing timber that has a high percentage of heartwood. There are exceptions: in France the author was informed that roadside trees make better matchwood, because of their slower and more uniform growth, than trees grown on alluvial bottom lands.

Utilization in Europe

The uses of poplar wood in Europe are manifold. Although log sizes required for different uses vary from country to country, and even from locality to locality within a country, the following specifications for minimum diameters—without bark, small end of the bolt or log—represent a fair average for all of Europe:

2.3 inches: Round poles for construction use.
2.75 inches: Pulpwood. Some mills take peeled wood as small as 1.5 inches.
6.0 inches: Wooden shoes.
6.0 to 10.0 inches: Box and building lumber. Specifications for saw logs are extremely variable. The smaller sizes are frequently marketable in southern Europe; the minimum diameter in northern Europe is seldom under 8 inches.
7.5 inches: Matchwood.
10.0 inches: Lowest grade veneer, for chip baskets, etc.
15.7 inches: Rotary veneer.
19.0 inches: Highest grade sliced veneer.

Log-length specifications are extremely diverse, depending on local custom and factory requirements. Bolts of many lengths up to 8 feet are specified for specialty and veneer use, but many factories buy poplar in tree lengths.

Specialty uses

Poplar wood has many specialty uses because of its white color, lack of odor and resins, workability, softness, light weight, relatively high strength in proportion to its weight, and resistance to splintering. It is used for artificial limbs and is extensively used for wooden shoes. Minor uses include turnery products and kitchenware such as ladles, wooden spoons, and bowls. It is also used for the production of excelsior.

Large quantities are used for boxes and crates of all kinds and for slack cooperage. It is particularly useful for containers because of its lightness, the relatively high strength in comparison to its weight, and its nailing quality. In Germany it is preferred for crating large mirror glass. It is in demand for tubs, pails, and barrels to be used as food containers because of its lack of odor and resins. Since the wood does not splinter it has been used as a safety measure for trim in railway cars. Because of its light weight and freedom from splintering it is used for wagon construction, for the bottom of truck bodies, and for the manufacture of various types of handcarts and wheelbarrows.

Poplar is used in all countries for the manufacture of furniture, particularly for interior members. The Forest Research Institute in Spain has produced some excellent samples of molded furniture from poplar veneer.

Because of its softness and even texture, poplar is frequently used for drawing boards; and it is preferred for carving and toys. *P. alba* is used by at least one manufacturer in France for drafting instruments.

In recent years compressed-board products have been made from poplar. The compression of the wood raises the strength quality but also increases the density.

Veneers

Poplar is used in all countries for the production of both rotary and sliced veneer. It is veneered cold, without steaming or soaking, up to 6 months after cutting—and sometimes longer. Rotary veneer is used in the manufacture of matches (fig. 30), match boxes, fabricated plywood doors, plywood sheets for building purposes, cigar boxes, boxes for various packaging purposes, chip baskets, and woven baskets. It is used in Germany for storage-battery separators because of its freedom from chemical contaminants.

Some manufacturers of veneer baskets and boxes saw out short planks clear of knots to the width and length of the required veneer pieces. These blocks are then sliced on a guillotine-type machine that can cut through as much as 12 inches of poplar plank. The baskets or boxes are made immediately, without seasoning the veneer.

Sliced veneer is used to a considerable extent as a face veneer for furniture. Burly poplar, called Maser Pappel, commands a premium price for such use in Germany.

The presence of tension wood in poplar will make it unsuitable for veneer production. Tension wood causes warping and buckling of veneer; and it produces rough fuzzy surfaces when the wood is machined. Such surfaces are extremely difficult to work and are reported to require 60 percent more glue. The causes of tension wood are not definitely known but it is usually correlated with lean, eccentric growth, and possibly with the mechanical effect on the stemwood of swaying by wind. Other important defects that make the wood unsuitable for veneer use are insect and fungous damage, large knots, numerous small knots produced by epicormic branching, and, occasionally, spiral grain.

F-482569

FIGURE 30.—Poplar logs for matchwood, Saintines, France.

Lumber

The wood of the European black poplar has been used for centuries as round or sawed lumber for interior building construction where high strength is not required and where it is not subject to moisture. The Lombardy is preferred in the Mediterranean region of France for building construction because the wood is believed to be stronger than that of other poplars grown in the region. Round poles are used for rafters, stringers, and frequently for staging in the construction of buildings.

Poplar lumber must be carefully stacked and seasoned because it is subject to serious warping and twisting (fig. 31). Many mills saw the poplar logs into halves or into thick planks for seasoning, and resaw the seasoned lumber to the finished product. The lumber is stable after seasoning, and there is seldom warping after manufacture; but seasoned wood is somewhat more difficult to work than green wood.

Pulp

Poplar is used for both mechanical and chemical pulp, but in some localities the demand and higher prices for veneer and saw logs leaves only a small proportion of the supply available for pulpwood use. Practically all grades of paper, from writing paper and magazine stock to newsprint and wrappings, are made in Italy with a furnish containing poplar groundwood or chemical pulp. A mill in the Po Valley, visited by the author, was making

F-482570

FIGURE 31.—Members of the International Poplar Commission inspecting poplar lumber in the yard of a sawmill near Granada, Spain. All the lumber in this yard is poplar.

newsprint reported to be 50 percent unbleached poplar groundwood, 20 percent spruce groundwood, and 30 percent spruce sulfite; they also made a supercalendered sheet described as 70 percent bleached poplar groundwood and 30 percent spruce sulfite. A mill in southern Italy was using a furnish of 75 percent poplar groundwood and 25 percent coniferous chemical pulp.

Utilization in the United States

Our native poplars are utilized for the same purposes as the European poplars, with relatively few exceptions. Cottonwood lumber has been used in the upper Mississippi basin since pioneer days; and where it reaches its best development it has been an important veneer species for a long time. Records show that the excellent cottonwoods along the Hoosic River in northwestern Massachusetts and southwestern Vermont brought premium prices 100 years ago.

On the other hand, until very recently our native aspen was generally considered a weed tree, suitable only for limited pulpwood use. During the war years, this situation changed in the Lake States region. Since 1947 the Lake States Forest Experiment Station has published 22 reports by 9 cooperating agencies on the availability and supply, properties and uses, and management of aspen.

In recent years the use of poplar, with the exception of pulpwood in certain regions, has been increasing as rapidly as the sup-

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ply and log quality would permit. The most profitable future increase may be expected in the demand for high-quality logs for the veneer and lumber industries.

Utilization of poplar will surely keep pace with even the most optimistic predictable increase in the production of high-quality logs. Steady and reliable log markets will be available only where there is an assured supply of good poplar timber. Intensive management of native cottonwood and aspen can assure such supplies in some regions. But intensive culture of thoroughly tested hybrid clones will eventually provide the most profitable, constant, and uniformly high-quality timber supply.

Although hybrid-poplar culture in the United States is still in the experimental stage, European utilization provides complete assurance that properly selected and tested hybrids will meet, and possibly surpass, the use requirement of our native species.

Pulp and paper

All species of poplar are easily pulped by the standard chemical or mechanical methods, and they are also suitable for mechanical defiberizing processes. Poplar is used in high-grade papers (book, tissue, and specialities), and also for fiberboard, wallboard, and impregnated building board or felt.

The chemical pulp yield from poplar wood is lower, on a weight-per-cord basis, than the yield from the heavier hardwoods. During the past 25 years, most pulp mills in regions that have abundant native hardwood species have changed, in part or entirely, to the utilization of these heavier species. Poplar is still in demand in regions like the Lake States where there is a high concentration of paper and pulp industries. Increased utilization of the short-fibered woods for groundwood and chemigroundwood pulp may bring poplar into increasing competition with the heavier hardwoods.

Veneer

Among veneer woods, cottonwood ranked seventh on a national basis in 1944. As a core stock for doors, building panels, and furniture, poplar is competing successfully with other native species such as yellow-poplar (*Liriodendron tulipifera* L.). Large volumes of poplar veneer are used for food containers such as cheese boxes, egg cases, fruit and berry boxes, and soft drink and beer cases. The use of poplar for veneer is presently limited by the supply of veneer-quality logs.

Boxes and crating

The use of poplar lumber and veneer for shipping containers of all sorts was greatly expanded during the war, when its adaptability for such utilization was adequately tested. Since the war it has gained steadily in preference over other box woods for many uses.

Lumber

Poplar lumber is used locally in building construction for rafters, stringers, studding, sheathing, shiplap, flooring, and interior moldings and trim. Its use as lumber has been limited by spotty supply of logs of suitable size and quality, poor manufacture and seasoning by small mills, lack of standard grading rules, and relatively little effort to expand the market.

Furniture and specialty uses

Poplar is used for painted furniture, furniture shelving, backs, drawer ends and bottoms, and dust separators. Specialty uses in the United States include excelsior, turnery products, toys and novelties, and wagon-box boards.

Farm uses

Home-grown poplar has been used in the construction and repair of dwellings, barns, and other farm buildings. A Massachusetts apple grower obtained several years' supply of excellent apple-box lumber from a few large hybrid poplars originally planted as shade trees. Poplar wood is too susceptible to decay to be used for fence posts unless treated with a preservative; pressure-treated aspen posts in test plots were in good condition after more than 15 years. Creosoted aspen has also given good wear as bridge planking.

APPENDIX

Identification and Naming of Poplars

The genus *Populus* is divided into 5 generally accepted sections, only 3 of which are of importance in European poplar culture. Aigeiros poplars (Section *Aigeiros* Duby; spelled also *Aegirus*) include the cottonwoods and black poplars. Leuce poplars (Section *Populus;* known commonly as Section *Leuce* Duby [18]) are the white poplars and aspens. The use of Tacamahaca poplars, also called balsam poplars (Section *Tacamahaca* Spach) has been very limited.

Taxonomic studies of the European poplars were neither contemplated nor attempted in connection with these investigations. The native poplar species of Europe are reasonably well defined, but it will be very difficult to establish the validity of natural varieties of *Populus nigra* L. and *P. alba* L. because of the extensive natural hybridization and probable introgression within the sections to which these two species belong.

European poplar culture, with the exception of aspen in the Scandinavian countries, is based on the use of clones. Its economic importance stems primarily from the possibility of maintaining hybrid vigor and other superior qualities of a single individual through vegetative propagation. This exclusive use of clones is unique in the practice of timber and cellulose production.

Although the term clone is now in general use, it is still necessary to stress its significance as Stout [19] did in 1929:

> In considering the status of a clone it should be constantly held in mind that an entire clone, even though it comprises thousands of plants, is merely one seedling plant that has been multiplied by vegetative propagation. . . . the tendency has been to give clones a specific or a varietal rank that is not warranted, and to bestow on them scientific names that ignore the horticultural status of the clone.

In the same paper Stout also proposed that the word *ramet* (from the Latin *ramus,* meaning branch) be used for a member (an individual tree) of the clone. To indicate the original seedling plant from which the clone is derived he suggested that the word *ortet* (from the Latin *ortus,* meaning origin) may be used. These terms are used in this report.

In the poplar regions of Europe, particularly in France, Germany, and Italy, literally hundreds of clones have been planted. Unfortunately the extent and degree of this heterogeneity can

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[18] Under the International Code of Botanical Nomenclature (Art. 22. 1956), as amended in 1950, the section of a genus including the type species repeats the generic name without citation of an author. If *Populus alba* L. is taken as the type species of this genus, the section of white poplars and aspens should be called *Populus* section *Populus*. However, the common name Leuce poplars, long in international usage, can be retained for this section.

[19] Stout, A. B. *The clone in plant life.* N. Y. Bot. Gard. Jour. 30: 25–37. 1929.

never be accurately determined because closely related clones may be practically identical in their taxonomic characters. Differences in physiological characteristics often appear only under special conditions such as unusual climate, disease epidemics, or insect infestations. Growth rate of individual trees in the same planting can seldom be used as a distinguishing physiological characteristic because of the effect of local soil variability.

The International Poplar Commission apparently recognized the impossibility of distinguishing many closely related clones when it originally proposed to name the cultivated poplars with a binomial followed by a "forma" name. Later, at its 8th session in Madrid (1955) the Commission adopted, for naming the cultivated poplars, the International Code of Nomenclature for Cultivated Plants.[20] Under this code the "forma" is replaced by the category "cultivar" (abbreviated cv.) or the restrictive category "clone" (abbreviated cl.).

Since a cultivar name may include any number of clones that are taxonomically similar, the use of cultivar names will not solve the very practical problem of separating taxonomically similar poplar clones that are physiologically different. This can be accomplished only by the selection of single trees as ortets for vegetative propagation, and the distribution of all ramets from a single ortet under strictly controlled clone numbers or names. It is practically impossible to establish the clonal identity of taxonomically indistinguishable poplars without proof of their origin from the same ortet.

Thousands of ortets are being selected for clonal tests by European foresters, nurserymen, farmers, and landowners; and in most cases the selectors maintain the clonal identity of their ramets. Since the ortets are often plantation trees it is to be expected that within a locality, and even in different countries, genetically identical clones are being propagated and tested under different clonal designations. Such duplication is unavoidable but will not lead to serious difficulties in research or practice. Yet too large a minority of poplar selectors are still propagating mixtures of ramets from two or more ortets that are taxonomically indistinguishable. These mixtures may be given new names, or they may be included under an older cultivar name if they fit the general description. In either case this can lead only to further confusion in practice and research.

The International Poplar Commission, in its 1955 session, instructed the Committee on Nomenclature and Registration of Poplar Names to begin work on an International Register of cultivar names in accordance with the International Code of Nomenclature for Cultivated Plants. In 1957, at the 9th session in Paris, the Commission accepted the proposal that the following names, accompanied by the corresponding description card and under the numbers indicated below, be entered in the special register that

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[20] Stearn, William T., ed. *International code of nomenclature for cultivated plants.* 29 pp. Royal Horticultural Society, London. 1953.

will be opened at the Secretariat of the International Poplar Commission:

57/1—*Populus* ×*euramericana* 'serotina d'Exaerde'. Common name: Poplar "Bleu d'Exaerde".
57/2—*Populus* ×*euramericana* 'serotina de Selys'. Common name: de Selys poplar.
57/3—*Populus* ×*euramericana* 'serotina'. Common name: Swiss poplar.
57/4—*Populus* ×*euramericana* 'serotina de Champagne'.
57/5—*Populus* ×*euramericana* 'serotina du Poitou'. Common name: White Poitou Poplar.
57/6—*Populus deltoides* 'angulata de Chautagne'.
57/7—*Populus deltoides* 'carolin'. Common name: Carolin poplar.
57/8—*Populus deltoides* 'virginiana de Frignicourt'. Common name: Virginia poplar.
57/9—*Populus* ×*euramericana* 'robusta'.
57/10—*Populus* ×*euramericana* 'I–154'.
57/11—*Populus* ×*euramericana* 'I–214'.
57/12—*Populus* ×*euramericana* 'I–262'.
57/13—*Populus* ×*euramericana* 'I–455'.

Selection of poplars in the United States has already resulted in the description and naming of at least a dozen cultivars, and this number may be greatly increased within the next few years. To avoid confusion, such names and descriptions should conform to the revised International Code of Nomenclature for Cultivated Plants published in 1958.[21] Because the 1953 Code was prepared primarily for horticulture, a revision more applicable to cultivated plants in general was needed. The revision was made by an International Commission composed of horticulturists, agronomists, and foresters.

Poplar Names Used in This Report

Botanical names

The botanical names of the poplar species used in this report follow Little [22] for the United States and Rehder [23] for others.

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[21] International Commission for the Nomenclature of Cultivated Plants. *International code of nomenclature for cultivated plants.* 28 pp., rev. Utrecht. 1958.

[22] Little, Elbert L., Jr. *Check list of native and naturalized trees of the United States (including Alaska).* U. S. Dept. Agr., Agr. Handb. 41, 472 pp. 1953.

[23] Rehder, Alfred. *Manual of cultivated trees and shrubs hardy in North America.* Ed. 2. 996 pp. New York. 1954.

——— *Bibliography of cultivated trees and shrubs hardy in the cooler temperate regions of the northern hemisphere.* 825 pp. Jamaica Plain, Mass. 1949.

American and most European taxonomists accept the validity of *Populus* ×*canadensis* Moench (*P. deltoides* × *nigra*).[24] European poplar experts have objected to this name as being a source of confusion and the International Poplar Commission has officially accepted *Populus* ×*euramericana* (Dode) Guinier,[25] published in 1950,[26] as the collective name for hybrids of *P. deltoides* × *nigra*.

According to Rehder,[27] Moench's *Populus canadensis* is apparently the oldest name for the hybrid between *P. nigra* and *P. deltoides,* and his description, though meagre, is adequate.

G. Houtzagers,[28] commenting on the use of the name *Populus* ×*canadensis* Moench, was of the opinion that it is taxonomically and genetically incorrect to name all new forms of *P. deltoides* × *nigra,* or of their hybrids, as varieties of P. ×*canadensis* Moench, but agreed if "varietas" were changed to "forma" the name *P.* ×*canadensis* Moench forma *serotina,* forma *regenerata* etc. would be in accordance with the International Rules of Botanical Nomenclature. Nevertheless, he suggested that the name *P.* ×*canadensis* be rejected because it has been used erroneously by various authors.

Under the present International Code (Arts. H.1 and H.5) a collective Latin binomial includes the hybrids of all generations, including backcrosses. It is not genetically incorrect to use such a collective hybrid name, provided its collective significance is clearly understood. Although a name may be rejected if it is used in different senses and so has become a long-persistent source of error, rejection of the name *P.* ×*canadensis* Moench would require acceptance of the next oldest name, perhaps the name *P.* ×*serotina* Hartig.

The Netherlands taxonomist, B. K. Boom, has presented the soundest evidence for maintaining the name *P.* ×*canadensis* Moench.[29] In 1956, Boom visited the park and the Natural History Museum at Kassel to search for some of Moench's original material. He reported that the original trees are no longer in existence and that Moench's herbarium was destroyed during World War II. However, he did find an old xylothec with leaves and fruit, and sufficient documentation to state: "Therefore I am convinced that we may safely accept the contents of box 188 of Schildbach's

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[24] Moench, Konrad. *Verzeichnis ausländischer bäume und sträuche des lustschlosses weissenstein bei cassel.* 144 pp. [p. 81.] Frankfort and Leipsig. 1785.

[25] Report of the Standing Executive Committee on the application to the genus *Populus* of the rules laid down in the International Code of Nomenclature for Cultivated Plants. UN FAO, Internatl. Poplar Comn., 8th Sess. (Madrid), 13 pp. 1955. (Mimeog.)

[26] UN FAO Internatl. Poplar Comn. Rpt., 4th Sess., p. 16; Geneva, 1950.

[27] Rehder, Alfred. *New species, varieties, and combinations from the herbarium and the collections of the Arnold Arboretum.* Arnold Arboretum Jour. 4 (2): 111. 1923.

[28] Houtzagers, G. *Het geslacht Populus in verband met zijn beteekenis voor de houtteelt.* 266 pp. Wageningen, The Netherlands. 1937.

[29] Boom, B. K. *Populus canadensis Moench versus Populus euramericana Guinier.* Acta Bot. Neerlandica 6: 54–57. 1957.

xylothec as neotype of *P. canadensis* Moench. Which clone it presents is not absolutely certain, but the leafshape and the female character suggests that it may be cv. 'regenerata'."

Cultivar names

The poplar names used in this. report conform to the International Code of Nomenclature for Cultivated Plants and accordingly have been placed in single quotation marks. For the sake of brevity, the cultivar names directly follow the generic name, as permitted by the code.

Table 7 lists the briefed cultivar names as they appear in this report, the full name in accordance with the International Code of Nomenclature for Cultivated Plants, and the names most commonly used in the poplar literature.

TABLE 7.—*Summary of poplar cultivar names used in this report*

ames used in this report	Full name in accordance with the International Code of Nomenclature for Cultivated Plants	Names most commonly used in the literature
Populus 'Allenstein'	*P.*×*canadensis* 'Allenstein'	Allenstein *P.*×*euramericana* 'Allenstein'
P. 'Angulata'	*P. deltoides* 'Angulata'	*P. deltoides angulata*
P. 'Angulata de Chautagne'	*P. deltoides* 'Angulata de Chautagne'.	*P. deltoides* 'Angulata de Chautagne'
P.×*berolinensis* Dipp	*P.*×*berolinensis* Dipp. (=*P. laurifolia* × *nigra* 'Italica').	×*P. berolinensis*
P. 'Bietigheim'	*P.*×*canadensis* 'Bietigheim'	Bietigheim *P.*×*euramericana* 'Bietigheim'
P. 'Blanc de Garonne'	*P. nigra* 'Blanc de Garrone'	Blanc de Garonne
P. 'Blanquillo'	*P. nigra* 'Blanquillo'	Blanquillo Blanco
P. 'Bolleana'	*P. alba* 'Bolleana'	*P. alba bolleana*
P. 'Bordils'	*P. nigra* 'Bordils'	Bordils
P. 'Brabantica'	*P.*×*canadensis* 'Brabantica'	×*P. brabantica* *P.*×*euramericana* 'brabantica'
P.×*canadensis* Moench	*P.*×*canadensis* Moench (=*P. deltoides* × *nigra*)	×*P.canadensis* *P.* ×*euramericana* (Dode) Guinier
P.×*canescens* (Ait.) Sm	*P.*×*canescens* (Ait.) Sm. (=*P. alba* × *tremula*)	×*P.canescens*
P. 'Carolin'	*P.*×*deltoides* 'Carolin'	×*P. carolinensis* *P. deltoides* 'carolin'
P. 'Drömling'	*P.*×*canadensis* 'Drömling'	Drömling *P.*×*euramericana* 'Drömling'
P. 'Eckhof'	*P.*×*canadensis* 'Echof'	Eckhof *P.*×*euramericana* 'Eckhof'
P.'Eugenei'	*P.*×*canadensis* 'Eugenei'	×*P. eugenei* *P.*×*euramericana* 'eugenei'
P. 'Eugenei Feminine'	*P.*×*canadensis* 'Eugenei Feminine'	×*P.*eugenei feminine *P.*×*euramericana* 'eugenei feminine'
P. 'Eukalyptus'	*P.*×*canadensis* 'Eukalyptus'	Eukalyptus *P.*×*euramericana* 'Eukalyptus'
P. 'Flachslanden'	*P.*×*canadensis* 'Flachslanden'	Flachslanden *P.*×*euramericana* 'Flachslanden'
P. 'Gelrica'	*P.*×*canadensis* 'Gelrica'	×*P. gelrica* *P.*×*euramericana* 'gelrica'
P.×*generosa* Henry	*P.*×*Generosa* Henry (=*P. trichocarpa* × *angulata*)	×*P. generosa*

TABLE 7.—*Summary of poplar cultivar names used in this report*—Continued

Names used in this report	Full name in accordance with the International Code of Nomenclature for Cultivated Plants	Names most commonly used in the literature
P. 'Grandis'	*P.×canadensis* 'Grandis'	Grandis *P.×euramericana* 'Grandis'
P. 'Heidemij'	*P.×canadensis* 'Heidemij'	*P. deltoides missouriensis* *P. deltoides* 'missouriensis' *P.* 'Heidemij'
P. 'I-28'	*P.×canadensis* 'I-28'	I-28 *P.×euramericana* '*I*-28'
P. 'I-37	*P.×canadensis* 'I-37'	I-37 *P.×euramericana* 'I-37'
P. 'I-65'	*P.×canadensis* 'I-65'	I-65 *P.×euramericana* 'I-65'
P. 'I-137'	*P.×canadensis* 'I-137'	I-137 *P.×euramericana* 'I-137'
P. 'I-154'	*P.×canadensis* 'I-154'	I-154 *P.×euramericana* 'I-154'
P. 'I-214'	*P.×canadensis* 'I-214'	I-214 *P.×euramericana* 'I-214'
P. 'I-262'	*P. ×canadensis* 'I-262'	I-262 *P. ×euramericana* 'I-262'
P. 'I-455'	*P. ×canadensis* 'I-455'	I-455 *P. ×euramericana* 'I-455'
P. 'I-477'	*P. ×canadensis* 'I-477'	I-477 *P. ×euramericana* 'I-477'
P. 'I-488'	*P. ×canadensis* 'I-488'	I-488 *P. ×euramericana* 'I-488'
P. 'I-Caroliniano Bianco de Cercenasco'	*P. ×canadensis* 'I-Caroliniano bianco de Cercenasco'	I-Caroliniano bianco de cercenasco *P. ×euramericana* 'I-Caroliniano bianco de cerenasco'
P. 'Isar'	*P. ×canadensis* 'Isar'	Isar *P. ×euramericana* 'Isar'
P. 'Italica'	*P. nigra* 'Italica'	*P. nigra italica* *P. nigra* 'italica'
P. 'Leipsig'	*P. ×canadensis* 'Leipsig'	Leipsig *P. ×euramericana* 'Leipsig'
P. 'Lloydii'	*P. ×canadensis* 'Lloydii'	*×P. lloydii* *P. ×euramericana* 'lloydii'
P. 'Löns'	*P. ×canadensis* 'Löns'	Löns *P. ×euramericana* 'Löns'
P. 'Mainou'	*P. ×canadensis* 'Mainou'	Mainou *P. ×euramericana* 'Mainou'
P. 'Manitobensis'	*P. ×canadensis* 'Manitobensis'	*×P. manitobensis* *P. ×euramericana* 'manitobensis'
P. 'Marilandica'	*P. ×canadensis* 'Marilandica'	*×P. marilandica* *P. ×euramericana* 'marilandica'
P. 'Monilifera'	*P. deltoides* 'Monilifera'	*P. deltoides monilifera* *P. monilifera*
P. 'Neupotz'	*P. ×canadensis* 'Neupotz'	Neupotz *P. ×euramericana* 'Neupotz'
P. 'Nigrito'	*P. ×canadensis* 'Nigrito'	Nigrito *P. ×euramericana* 'Nigrito'
P. 'Poncella'	*P. nigra* 'Poncella'	Poncella
P. 'Polla Carolina'	*P. deltoides* 'Polla Carolina'	Polla Carolina Carolina
P. 'Regenerata'	*P. ×canadensis* 'Regenerata'	*×P. regenerata* *P. ×euramericana* 'regenerata'
P. 'Regenerata Harff'	*P. ×canadensis* 'Regenerata Harff'	Harff poplar *P. ×euramericana* 'regenerata Harff'

TABLE 7.—*Summary of poplar cultivar names used in this report*—Continued

Names used in this report	Full name in accordance with the International Code of Nomenclature for Cultivated Plants	Names most commonly used in the literature
P. 'Regenerata d'Hautervive'	*P.* ×*canadensis* 'Regenerata d'Hautervive'	×*P. d'Hautervive* *P.* ×*euramericana* 'regenerata d'Hautervive'
P. 'Robusta'	*P.* ×*canadensis* 'Robusta'	×*P. robusta* *P.* ×*euramericana* 'robusta'
P. 'Robusta Bachelieri'	*P.* ×*canadensis* 'Robusta Bachelieri'	×*P. Bachelieri* *P.* ×*euramericana* 'Bachelieri'
P. 'Robusta Vernirubens'	*P.* ×*canadensis* 'Robusta Vernirubens'	×*P. vernirubens* *P.* ×*euramericana* 'robusta vernirubens'
P. 'Robusta Zeeland'	*P.* ×*canadensis* 'Robusta Zeeland'	×*P. robusta Zeeland* *P.* ×*euramericana* 'robusta Zeeland'
P. 'Serotina'	*P.* ×*canadensis* 'Serotina'	×*P. serotina* *P.* ×*euramericana* 'serotina'
P. 'Serotina de Champagne'	*P.* ×*canadensis* 'Serotina de Champagne'	×*P. serotina de champagne* *P.* ×*euramericana* 'serotina de Champagne'
P. 'Serotina d'Exaerde'	*P.* ×*canadensis* 'Serotina d'Exaerde'	*P.* ×*euramericana* 'Serotina d'Exaerde'
P. 'Serotina Erecta'	*P.* ×*canadensis* 'Serotina Erecta'	×*P. serotina erecta* *P.* ×*euramericana* 'serotina erecta'
P. 'Serotina Keppelse Groene'	*P.* ×*canadensis* 'Serotina Keppelse Groene'	*P.* ×*euramericana* 'serotina Keppelse Groene'
P. 'Serotina du Poitou'	*P.* ×*canadensis* 'Serotina du Poitou'	×*P. serotina de Poitou* *P.* ×*euramericana* 'serotina du Poitou'
P. 'Serotina de Selys'	*P.* ×*canadensis* 'Serotina de Selys'	*P.* ×*euramericana* 'Serotina de Selys'
P. 'Vert de Garonne'	*P. nigra* 'Vert de Garonne'	Vert de Garonne
P. 'Virginiana'	*P. deltoides* 'Virginiana'	*P. deltoides virginiana* ×*P. virginiana*
P. Virginiana Carolin'	*P. deltoides* 'Virginiana Carolin'	*P. deltoides* 'Virginiana Carolin' ×*P.* virginiana carolin
P. 'Virginiana de Firgnicourt'	*P. deltoides* 'Virginiana de Frignicourt'	*P. deltoides* 'Virginiana de Frignicourt'

Insect Names Used in This Report

American and European entomologists do not agree on the legitimate scientific names of all insects. The names used in this report are those officially accepted by the entomologists of the United States Department of Agriculture who are responsible for insect identification. The following tabulation lists the insects mentioned in this report under names that differ from those used in Europe or in the older American literature.

Names used in this report	Names used in Europe or in the older American literature
Aegeria apiformis (Cl.)	*Sesia apiformis* Cl.
Chalcoides aurata (Marsh.)	*Crepidodera aurata* Marsh.
Chalcoides helxines (L.)	*Crepidodera helxines* L.
Chrysomela populi L.	*Melasoma populi* L.
Chrysomela tremulae F.	*Melasoma tremulae* F.
Cryphalus asperatus (Gyll.)	*Cryphalus binodulus* Ratz.

Names used in this report	Names used in Europe or in the older American literature
Dicranura vinula (L.)	*Cerura vinula* L.
Gypsonoma acerina Dup.	*Semasia acerina* Dup.
Harmandia loewi (Rübs.)	*Diplosis tremulae* Wtg.
Phratora vulgatissima (L.)	*Phyllodecta vulgatissima* L.
Phratora vitellinae (L.)	*Phyllodecta vitellinae* L.
Phratora laticollis Suffr.	*Phyllodecta cavifrons* Thomas
Phytagromyza populi Kalt.	*Napomyza populi* Kalt.
Phytobia carbonaria (Zett.)	*Agromyza carbonaria* Zett.
Sciapteron tabaniformis Rott.	*Sesia tabaniforme* Rott.
Sternochetus lapathi (L.)	*Cryptorhynchus lapathi* L.

Description of Poplar Stands Listed in Table 2

Cases 1 to 3.—Vicinity of St. Oedenrode, The Netherlands. A rather wet site well drained by many deep ditches. Soil is a heavy fertile loam; pH tested 6.5 to 7.0. Ground covered by grass, weeds, and nettles. Case 2 is on a slightly higher site with somewhat more slope than case 3. Original spacing: Case 1, 23 by 28 feet; case 2, 23 feet square; case 3, 26 by 30 feet.

Case 4.—Near Neunen, The Netherlands. On deep sandy loam of excellent texture but probably low in fertility; pH 6.0. This land, originally in oak coppice, was cleared and used several years for crops before the poplars were planted. It has been in grass for many years. Thinned at 27 years. Original spacing: 13 by 30 feet.

Case 5.—Vicinity of Mons, Belgium. On deep alluvial silt loam with a high organic content. Summer water table about 2.5 feet. Often flooded in winter. Grass and poplar management. Thinned at 10 years. Original spacing: 15 feet square.

Case 6.—Near Mons, Belgium, on the same excellent silt loam as case 5. This site has been poorly drained for the last 10 years because of a change in drainage control. Grass and poplar management. Thinnings at 10, 11, and 17 years. Original spacing: 13 feet square.

Case 7.—Grammont, Belgium. A bottom-land site subject to only occasional overflow and well drained by ditches. The soil is a rather heavy silt loam, with grass and weed cover. At least one thinning. Original spacing: 11 feet, triangular.

Cases 8 and 9.—Schleswig-Holstein, Germany. Cases 8 and 9 represent two locations in the same stand on an excellent bottom-land site. Soil is well drained with a rather high water table. The poplars were planted in openings in a 20-year-old beech-oak stand. No information about the original spacing, stand density, or how the poplars were released. Forest ground cover.

Cases 10 to 15.—Along the river Erft in the vicinity of Grevenbroich, Gustorf, and Frimmersdorf, Germany. On excellent bottom land with considerable local variation in soil. These sandy loams to loamy sands are generally fertile but usually too wet in the spring for agriculture. Under grass and poplar management. Original spacing: Case 10, 23 feet square; case 11, 26 feet square; case 12, 23 by 26 feet; cases 13 and 14, each 16 by 23 feet; case 15, 23 by 26 feet.

Case 16.—Bottom-land site in the Ems lowlands near Glandorf, Germany, on deep, moist, organic sand with ground water at about 2 feet. Original spacing: 10 feet, triangular.

Case 17.—Near Warendorf, Germany. On deep humus-poor sand with ground water at 6.5 to 8.0 feet. Trees fertilized at the time of planting. Original spacing: 20 feet, triangular.

Cases 18 and 19.—On strongly loamy sand, so-called "Senkelboden," near Everwinkel, Germany. Ground water at about 2 feet. Case 18 includes inside trees only. Border trees averaged 14.0 inches d. b. h. and 79 feet in height. Original spacing: Case 18, 10 by 13 feet; case 19, 16 feet square.

Case 20.—Vicinity of Dingden, Germany. An excellent site that was formerly a pond. Light sandy soil, more than 3 feet deep, drained by numerous deep ditches to a larger ditch with constantly flowing water. An underplanting of Norway spruce at wide spacing has produced a good profit from Christmas tree sales. Original spacing: 16 feet square.

Cases 21 and 22.—Lignite district west of Cologne, Germany. Plantations on strip-mine banks, with filler trees of white alder, locust, and maple. The trees were fertilized at time of planting. The fill is a mixture of sand and gravel with some clay particles but without organic matter. Roots of poplars planted on new mine banks, loose fill, are reported to penetrate 33 feet deep within 5 years after planting. Original spacing: Case 21, 8 feet square; case 22, 14 feet square.

Case 23.—Lignite district west of Cologne, Germany, on a strip-mine bank; gravelly sand rich in mineral nutrients, with some clay but no organic material. White alder planted 5 by 5 feet as filler trees; cut at 10 years. Poplars thinned twice. Original spacing: 10 feet square.

Cases 24 and 25.—Lignite district near Hermulheim and Frechen, Germany, respectively. Plantations on strip-mine banks; loamy sand, somewhat gravelly without organic matter; pH reported to be 7.0 to 8.0. Planted the year the banks were completed. No fertilizer was used. White alder, spaced 5 by 5 feet as filler trees; cut at 12 years; one thinning of poplars. Case 24A is on a low terrace with only 6.5 to 10 feet of fill over the original heavier soils. Case 24B is on a higher terrace that has 16.5 to 23 feet of fill. Original spacing: Cases 24A and B, and 25, each 10 feet square.

Case 26.—Vicinity of Wavelinghoven, Germany. On excellent bottom land originally too wet for agriculture because of flooding in the spring. Much of it has been drained through river improvement. Grass under the poplars. Original spacing: 26 by 39 feet.

Case 27.—This stand near Grevenbroich, Germany, had been cut because of heavy shell damage during the war. An excellent bottom-land site. Original spacing: 16 by 23 feet.

Cases 28 and 29.—Erft River bottom land, Harff, Germany. On excellent sandy silt loam and loess-loam soils high in lime. Poplars interplanted among widely spaced bottom-land hardwoods. Original spacing not known but poplars are said to have "suffered from the pressure of an old stand now cut." Measurements represent the best trees. Forest ground cover.

Case 30.—On upland site near Harff, Germany. Loess-loam soil, water table very deep, annual rainfall 21.7 inches. Heavy losses from rabbits and war damage. Original spacing: 20 by 27 feet.

Case 31.—Bad Rothenfelde, Germany. On deep organic diluvial sand with weak "bänderton" at about 3 feet. Ground water at approximately 2.5 feet. Two thinnings. Original spacing: 16 feet square.

Cases 32 to 35.—Rhine valley near Karlsruhe, Germany. Approximately 15 inches of clay loam varying to sandy and silty clay over coarse sand and gravel. The moderately heavy to heavy texture of these soils is not favorable for growth of poplars. The pH at 15 to 25 inches is reported to be approximately 7.0. Cases 32 and 33 are sample plots in the same stand, originally interplanted with 2 rows of ash and 1 row of alder between the poplar rows. First thinning was at 41 years, at least one thinning between 41st and 57th year. Case 34 interplanted with ash and alder. Forest ground cover in all cases. Original spacing: Cases 32 and 33, 20 by 39 feet each; cases 34 and 35, unknown.

Case 36.—Rhine Valley near Rappenwört, Baden, Germany. On fertile reclaimed bottom-land soil. Mixed hardwood understory; forest ground cover. Original spacing unknown.

Case 37.—Rhine Valley near Karlsruhe, Germany. On deep, fertile, silt loam to silty clay loam, subject to overflow; pH 6.0+. Filler trees of ash and alder. Forest ground cover. Original spacing: 26 by 49 feet.

Case 38.—Rhine Valley near Neuburgweier, Baden, Germany. On deep, fertile, well-drained silt loam to silty clay loam; pH 6.5–7.0. Interplanted with *Acer pseudoplatanus*. Forest ground cover. Original spacing: 26 by 49 feet.

Cases 39 to 42.—Bottom land at the juncture of the Danube and Isar Rivers, Bavaria, Germany. Very fertile soils, 6.5 feet or more of silt loam subject to annual overflow; pH reported 5.5 to 6.0. Early culture of the older stands uncertain. In recent years the land has been in grass; the younger stands were established in grass. Original spacing: Cases 39-41, each 11 feet square; case 42, unknown.

Cases 43 and 44.—Marne Valley near Perthois, France. On excellent bottom-land soils subject to frequent overflow. Soil is highly fertile, deep, silty clay loam; pH 6.0+. Said to be one of the best soils in this area. *P.* 'Virginiana' (case 42) and 'Robusta' (case 43) on adjacent areas. Grass and poplar culture. Original spacing: each 23 feet square.

Case 45.—On bottom land in the Voire Valley, France. Rather heavy alluvial soil. Hay and pasture under the poplars. Original spacing: 23 feet square.

Case 46.—Voire Valley, France. Alluvial bottom land with about 12 to 20 inches of gravel underlain by a compact clay subsoil. Grass and poplar culture. Original spacing: 23 feet square.

Case 47.—Voire Valley, France. Bottom land with about 2 feet of light loamy sand over gravel on a clay subsoil. Organic content high in upper 10 to 12 inches of the soil. Site, originally in oak coppice, was cropped before it was planted to poplars. Original spacing: 26 by 30 feet.

Case 48.—Near Wassy (Blaise Valley), France. On a very deep, alluvial, marly, clay loam subject to overflow. Original spacing unknown.

Case 49.—Blaise Valley, France. Bottom land with medium-heavy alluvial soil over clay. Grass under the poplars. Original spacing: 23 feet square.

Case 50.—Rhone Valley near Rochemaure, France. On excellent deep silt loam over coarse sand on a terrace well above the river and not subject to overflow; pH above 6.0. Grass ground cover. It is reported that in dry summers the water table could drop to 13 feet. The last 10 years have been dry; 1947 and 1949 reported to have been particularly dry years—70 days of drought in the summer of 1949. Original spacing: 13 feet square.

Case 51.—Near La Palud, France, in the Rhone Valley. On low wet land adjacent to the river side of the protection dike. Soil is a deep, fertile alluvium subject to overflow. Early culture uncertain. Original spacing: 10 feet square.

Case 52.—Rhone Valley near Bourg-St.-Andeol, France. On fertile bottom land subject to overflow. Well-drained silt loam; pH above 6.0. Grass and herbaceous ground cover. Original spacing: 10 by 16 feet.

Case 53.—Garonne Valley near Toulouse, France. On bottom-land terrace with light sandy soil, low in fertility, and subject to overflow only at very high flood stage. Summer water table 3 to 6 feet; in dry years considerably deeper. After supporting a previous stand of poplar, the land was used for crops for about 10 years before it was replanted to poplar. Present stand intercropped 4 years after planting, followed by hay and later grazing. Original spacing: 20 feet square.

Case 54.—Reclaimed land near Yvonaud, Switzerland. This land was lake bottom and swamp land until reclaimed through control of the river Aare. A very fertile sandy loam to silt loam with a high organic content. Early culture not known, apparently interplanted with other bottom-land species including alder. Forest ground cover. Original spacing unknown.

Cases 55 to 59.—Po Valley, Casale Monferrato, Italy. On bottom lands subject to overflow. Early culture with crops 3 or 4 years, followed by grass and weeds. Soils are variable even in the same plantations. Cases 56 and 57 are in the same plantation rows where there is a soil gradient from poor loamy sand (case 56) to a fertile silty loam with a good ground cover of nettles (case 57). Original spacing: Cases 55-58, each 11 by 33 feet; case 59, 13 feet, triangular, in double rows 39 feet apart.

Cases 60 and 61.—Po Valley near Isolone, Italy. Excellent fertile alluvial soil subject to overflow. Case 60 is on land previously used for poplar, cleared and cropped for 1 year before replanting to poplar, then intercropped and irrigated during the first 3 years after the poplars were planted. Case 61 was intercropped for 4 years after planting, then cultivated for an additional 3 years. Original spacing: Case 60, 11 by 30 feet; case 61, 16 feet square.

Case 62.—Po Valley near Piacenza, Italy. On excellent well-drained bottom land subject to overflow. Mixture of about 60 clones selected at Casale Monferrato from open-pollinated seed from selected mother trees. Intercropped during the first 3 or 4 years; now in grass and weeds. Original spacing: 11 by 33 feet.

Case 63.—Albalate del Arzobispo, Spain. One-year-old trees planted on excellent fertile bottom land subject to overflow and previously used for garden crops. Interplanted with *Pinus halepensis* and *P. canariensis.* Cultivated until plantation was closed. Original spacing: 13 feet square.

Case 64.—Toradera River Valley near Hostalrich, Spain. Plantation established with unrooted sets. On well-drained loamy sand to sandy loam with a low summer water table. Plantation is still irrigated when necessary with water pumped from the river. Intercropped in the early years followed by light stand of grass cut for fodder. Original spacing: 16 feet square.

Description of Row Plantings Listed in Table 5

Case 65.—Vicinity of Sutphen, The Netherlands, on sandy loam between a paved road and a 3- to 4-foot-deep highway ditch. No information on water table; probably not lower than 4 to 5 feet in summer.

Cases 66A–C.—Near Meppen, Germany, on well-drained sandy soil around the border of a pasture that was fertilized at irregular intervals. Water table not lower than 3 feet. The poplars were not fertilized at the time of planting.

Cases 67 to 70.—Nos. 67 and 68 are single rows, 69 and 70 are double rows, in the vicinity of Warendorf, Germany. They are all on deep sand deficient in organic matter. The planting stock, 2-year-old trees, was fertilized with 11 pounds of Thomasmehl mixed with the soil in each planting hole. Ground water on sites 67 and 68 was at 6.5 to 8 feet, on sites 69 and 70 at 9.5 to 10 feet.

Case 71.—Trees along an old filled road near Everswinkel, Germany. The soil is a loamy sand with ground water at about 2 feet.

Case 72.—A double row in Holtwick, Germany, on deep sandy loam of good texture and fertility. Considerably better soil than case 73.

Case 73.—Holtwick, Germany. Deep loamy sand; ground water at 2 to 2.5 feet. Soil rated as "medium sour"; the poplars have been limed.

Cases 74 to 76.—Vicinity of Glandorf, Germany. On deep moist sand with considerable organic content and ground water at about 2 feet. Rows 75 and 76 established with unrooted sets. Case 75 is a row along a brook bank and is underplanted with alder.

Case 77.—Frimmersdorf, Germany, on excellent fertile bottom land subject to overflow. Grass and poplar culture.

Case 78.—Near Baden-Baden, Germany, on a fertile bottom-land soil of medium texture.

Case 79.—Vicinity of Karlsruhe, Germany. Fertile overflow land with 2 to 2.5 feet of loam or sandy loam over coarse sand and gravel. Excellent poplar site.

Case 80.—Very fertile bottom land subject to frequent overflow at the juncture of the Danube and Isar Rivers, Bavaria, Germany. Same site as cases 39 to 42.

Cases 81 and 82.—Seine Valley, St. Hilaire, France. Fertile silty clay loam with high organic content; pH 6.0 to 7.0; subject to occasional overflow. Depth of water table varies from 1 to 2.5 feet, never below 3 feet in dry summers.

Cases 83 and 84.—Vicinity of Saint-Urbain, France. Row plantings along the Marne canal on excellent bottom-land soil. Grass under the trees.

Case 85.—Voire Valley, Puellemontier, France. Four rows along a low embankment across good bottom land. The rows are 20 feet apart.

U. S. GOVERNMENT PRINTING OFFICE: 1959