FORESTRY BRANCH

DEPARTMENTAL
PUBLICATION NO. 1205

1968

GROWTH AND UTILIZATION OF POPLARS IN CANADA

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EPARTMENT OF FORESTRY AND RURAL DEVELOPMENT

GROWTH AND UTILIZATION OF POPLARS IN CANADA

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Published under the authority of the
Minister of Forestry and Rural Development
Ottawa, 1968

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1968

Catalogue No. Fo 47-1205

PRINTED IN CANADA

PREFACE

Poplars occupy a unique and anomalous position in the Canadian forest economy. They have the widest range and greatest volume of any of the hardwood genera yet only an insignificant part of the theoretical yield is harvested and utilized. Poplars grow on a wide range of site conditions: on some sites the growth is so poor that merchantable size is never attained, but on others the poplars are the fastest growing of all our native species. These and many other paradoxical characteristics make *Populus* a fascinating genus from a scientific standpoint, but an extremely frustrating one for those who wish to grow and utilize it.

In Europe and Asia the genus has received much scientific study and has been intensively cultivated in many countries over a wide range of growing conditions for many years. Although some of the best material originated in North America, until comparatively recently there has been little Canadian interest in the more effective utilization of natural stands or in the high yield potential of plantations under intensive cultivation. Now, the general trend towards a greater utilization of hardwood species, together with reduced wood supplies in areas close to mills is focusing attention on species such as poplar that have a capacity for high yields on short rotations.

In response to the rapidly developing interest in poplar, the Forestry Branch, Department of Forestry and Rural Development, organized a Poplar Symposium in February 1967 at Harrison Hot Springs in British Columbia, to review and discuss the status of poplar in Canada. This was considered to be an essential preliminary to future scientific, technical, and economic programs designed to improve the contribution of these species to the national forest economy. A complementary objective was to make generally available a comprehensive and authoritative account of the state of knowledge relating to poplars in Canada. This publication provides such an account.

All of the papers presented at the symposium by representatives of government, industry, and universities are included in this volume and cover the main aspects of poplar supply, silvical characteristics, management, manufacture, and marketing in Canada. To provide broader coverage, two additional papers (by O.A. Feihl and V. Godin, and G.P. Thomas), published prior to the symposium, are reprinted herein. In addition, an introductory paper by J.S. Maini briefly describes the physiography, climate, and vegetation of Canada to provide a broad framework within which the other papers may be oriented. Conclusions from the workshop sessions held during the three day meeting are not included since they were published in the Forestry Chronicle, June 1967.

As organizer and chairman of the symposium I wish to acknowledge both personally and on behalf of the Forestry Branch the fine cooperation and major assistance provided by the authors of these papers and their organizations, and to thank them for their participation. Special thanks are extended to Mr. G. Blom of West Tree Farms and Dr. J.H.G. Smith of the University of British Columbia for the organization and conduct of the field tours.

A. Bickerstaff,
Chairman,
Poplar Symposium, 1967,
Forest Management Institute,
Department of Forestry and Rural Development,
Ottawa, Ontario.

CONTENTS

NOMENCLATURE

Nomenclature for Canadian species used in this publication generally conforms to the Checklist of the Native Trees of Canada (Anon. 1961); for other poplars, it is according to Little's (1935) Checklist of Native and Naturalized Trees of the United States and to the nomenclature used in "Poplars in Forestry and Land Use" (Anon. 1958). However, in certain instances where either nomenclature or derivation are unclear or are contentious, various alternatives are presented. An alphabetical listing of all poplars mentioned in the report is included in ~~this~~ Appendix I and the editors would like to express their gratitude to Dr. C. Heimburger, Retired, Ontario Department of Lands and Forests, Dr. L. Zufa, Ontario Department of Lands and Forests, and F.B. Armitage, Department of Forestry and Rural Development, for assistance in preparing the list.

Within the text all native species, all European poplar species, and well-known poplar varieties are referred to by their common names, while lesser-known varieties are referred to by their scientific names. For brevity, cultivar names directly follow the generic name as permitted by the International Code of Nomenclature for Cultivated Plants. All common names and abbreviated cultivar names that are used in the text are shown in the listing.

GROWTH AND UTILIZATION OF POPLARS IN CANADA

ERRATA

Page vii, line 8 should read "...included in Appendix I ...".

Page 15, line 5 should read "...Maini 1960, 1966...".

Page 53, last line should read "...programs and possibly to...".

Page 107, lines 25, 26, 30 should read "acre" for "hectare".

Page 129, both captions should read "*igniarius*" for "*igniaris*".

Page 181, Table 2 footnote (a) should read Anon. 1964.

Page 183, Table 4 footnote (a) should read Anon. 1967(a).

Page 184, Table 5 footnote (a) should read Anon. 1967(a).

Page 190, the following references should be added:

Anon. 1964. Dominion Bureau of Statistics. Cat. No. 36-204. The Queen's Printer, Ottawa.

Anon. 1965. Dominion Bureau of Statistics. Cat. No. 36-204. The Queen's Printer, Ottawa.

Anon. 1967(a). Data kindly supplied by a Maintaining Member of the Pulp and Paper Research Institute of Canada.

Leask, R.A. 1967. Private communication; data supplied by courtesy of the Bauer Bros. Co., Springfield, Ohio.

The following reference should be deleted:

Anon. 1965. Canadian forestry statistics. 1962, Ind. Div. Cat. No. 25-202. Dom. Bur. Statist. Ottawa.

CHAPTER I

LANDSCAPE AND CLIMATE OF CANADA

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INTRODUCTION

This article has been prepared to provide a background for subsequent articles in this volume and to describe some salient features of Canadian landscape and climate, especially those factors considered significant in affecting the broad patterns of vegetation distribution.

Canada extends through nearly 42° of latitude (about 2,800 miles; 4,480 km) and about 90° of longitude (about 3,000 miles; 4,800 km). With an area of 3,845,144 square miles (10 million km^2), Canada is the third largest country in the world and is nearly equal in size to Europe. The enormity of the area and the scope of this report necessitates broad generalizations on the physiography, geology, soils, climate and natural vegetation. Dominant features of only the upland vegetation have been described and those of Tundra (arctic and alpine) mentioned briefly.

PHYSIOGRAPHY

The mainland of Canada is flanked by large islands on both east and west coasts and by an extensive archipelago on the north (Fig. 1). Extensive glaciation during the Pleistocene has profoundly influenced the physiography and the Canadian landscape is traversed by streams and studded with lakes, particularly in the north where water bodies occupy a high proportion of the land surface. Canada may be divided into the following physiographic regions (Putnam 1952; Anon. 1957; Leahey 1960):

<u>Appalachian</u> region is mountainous and comprises a number of upland areas (several over 4,000 ft (1,200 m) high and some above the treeline) that are separated by deep valleys and rolling to undulating lowlands.

<u>Canadian Shield</u> is characterized by knobs and ridges ranging from 500-2,000 ft (150-600 m) in altitude, and an extensive network of streams, lakes, ponds and bogs; the height of the land generally lies closer to the northern boundary of the shield.

Region	Per cent of the total area	Area sq miles	Km^2
Canadian Shield	49.3	1,895,656	4,909,727
Interior Plains	18.3	703,661	1,822,473
Cordilleran	15.9	611,378	1,583,461
Arctic	8.3	319,147	826,587
Hudson Bay Lowland	3.5	134,580	348,560
Appalachian	3.4	130,735	338,602
Great Lakes and St. Lawrence	1.3	49,987	129,466
Canada (Total)	100.0	3,845,144	9,958,876

Great Lakes and St. Lawrence region is subdivided into: (i) St. Lawrence Plain, comprised mainly of gently sloping Paleozoic dolomite, sandstone, limestone and shales overlaid by deep glacial till and by post-glacial marine sands and clay, and (ii) flat to gently rolling Southern Ontario Plains, formed by glacial till and post-glacial lacustrine and alluvial deposits underlaid by nearly horizontal Paleozoic sediments.

Hudson Bay Lowland is formed by unconsolidated glacial and post-glacial deposits underlaid by nearly horizontal Paleozoic sediments. Most of the region was submerged near the end of the last glacial period; at present it is poorly drained and abounds with bogs and shallow lakes.

Interior Plains consist of the Mackenzie Lowlands, mainly confined to the Northwest Territories and comprising large tracts of muskeg interspersed by a few low rugged mountain ranges, and three levels or "steppes": (i) flat and undissected Manitoba Lowlands (avg alt about 750 ft; 225 m), formed by water-laid clay in the bed of Lake Agassiz, and bounded on the west by the Manitoba escarpment; (ii) the Saskatchewan Plains (avg alt about 1600 ft; 500 m), consisting mostly of rolling till and partly of level clay, bounded on the west by the Missouri Coteau; and (iii) Alberta Plains (avg alt about 2,500 ft; 775 m), more rolling than the Saskatchewan Plains but with less extensive lacustrine clays.

Cordilleran Region comprises two major ranges, the Rocky Mountains in the east (alt over 12,000 ft; 3,700 m), composed of sedimentary rocks, and the Coast Range in the west (alt over 9,000 ft; 2,750 m), composed of granite rocks. The latter has steep western slopes with deep glaciated valleys and fiords. Southward, the land between the two ranges comprises a series of north-south tending valleys; northward, it is traversed by the tributaries of the Fraser River that discharges into the Strait of Georgia in the vicinity of Vancouver. Further northward, the region is a high plateau dissected by the tributaries of the Liard, Yukon, and Porcupine rivers.

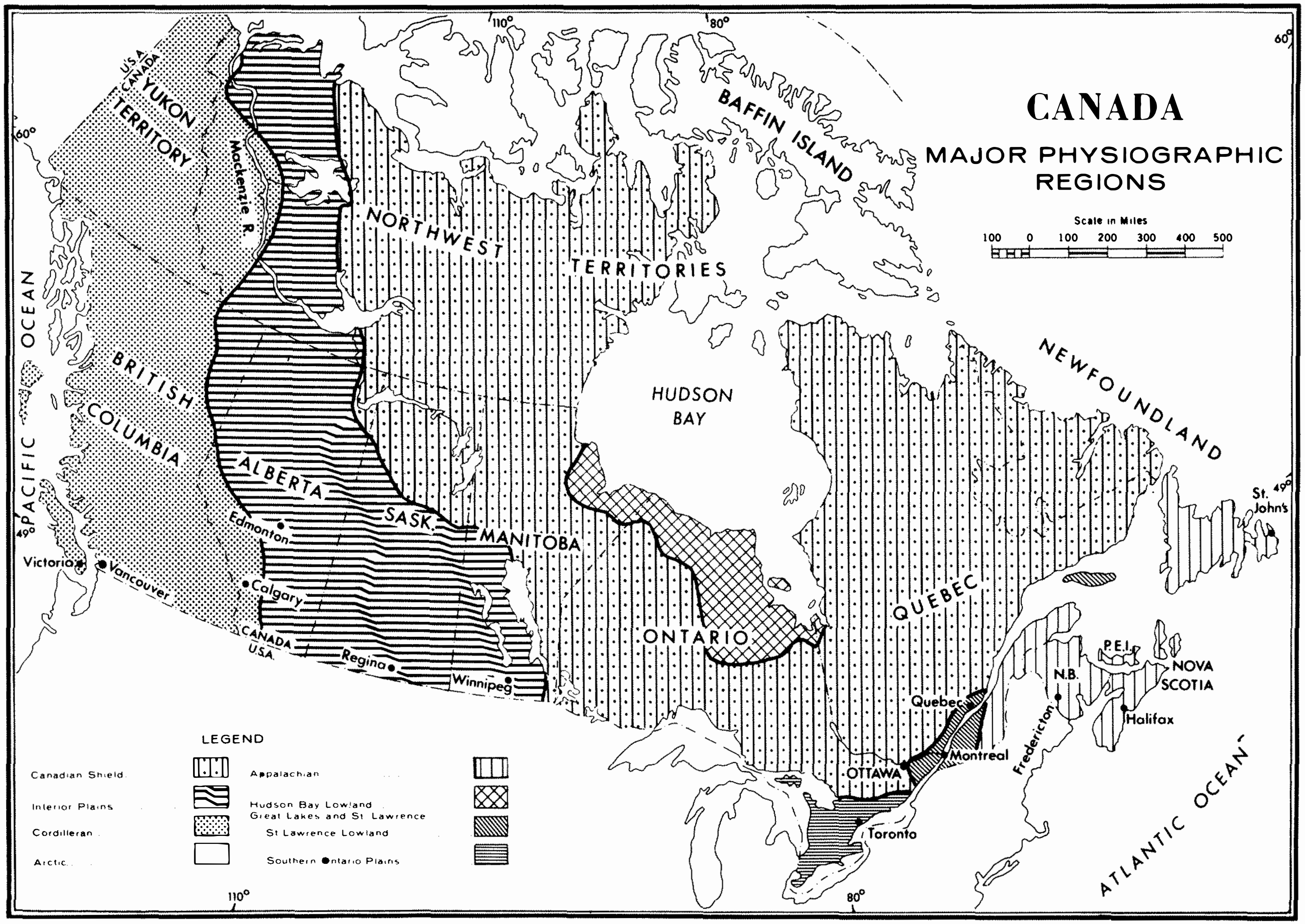


Figure 1. Physiographic regions of Canada (from Anon. 1957).

Arctic Archipelago, largely an extension of the Canadian Shield, is characterized by low relief, marine beaches, shallow lakes and boggy lowlands. However, a zone of Paleozoic sediments in the east forms a mountain chain (in places 8,000 ft, 2,450 m, with permanent ice caps) extending from Baffin Island to Ellesmere Island.

CLIMATE

Canadian climate is varied and greatly influenced by the shape of the continent and the physiographic features (Thomas 1953; Boughner and Thomas 1962; Chapman and Brown 1966). The western ranges of the Cordillera are a major barrier to the movement of lower atmosphere and influence the climate of British Columbia and the western Prairie Provinces. Large bodies of water, including Hudson Bay, the Great Lakes, and the Gulf of St. Lawrence, ameliorate the climates inland from their lee shores. Over most of Canada, winds most frequently blow from a westerly direction, except along the Pacific Coast where southeast winds predominate. Mean wind speed over most areas throughout the year is about 10 mph (16 kmph).

Temperature

In southwestern British Columbia, the mean annual temperature is about 50F (10C). The area south of 40F (5C) isotherm includes almost all of southern and coastal British Columbia except for high altitudes, and the coastal region of the four Atlantic Provinces (New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland). Most densely populated and agricultural areas lie south of the 32F (0C) isotherm. The mean annual temperature of most of Canada is below 35F (2.0C), and that of the Arctic Archipelago ranges from 0 to 10F (-18 to -12C).

July is generally the warmest month; the mean July daily temperatures range from 73F (23C) in extreme southwestern Ontario to below 40F (5C) in the northern Arctic. Areas with average July temperatures above 65F (18C) include the Maritime Provinces (New Brunswick, Nova Scotia and Prince Edward Island), most of southern Ontario, the southern part of the Prairie Provinces (Manitoba, Saskatchewan and Alberta) and the interior valleys of British Columbia. East of the Rocky Mountains, the July isotherms deflect northwards, indicating the Mackenzie Valley as the warmest part of Canada at high latitudes.

Mean January temperatures range from 35F (2C) on the Pacific Coast to less than -30F (-35C) on the Arctic Archipelago. Three-fourths of the country lies north of the 10F (-12C) January isotherm, which runs through Calgary and Ottawa, making them similar to Leningrad and Moscow. Differences between the mean annual maximum and minimum temperatures in the continental interior are about 135F (57C), in southern Ontario and the Arctic Archipelago they are 100F (38C), on the southeast coast from 80 to 100F (27-38C) and on the Pacific Coast as low as 60F (16C).

Growing season and degree-days above 42F

The growing season in Canada is defined as that part of the year when the mean daily temperature is above 42F (5.6C); most of the plants are apparently dormant below this temperature. The last spring and first autumn frosts occur during the growing season which ranges from 260 days on Vancouver Island to 40 days or less in the Arctic Archipelago (Fig. 2).

Degree-days (dd) above 42F (5.6C), defined as the number of degrees above 42F for all days during the growing season, is a useful index of the length and warmth of the growing season. Pelee Island, at the southern tip of Ontario and near 42N latitude, has an average of 4,450 dd above 42F; the area north of 2,500 dd isoline has a limited agricultural potential, and 1,000 dd isoline roughly approximates the southern boundary of the Arctic Tundra (Fig. 3).

Moisture

The distribution pattern of mean annual rainfall is generally similar to that of the mean annual precipitation. The heaviest mean annual precipitation in Canada occurs on the Pacific Coast where it ranges from 60 to 100 inches (150-250cm) with a maximum of 175 inches (445 cm) recorded at Ocean Falls, about 300 miles (480 km) north of Vancouver. West of the Coast Range, a pronounced rain-shadow is formed in the Okanagan Valley in south-central British Columbia. In the southern parts of the Prairie Provinces the mean annual precipitation is about 12 inches (30 cm); northward, the precipitation increases to 15-18 inches (38-45 cm) followed by a gradual decline to 10 inches (25 cm) in the Tundra and 5 inches (13 cm) in the Arctic Archipelago. Precipitation increases eastward from 17.5 inches (45 cm) in southeastern Saskatchewan, to 20 inches (50 cm) in Winnipeg, Manitoba, 35 inches (90 cm) in Ottawa, Ontario, and 50 inches (125 cm) along the Atlantic Coast. The Pacific Coast and Newfoundland receive high winter - low summer precipitation; the area eastward from the Rocky Mountains to Quebec is characterized by high summer - low winter precipitation regime.

Potential evapotranspiration and moisture indices

Potential evapotranspiration is defined as the amount of water that would be transferred from the soil to the atmosphere by evaporation and transpiration if water were constantly available in optimum quantity; it is an estimate of water need and serves as an index of thermal efficiency. In Canada, water need is normally zero during the winter months, increasing to a maximum of about 4.0-5.5 inches (10.0-14.0 cm) in July; only the Pacific Coast regions have water need every month. Generally, the areas with water deficiency lie west of the Manitoba-Ontario boundary and those with water surplus east of this boundary (Fig. 4).

"Moisture indices" for various parts of Canada have been calculated according to Thornthwaite's concepts (Sanderson 1948). It is interesting that through central Canada the various moisture regimes appear

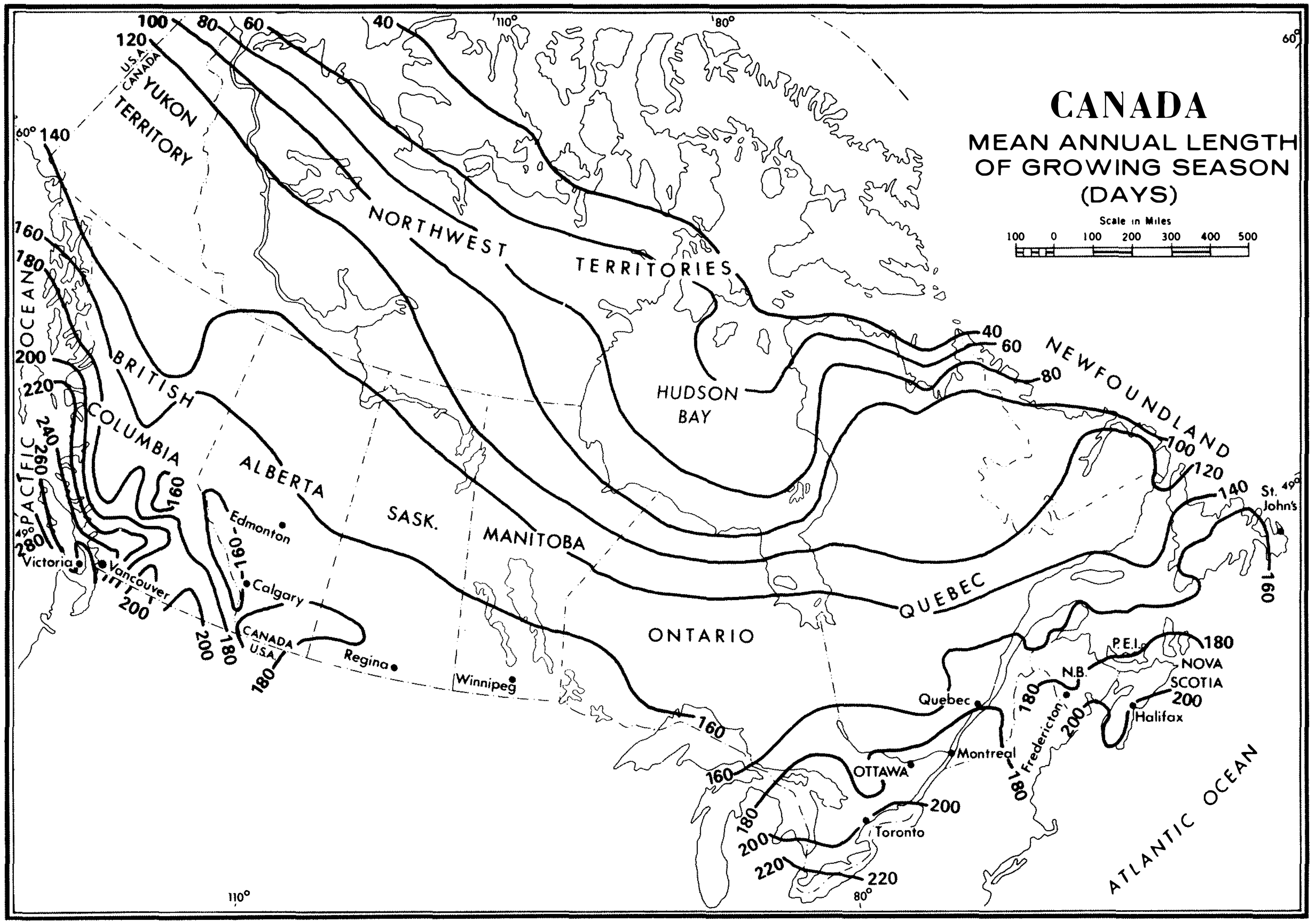


Figure 2. Mean annual length (days) of growing season in Canada when the daily mean temperature is above 42F (5.6C) (from Anon. 1957).

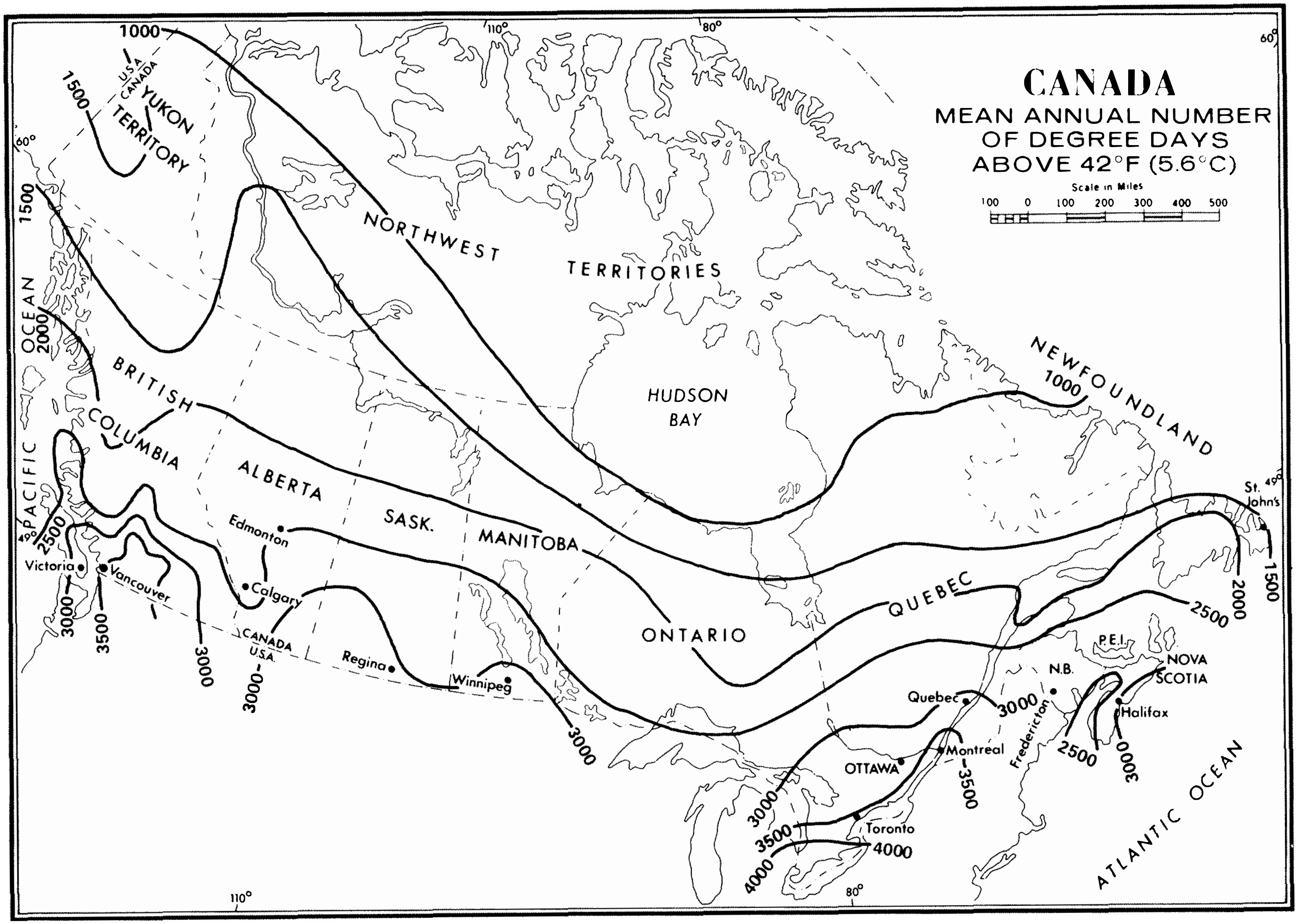


Figure 3. Mean annual number of degree-days above 42F (5.6C) in Canada (from Anon. 1957).

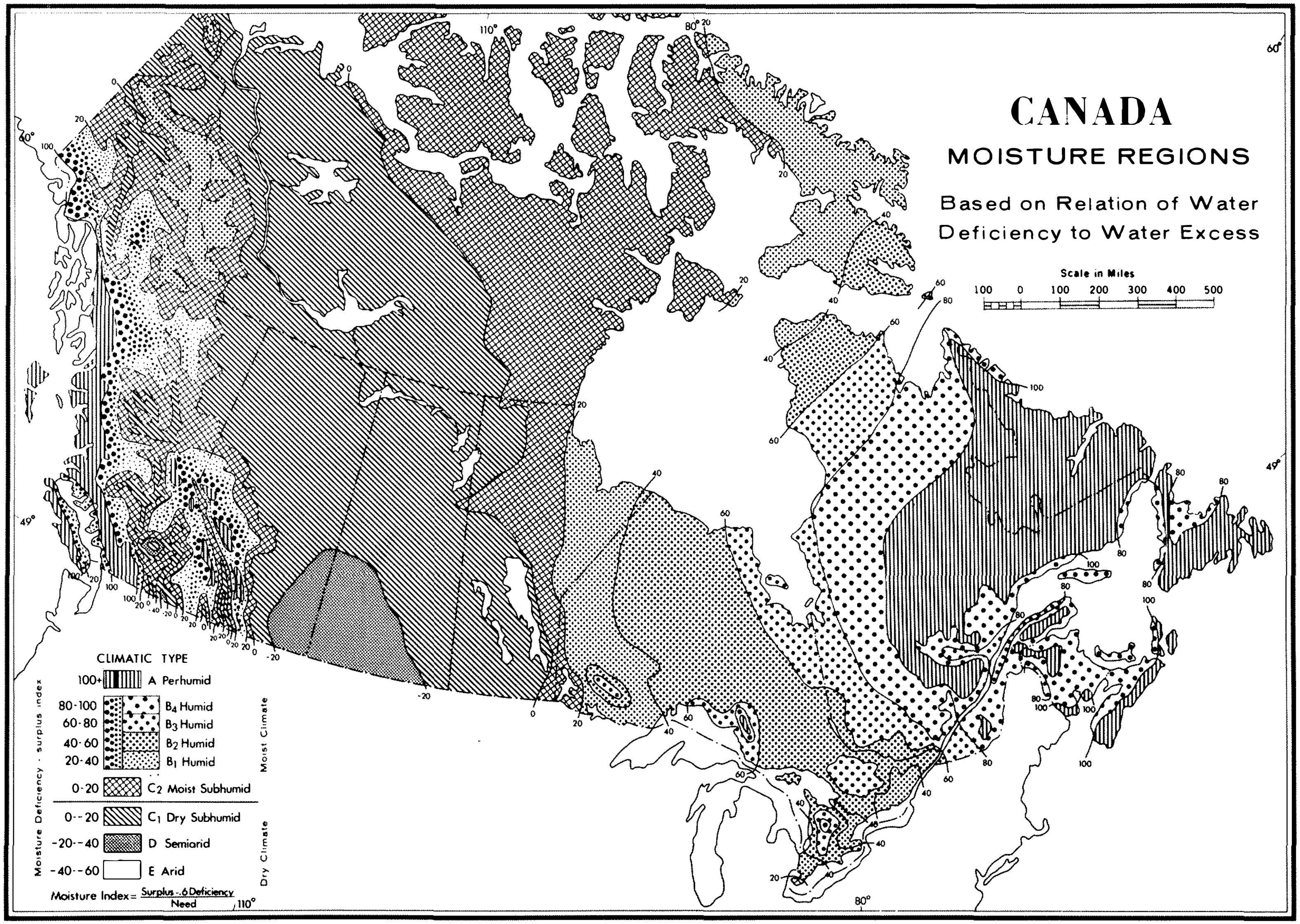


Figure 4. Moisture regions in Canada based on relation of water deficiency to water excess (redrawn from Sanderson 1948).

as north-south lines without the east-west zonation of the various parameters of temperature regimes (cf Figs. 2, 3 and 4).

The following localities in Canada and other parts of the world have a somewhat similar climate: the Pacific Coast of British Columbia and the coast of Norway; Vancouver, B.C., and the vicinity of Bergen, Norway; Victoria, B.C., and Belgium and Holland; the Prairie Provinces and central regions of European U.S.S.R.; Calgary, Alta., and an area north of Moscow; Ottawa and Harbin, Manchuria; and coastal Nova Scotia and Hokkaido, Japan (Boughner and Thomas 1962).

SOILS

Relatively little time has elapsed since the last glaciation so Canadian soils are younger, generally shallower, and less weathered than those in many parts of the world. However, the interaction of parent material, climate, vegetation, topography and drainage has resulted in the development of characteristic soil profiles extending up to 4 ft (120 cm) or more in depth. Only a few "great soils groups" have been recognized (Leahey 1960; Leahey 1965[1]) on the basis of profile characteristics (Fig. 5). More than 1,500 different types of soils have been studied and described in Canada.

Chernozemic and Solonetzic soils

The well-drained Chernozemic soils are chiefly found associated with the Grassland Region in the Prairie Provinces, where the relatively non-saline parent material contains significant amounts of Ca, Mg, K, P, carbonates and sulphates but is very low in chlorides. Moderately drained areas with saline parent materials develop Solonetz, Solodized-solonetz and Solod soils. A gradient in moisture efficiency has mainly contributed to the development of Brown, Dark Brown, and Black soils, which extend in broad concentric belts from semiarid to dry subhumid climate. Degraded Black soils occur as an irregular band, form a transition between the Chernozem soil zone and the Grey-wooded soil zone, and are associated with the forest-grassland transition. Moisture efficiency, depth of the mineral-organic surface horizon and depth of the lime-enriched subsurface horizon increases from Brown to Degraded Black soils. Drought is frequent in the Chernozem soil zone, particularly in the Brown soil zone.

Podzolic and Brunisolic soils

These soils are widespread in Canada and are associated with forest or heath vegetation. The Podzolic soils are characterized by a leached

[1]Leahey, A., [*Chairman*] 1965. Report on the sixth meeting of the National Soil Survey Committee of Canada. Can. Dep. Agr. Rep. (Mimeograph). 132p.

greyish horizon near the surface overlying a darker subsurface illuvial horizon. The Brunisolic soils have dominantly brown profiles, where leaching has not resulted into distinct elluvial and illuvial horizons. The following main types of forest soils have been recognized in Canada (Fig. 5):

The Grey-wooded soils, associated with the Mixedwood Section of the Boreal Forest covering the Interior Plains, have developed under cooler and more mesic conditions than those in the Grasslands. The High-lime soils, occupying the interlake area of the Manitoba Lowlands, are highly variable and are derived from calcareous bedrock and highly calcareous glacial drift. The Podzol soils are associated with a cool moist climate, conifer and mixed forest cover, well-drained sites and coarse non-calcareous parent material; surface horizons are moderately to strongly acid and the solum generally has a low degree of base saturation. The Grey-brown Podzolic soils are found under a cover of deciduous or mixed forest in southern Ontario, where the climate is warmer and more humid than the area of Grey-wooded soils. Dark-grey Gleysolic soils that occur in this area are darker in color, nearly neutral in reaction, lack the illuvial subsurface horizons, and are moderately saturated with bases. Grey-brown Podzolic-Podzol Transition soils are made up of a wide variety of soils, including Dark-grey Gleysolic soils; Grey-brown Podzolic and Brown Forest soils occur on calcareous materials; Brown Podzolic and Podzol soils on sandy, non-calcareous materials; and black muck and peat soils develop under imperfectly drained conditions.

Soils of the Canadian Shield Region

Southern division: This area is characterized by shallow layers of stony, sandy till usually less than 10 ft (3 m) in depth, underlaid by resistant rock, which is frequently exposed. A wide variety of soils are found in this area and include: Grey-wooded soils, commonly occurring on fine-textured materials with low to high lime content; Podzol and Brown Podzolic soils on coarse, medium and silty sands derived from granites and gneisses, and with a low- to very low-base content; the Brown Podzolic soils with the organic horizon, generally more decomposed than that of the Podzol; and the Gley and organic soils which develop locally in poorly drained areas.

Clay belts have been derived from fine-textured material eroded either from Paleozoic bedrock located in the Hudson Bay Lowland or from earlier lacustrine or morainic deposits.

Subarctic division: This component of the Canadian Shield is characterized by forest cover with permafrost in the mineral soils. The tree line delineates the northern limit of this division; however, the southern boundary is difficult to define.

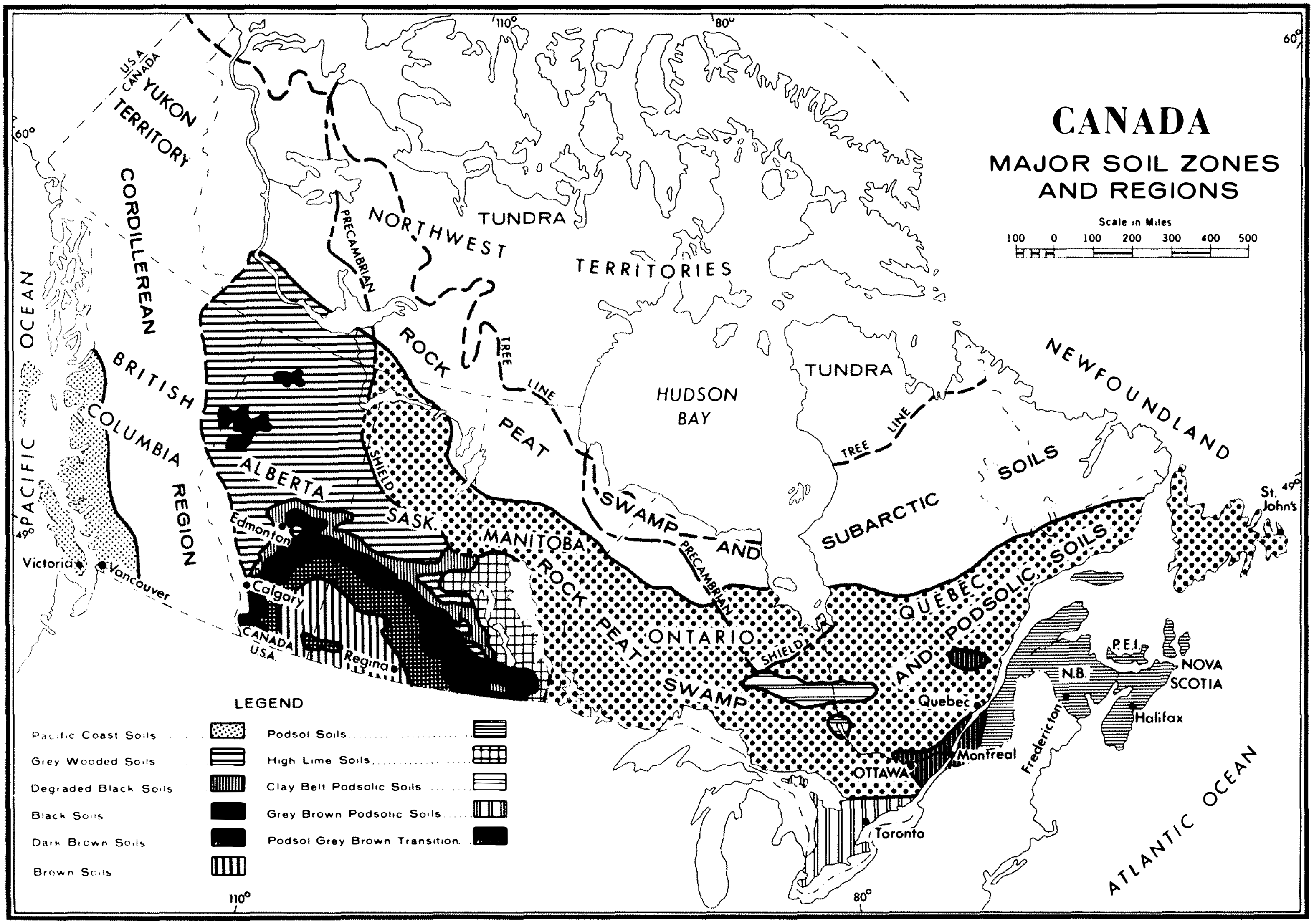


Figure 5. Major soil zones of Canada (redrawn from Munroe 1956).

Arctic soils

Soils in the southern part of the arctic resemble those in the subarctic, except that the profile is even less developed, organic soils are not as prevalent and permafrost lies near the surface.

Cordilleran soils

Limited information is available on the soils of the Cordilleran Region which encompasses a wide range of altitude and climate. These soils, mostly derived from till, are highly variable; altitudinal zonation plays a significant role in the complex soil pattern. Various soil types resemble typical soils of other regions. In the warm and humid coastal region, Brown Podzolic, Concretionary Brown and Podzolic soils occur widely under dense forest cover. Throughout the central Interior Plateau, Grey-wooded and related soil groups predominate. The dry interior is occupied by Light Brown, Brown, Dark Brown and Black Chernozemic soils. Highly productive alluvial soils occur along the main rivers, particularly the lower Fraser. Large areas of Lithosols, Alpine and Tundra soils are found throughout the region at higher altitudes.

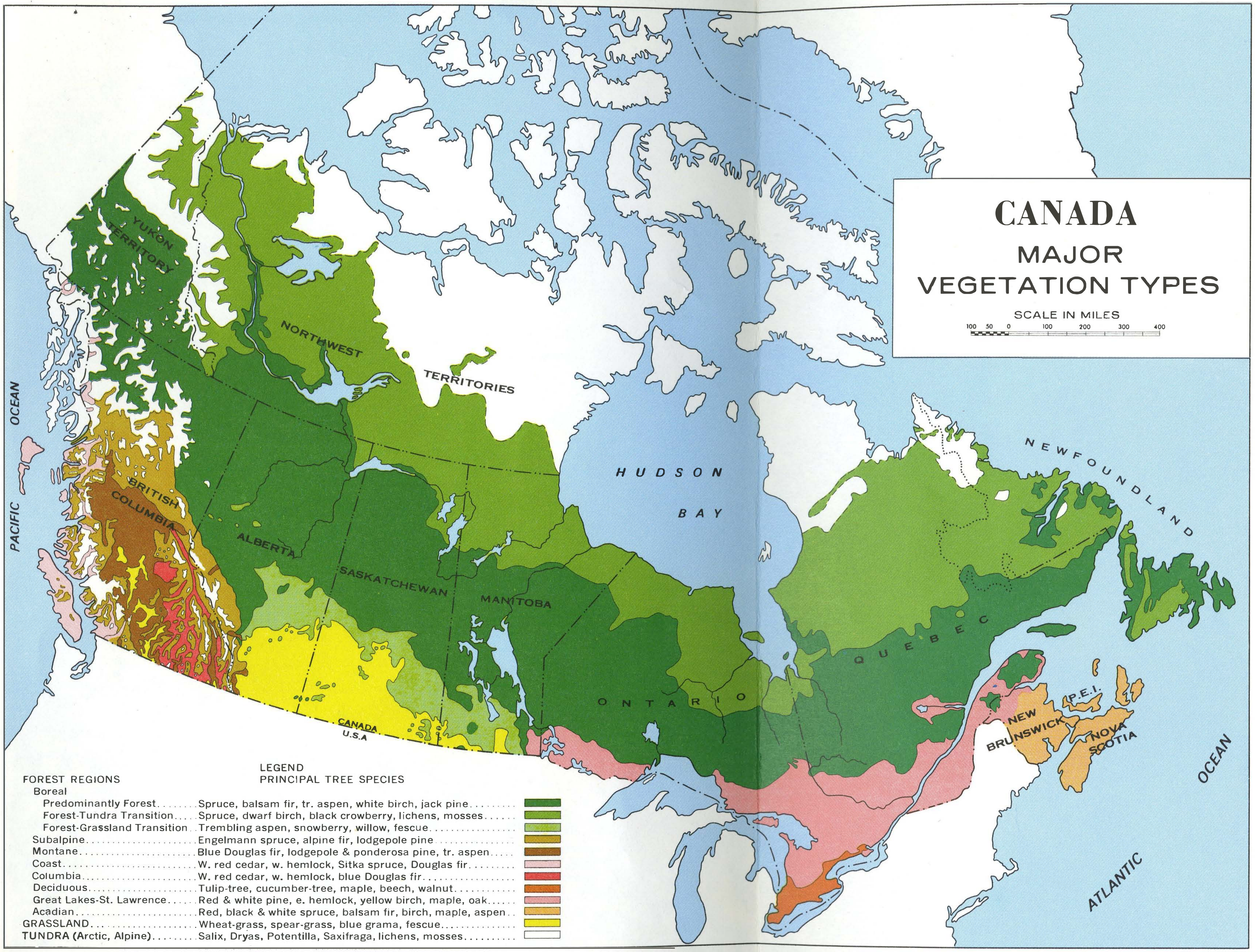
NATURAL VEGETATION

Canada, extending between the Atlantic and Pacific Coasts and from the middle latitudes to near the north pole, encompasses a wide range of habitat conditions for plant growth. However, relatively little time has elapsed since deglaciation and apparently some species have not yet attained their potential distribution limits; compared to the southern latitudes, Canadian flora is impoverished. A more or less homogeneous set of species and life forms extend over large areas. Physiognomically, the Canadian vegetation consists of three broad vegetation types: Grasslands, Forests (coniferous and deciduous) and Tundra (Arctic and Alpine). Conspicuous broad ecotones exist between the three vegetation types (Fig. 6).

Grasslands

Floristically, the natural grasslands of Canada have been divided into four geographic entities: (i) the Palouse Prairie in British Columbia which has affinities with intermontane grasslands of Washington and Idaho; (ii) the Mixed Prairie and (iii) the True Prairie in the Prairie Provinces which are the northern extensions of the grasslands of the Great Plains of the United States; and (iv) the Fescue Prairie, mostly confined to Canada, found to the north, northwest and west of the Mixed Prairie and in the Cypress Hills located in southwestern Saskatchewan and southeastern Alberta (Coupland 1952, 1961; Coupland and Brayshaw 1953).

Figure 6 (Facing page). Major vegetation types of Canada.


CANADA
MAJOR VEGETATION TYPES
SCALE IN MILES
100 50 0 100 200 300 400
YUKON TERRITORY
NORTHWEST TERRITORIES
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
NEW BRUNSWICK
NOVA SCOTIA
P.E.I.
HUDSON BAY
PACIFIC OCEAN
ATLANTIC OCEAN
CANADA
U.S.A
LEGEND
FOREST REGIONS
PRINCIPAL TREE SPECIES
Boreal
Predominantly Forest........Spruce, balsam fir, tr. aspen, white birch, jack pine.........
Forest-Tundra Transition.....Spruce, dwarf birch, black crowberry, lichens, mosses......
Forest-Grassland Transition....Trembling aspen, snowberry, willow, fescue.................
Subalpine......................Engelmann spruce, alpine fir, lodgepole pine...............
Montane.......................Blue Douglas fir, lodgepole & ponderosa pine, tr. aspen.....
Coast..........................W. red cedar, w. hemlock, Sitka spruce, Douglas fir..........
Columbia.......................W. red cedar, w. hemlock, blue Douglas fir.................
Deciduous......................Tulip-tree, cucumber-tree, maple, beech, walnut............
Great Lakes-St. Lawrence.......Red & white pine, e. hemlock, yellow birch, maple, oak......
Acadian........................Red, black & white spruce, balsam fir, birch, maple, aspen..
GRASSLAND......................Wheat-grass, spear-grass, blue grama, fescue..............
TUNDRA (Arctic, Alpine).........Salix, Dryas, Potentilla, Saxifraga, lichens, mosses..........

Forests

Eight major forest regions recognized in Canada include Boreal, Subalpine, Montane, Coast, Columbia, Deciduous, Great Lakes-St. Lawrence and Acadian (Rowe 1959). The Boreal forest is separated from the Grassland and the Tundra by two broad ecotones, the Forest-Grassland Transition and Forest-Tundra Transition, respectively (Moss 1955; Maini 1960, 1966 ; Bird 1961).

Tundra

The Tundra is characterized by the absence of trees. It occupies the area beyond the tree line, including the north and northeast coasts of the mainland, the entire Arctic Archipelago, and extends southward at gradually increasing altitude in the mountains. At present the two components of the Canadian Tundra (Arctic and Alpine) are connected. The southward extensions of the Tundra in the west comprise a fairly continuous chain, but in the east they are isolated and confined to high peaks in Newfoundland and the Gaspé Peninsula in Quebec. It is possible that the present connection in the west was occasionally severed in the past.

VEGETATION-ENVIRONMENT RELATIONSHIPS

Youth is the most striking feature of this recently deglaciated, vast Canadian landscape which features a wide range of physiographic, edaphic, climatic and biotic conditions. Physiographic features such as the Western Cordillera, Hudson Bay, the Great Lakes, the Atlantic and Pacific Coasts significantly influence the climate.

Along the Pacific Coast, the warming effect of the North Pacific Drift is less effective than the Gulf Stream on the coast of Europe. The mean annual isotherm of 40F includes almost all of southern and coastal British Columbia where a larger proportion of the annual rainfall, ranging from 60-100 inches (150-250 cm), is received during the winter rather than summer. In this area, Brown Podzolic, Concretionary Brown and Podzolic soils support lofty Coastal Forests comprising western red cedar[2] and western hemlock with Sitka spruce, Douglas-fir, and western white pine. The deciduous component of these Coastal Forests include black cottonwood, red alder, and broadleaf maple.

On the western slopes of high interior mountains ("wet belt"), Grey-wooded soils support the Columbia Forest which is dominated by western red cedar and western hemlock, commonly associated with Douglas-fir. At higher elevations, the Columbia Forest grades into the Subalpine Forest, which is characterized by Engelmann spruce, alpine fir and lodgepole pine.

[2]Nomenclature of trees is according to Anon. (1961) and that of the Gramineae according to Hitchcock (1935). Also see Appendices.

The Columbia Forest also contains elements of the Boreal (black spruce, white spruce, and trembling aspen), Montane (Douglas-fir) and Coastal Forests (western hemlock, western red cedar and Amabilis fir). At lower elevations, the Columbia Forest is replaced by the Montane Forest composed of Douglas-fir, ponderosa pine, lodgepole pine and trembling aspen. Along the dry and warm river valleys of the interior, Chernozemic soils support discontinuous patches of Palouse Prairie which extends from about 1,200-4,000 ft alt (370-1,220 m) and is characterized by *Agropyron* spp. and *Artemesia* spp.

From the Rocky Mountains eastward to the Atlantic Coast, the annual precipitation increases. However, the area between the Cordillera and Manitoba-Ontario boundary, mostly encompassing the southern part of the Interior Plains, has a semiarid to arid subhumid climate with annual precipitation 12-16 inches (30-40 cm) and experiences water deficiency annually. These vast, flat to rolling plains have an extreme continental type of climate with short warm summers and very cold long winters. Nearly half of the total annual precipitation falls during summer and it is least during autumn and winter. In this Grassland area, the True Prairie (average height above 18 inches: 46 cm) is confined to east of the 100th meridian in southwestern Manitoba and is characterized by *Andropogon gerardi*, *A. scoparius*, *Panicum virgatum*, *Stipa spartea*, *Sporobolus heterolepus* and *Koeleria cristata*. The Mixed Prairie (height 12-18 inches: 30-46 cm) is the most extensive of the four prairie types and covers the Brown soils and most of the Dark Brown soils in Saskatchewan as well as the drier half of these soils in Alberta; it is characterized by *Stipa comata*, *S. spartea* var. *curtiseta*, *Koeleria cristata*, *Agropyron Dasystachyum*, *A. smithii*, and *Bouteloua gracilis*. The Fescue Prairie (height less than 12 inches: 30 cm) occupies the Black soils in southwestern and central Alberta and west-central Saskatchewan and is characterized by *Festuca scabrella* and *Agropyron* spp. In the Grasslands, the aridity increases southward and drought is a common occurrence in the area with Brown soils.

The Forest-Grassland Transition, also known as the Aspen Grove Region, is a mosaic of groves of trembling aspen and patches of Fescue Prairie. Degraded Black soils are common in this ecotone, which is more mesic than the Grassland. The present aspen groves are of vegetative origin and regarded as remains of a more extensive post-glacial forest. A limited invasion of grassland by trembling aspen has taken place since the cessation of widespread prairie fires (Coupland and Maini 1959), and according to Maini (1960), the long-term mean annual rate of invasion commonly varied from 1.0-2.5 ft (40-75 cm).

Boreal Forests cover a large area of the Canadian Shield and the Interior Plains, extending over a wide range of edaphic, climatic and physiographic conditions. The mean annual precipitation ranges from 40-50 inches (100-125 cm) in the east and 10-15 inches (25-38 cm) in the west. The area, generally, has a humid continental type of climate with very cold, snowy winters, and moderately warm summers, receiving ample precipitation with a summer maximum. Gray-wooded and Podzolic soils have developed on well-drained upland areas that support coniferous or mixedwood forests which are composed of black spruce, white spruce, tamarack, trembling aspen, balsam poplar, and white birch. Common components in eastern and central portions include balsam fir and jack pine, while alpine fir and lodgepole pine occur in the western and southwestern parts.

The Great Lakes-St. Lawrence area is characterized by a warm and humid climate, with precipitation distributed fairly evenly throughout the year. Soils vary considerably in this area; most common types include Dark-grey Gleysolic on fine textured materials, Podzols on sandy deposits and Brown Podzolic on acid materials. The principal components of the dominant Great Lakes-St. Lawrence Forests are coniferous and deciduous elements and include eastern white pine, red pine, eastern hemlock, yellow birch, maples, oaks, basswood, trembling aspen, balsam poplar, and large-tooth aspen.

The climate of southwestern Ontario is influenced by the Great Lakes. Deciduous Forests cover the southern part of the Southern Ontario Plains where Grey-brown Podzolic soils have developed. The forests are chiefly composed of deciduous species and the conifers are of minor importance. The characteristic species include tulip-tree, cucumber-tree, papaw, sugar maple, beech, white elm, basswood, hickories, and oaks, while eastern white pine, tamarack, and red juniper are scattered and less prominent.

Most of the Atlantic Provinces receive abundant moisture, and the coastal areas have a high winter - low summer precipitation regime. Under the conditions of moisture surplus, Podzols, Eluviated Gley and Gleysol soil types have developed and support the Acadian Forest which is characterized by red spruce, balsam fir, yellow birch, sugar maple and a limited proportion of red pine, eastern white pine, eastern hemlock, black spruce, white spruce, white birch, trembling aspen, and balsam poplar. The Acadian Forest closely resembles the Great Lakes-St. Lawrence Forest and to a lesser extent the Boreal Forest.

A broad Forest-Tundra transition comprises a mosaic of arboreal and treeless areas. The characteristics of terrain mainly determine the pattern of vegetation: the protected upland supports spruce parkland where the ground cover is composed of *Cladonia*, *Stereocaulon*, *Empetrum*, *Vaccinium* and *Betula glandulosa*; the more mesic lakeshores support closed canopy forests dominated by black spruce with some tamarack and the ground is covered with *Hylocomium*, *Pleurozium*, *Sphagnum* and *Hypnum*. Exposed northerly treeless slopes support *Cladonia*, *Stereocaulon*, *Polytrichum*, *Empetrum* and *Vaccinium*.

The Arctic Tundra is a region of permafrost, low precipitation which decreases from east to west, and a short growing season which decreases northward. The vegetation cover and richness of flora declines northward where cryopedological processes become more prominent. The straits and sounds between the mainland and the Arctic Archipelago, Hudson Bay, and the Mackenzie Delta are significant barriers for dispersal of the flora. The Canadian Arctic comprises three phytogeographic divisions: (i) the Arctic

Archipelago; (ii) the continental Northwest Territories, Ungava and Labrador; and (iii) the Arctic Yukon; (Polunin 1948, Porsild 1955, Rowley 1955).

The Alpine Tundra is divided into three sections: (i) the Alpine areas in the Northern Alplands Section are more extensive and less isolated than the Southern Alplands Section, their flora is apparently similar to the southern Alplands; (ii) the Southeastern Alplands Sections consist of boulder fields and fell fields, both with sparse vegetation, and alpine meadows; and (iii) the Southwestern Alplands Section which is characterized by a higher precipitation and lower snowline.

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CHAPTER II

SILVICS AND ECOLOGY OF POPULUS IN CANADA

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INTRODUCTION

An increased demand on Canadian forest resources has necessitated a re-evaluation of available raw materials other than the traditionally prized conifers. The other species include deciduous trees (hardwoods) among which various species of *Populus* (poplars) occupy a significant position. Poplars constitute nearly 54% of Canada's net merchantable hardwood timber and 9% of the entire Canadian net merchantable timber resources (see Chap. XIV). To meet increased timber requirements, the potential of poplars was realized much earlier in Europe than the U.S.A., and only recently in Canada. Features particularly favoring poplars include their great ecological amplitude, ease of propagation, fast growth and the multifarious uses of their wood. Judicious management of extensive areas inhabited by some of the native poplars and development of new hybrids would contribute significantly towards Canada's future forestry resources. All *Populus* spp. native to Canada extend to the U.S.A. where numerous workers are investigating their biology; these studies have contributed considerably to our knowledge of *Populus* spp. on this continent. This report reviews the available information on the silvical characteristics and ecological behavior of *Populus* spp. under Canadian conditions.

TAXONOMY

Genera *Populus* L. and *Salix* L. constitute the family Salicaceae belonging to the order Salicales. These ament- or catkin-bearing plants constitute the group Amentiferae (Benson 1957). In Canada, the genus *Populus* comprises trees with smooth to furrowed bark and scaly, often resinous buds. Leaves are alternate, simple, broad, often ovate, rounded or cordate at base, crenulate to dentate; petioles terrate, channelled or laterally flattened; stipules small, caducous. The trees are dioecious with precocious flowers borne in drooping catkins; staminate and pistillate catkins on separate trees; bracts (scales) lacerate to lobed; stamens 6 to many, with distinct filaments, on a broad disc; ovary conic to ovoid, borne on a cup-shaped disc; stigmas 2-4; capsule opening by 2-4 valves.

Taxonomically, the genus *Populus* is divided into five groups (Anon. 1958); the following species, belonging to three groups, have been reported as native to Canada (Anon. 1961):

GROUPS	SPECIES
Leuce	*P. tremuloides* Michx. (trembling aspen)
	P. grandidentata Michx. (largetooth aspen)
Aigeiros	*P. deltoides* Marsh. (eastern cottonwood)
	P. deltoides Marsh. var. *occidentalis* Rydb. (plains cottonwood)
Tacamahaca	*P. acuminata* Rydb. (lanceleaf cottonwood)
	P. angustifolia James (narrowleaf cottonwood)
	P. balsamifera L. (balsam poplar)
	P. trichocarpa Torr. and Gray (black cottonwood)
Leucoides	Not represented in Canada
Turanga	Not represented in North America.

General morphological features and taxonomically useful characters of all Canadian *Populus* spp. have been described (Anon. 1961); poplar species occurring in Newfoundland and Labrador have been described by Bearns (1967), in Quebec by Marie-Victorin (1964), in Ontario by White and Hosie (1957) and Zavitz (1959), in Manitoba by Scoggan (1957), in Saskatchewan by Budd (1952), in Alberta by Moss (1959) and in British Columbia by Garman (1953). Recently, Brayshaw (1965a) has made a valuable contribution towards the description and analysis of native poplars and their hybrids found in southern Alberta. Other natural hybrids of poplars occurring in eastern Canada have been reported (Peto 1938; Rouleau 1942). Characteristic crown form of trembling aspen, largetooth aspen and balsam poplar is valuable in recognition of these species from aerial photographs taken during summer and winter (Sayn-Wittgenstein 1960; Zsilinsky 1966). Trembling aspen, largetooth aspen, balsam poplar and black cottonwood may be identified by the characteristic infrared spectra of the ethanol/benzene extractive of their wood (Salama 1966).

Leaves are usually a reliable means of identifying various species of *Populus* in Canada (Anon. 1961). However, great variation occurs between the size and shape of leaves borne on short, lateral shoots (brachyblasts) and those borne on vigorously growing long, terminal shoots (turions), epicormic branches, stump sprouts and on the shoots originating adventitiously from roots (suckers). There appears to be a sequential pattern in the variation of the size and shape of trembling aspen leaves borne on the vigorously growing long shoots (Maini, unpublished data), therefore, only those leaves borne on the short shoots may be employed reliably in identification of the various species (Fig. 1). Variation in the length of buds and internodes has also been recorded in three species of *Populus* (Maini 1966a). Sequential patterns of bud and internode length on the leaders of young individuals of trembling aspen, largetooth aspen and balsam poplar are inherent; the relative size of apical and subapical buds is characteristic (Fig. 2) and

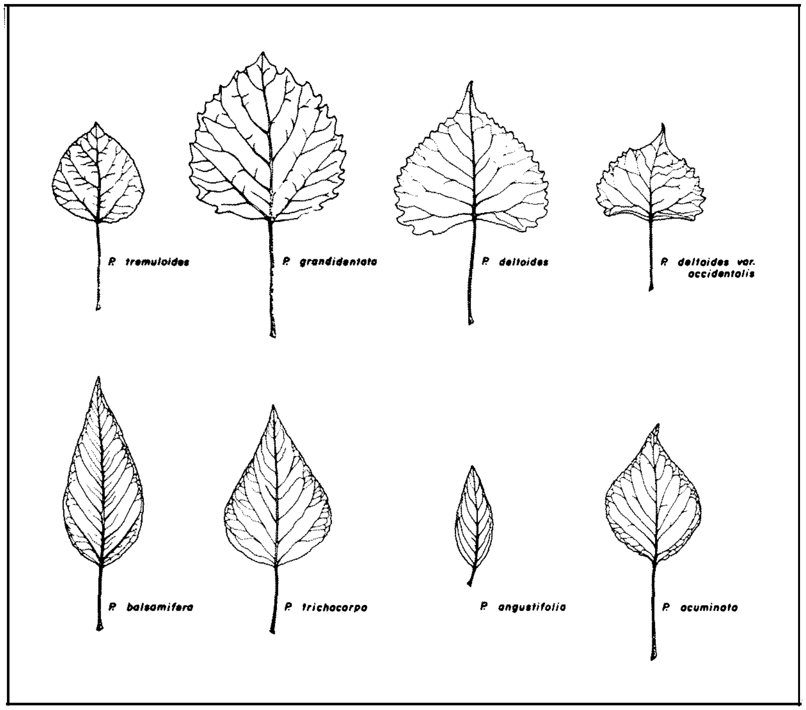


Figure 1. Shape of leaves borne on short lateral shoots (brachyblasts) of Populus *species reported in Canada (approx.* X *1/5).*

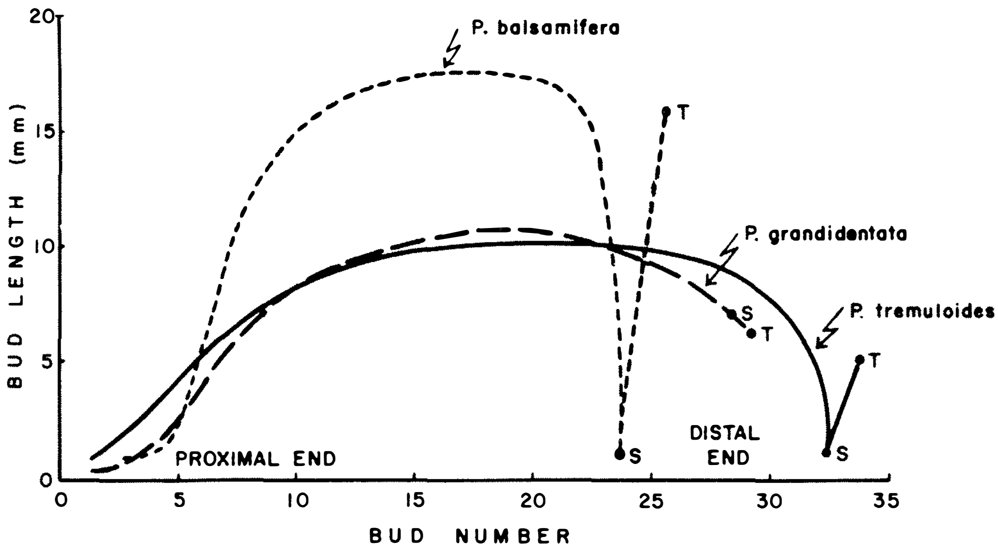


Figure 2. Generalized sequential pattern of bud length on long terminal shoots (turions) of three Populus *species. T, terminal bud; S, subterminal bud (From Maini 1966a).*

may be employed in identification of these three species in leafless condition (Maini 1966a). The following keys may be employed for the identification of various species of *Populus* by their vegetative characters (leaves, buds, bark, roots), both in leafy summer condition and leafless winter condition (Brayshaw 1960 and personal communication; Maini 1966a).

KEYS TO THE GENUS POPULUS IN CANADA

Leafy Summer Condition

1. Leaf narrow, lanceolate, fine-toothed. Petiole about ¼ length of leaf blade, flattened on top. Second year branchlets white or ivory-colored. Bud resinous. Range: Western plains and foothills of the Rocky Mountains. Narrowleaf Cottonwood, *P. angustifolia.*

   Leaf ovate or broader (may be lanceolate in seedlings of *P. balsamifera*). Second year branchlets usually greyish or yellowish....... 2

2. Petiole cylindrical, grooved on top, usually with glands at junction with blade, 1/3 to 1/2 length of blade. Leaf blade ovate to cordate, acuminate. Buds decidedly resinous...................... 3

   Petiole, at least in upper part, flattened in vertical plane, about 3/4 length of blade... 6

3. Staminate flower with 30 or fewer stamens. Capsule ovate, 2-valved, glabrous. Young shoots terete. Range: East, boreal forest, Rocky Mountains .... Balsam Poplar, *P. balsamifera*.. 4

   Staminate flower with 40 or more stamens. Capsule globose, 3-valved, young shoots commonly angled. Range: Pacific slope and southern Alberta .... Black Cottonwood, *P. trichocarpa*.... 5

4. Buds, petioles and leaves glabrous. Leaf base rounded .... *P. balsamifera* var. *balsamifera.*

   Buds, petioles and lower leaf surfaces finely puberulent. Leaf base broadly rounded to cordate. *P. balsamifera* var. *subcordata.*

5. Capsule simply globose, puberulent. Leaf broadly ovate, rounded to subcordate at base. Range: British Columbia, Yukon and Alaska .... *P. trichocarpa* var. *trichocarpa.*

   Capsule often broadly beaked, glabrous or nearly so. Leaf cordate, acuminate .... *P. trichocarpa* var. *hastata.*

6. Leaf orbicular to broadly ovate or elliptical, glandless. Buds not resinous .... Aspens.... 7

   Leaf deltoid, often with glands at junction of blade and petiole. Buds moderately resinous .... *P. deltoides*.... 9

7. Leaf coarsely sinuate-toothed; usually 10 or fewer teeth each side. Buds grayish-downy. Range: eastern .... Largetooth Aspen, *P. grandidentata.*

   Leaf finely serrate to crenate; usually 15 or more teeth each side .... Trembling Aspen, *P. tremuloides*.... 8

8. Buds glabrous, brown. Leaves glabrous. Range: transcontinental. .... *P. tremuloides* var. *tremuloides*.
Buds finely grayish-downy. Young leaves downy. Range: on Pacific coast .... *P. tremuloides* var. *vancouveriana*.

9. Buds glabrous. Leaves glabrous, many-toothed. Range: southern Saskatchewan to Quebec .... Eastern Cottonwood, *P. deltoides* var. *deltoides*.
Buds and young leaves minutely puberulent. Some leaves with 12 or fewer coarse, sinuate teeth each side below the conspicuously entire apex. Range: southern Saskatchewan and Alberta. .... Plains Cottonwood, *P. deltoides* var. *occidentalis*.

Leafless Winter Condition

1. Buds non-resinous .... Aspens.. 2
Buds resinous.. 3

2. Buds glabrous, brown (with grayish down in var. *vancouveriana* of Pacific coast), the terminal longer than the subjacent lateral bud. Smooth bark white, gray, or pale green; roots pale brown. Range: transcontinental ..... Trembling Aspen, *P. tremuloides*.
Buds grayish downy, the terminal and subjacent lateral buds of almost equal length. Smooth bark greenish yellow; roots dark reddish brown. Range: eastern .... Largetooth Aspen, *P. grandidentata*.

3. Second year branchlets dull gray or gray-brown. Buds very resinous.. 4
Second year branchlets pale yellowish to white. Buds moderately resinous... 6

4. Young shoots terete; the terminal bud longer than the subjacent lateral bud. Range: from continental height of land eastward .... Balsam Poplar, *P. balsamifera*..... 5
Young shoots commonly angled. Bud scales puberulent. Range: British Columbia, Yukon and Alaska.. Black Cottonwood, *P. trichocarpa*.

5. Buds glabrous .... *P. balsamifera* var. *balsamifera*.
Buds minutely puberulent .... *P. balsamifera* var. *subcordata*.

6. Second year branchlets white to ivory-colored, slender. Buds usually less than 10 mm long. Range: southern Alberta .... Narrowleaf Cottonwood, *P. angustifolia*.
Second year branchlets pale yellowish gray, usually stout. Buds usually more than 10 mm long .... *P. deltoides*...... 7

7. Buds glabrous. Range: southern Saskatchewan to Quebec .... Eastern Cottonwood, *P. deltoides* var. *deltoides*.
Buds minutely puberulent. Range: southern Saskatchewan and Alberta ... Plains Cottonwood, *P. deltoides* var. *occidentalis*.

The following taxonomic description of *Populus* spp. in Canada has been extracted from Sudworth (1934), Fernald (1950), Moss (1959), Anon. (1961) and Brayshaw (1965a).

P. tremuloides Michx.

Slender tree, the stem has a gradual taper and extends almost to the top of the tree; bark smooth, greenish gray to whitish, becoming dark and furrowed with age; twigs slender, glabrous, flexible, reddish brown, spreading or ascending; terminal bud 6-10 mm long (Fig. 3); leaves 3-8 cm long with slender flattened petioles; blades of short branches orbicular to broadly ovate, glabrous, short acuminate, finely serrate-crenate to nearly entire, dark green above, yellowish-green below, as long as or longer than broad. Aments soon pendulous; bracts deeply divided into 3-5 attenuate long-bearded segments; stamens 6-12 in an obliquely prolonged entire-margined disc; ovary glabrous with short stout style, bicarpellate; capsules slenderly conic, 3-5 mm long, warty. Seeds light with a tuft of hair attached to the basal end.

The western mountain variety *aurea* (Tid.) Dan. is distinguished from the typical by its shorter calyces, larger anthers and beautiful deep golden coloration (Sudworth 1934; Brayshaw 1965a).

In eastern form *pendula* Jaeger and Beissner, the branchlets are drooping (Fernald 1950).

In eastern form, *reniformis* (Tid.), the leaves are reniform or oblate and abruptly short tipped, as broad as or broader than long (Fernald 1950).

A coastal form *vancouveriana* (Trel.) Sarg. is restricted to Vancouver Island, B.C. (Sudworth 1934).

Variety *magnifica* Vict. has strongly lignified and conspicuously torulose branchlets with approximate gray nodes 6-12 mm thick, the branchlets often drooping and brittle at the base; mature lamina heavily coriaceous (Fernald 1950).

P. grandidentata Michx.

Slender tree with straight trunk; narrow, round-topped and very open crown composed of moderately stout and somewhat horizontally spreading branches; bark smooth, on young individuals with a slightly brownish-orange tinge during summer, turning greenish-gray during winter and generally indistinguishable from *P. tremuloides*, almost black and deep-furrowed at the base of old trunks (Fig. 4); twigs stiff, the young ones tomentulose. Buds canescent-pubescent. Expanding leaves heavily white-felted; mature blades 4-12 cm long, glabrate, coriaceous, narrowly to broadly ovate, short-acuminate, cuneate to rounded at the base; each margin with about 15 coarse,

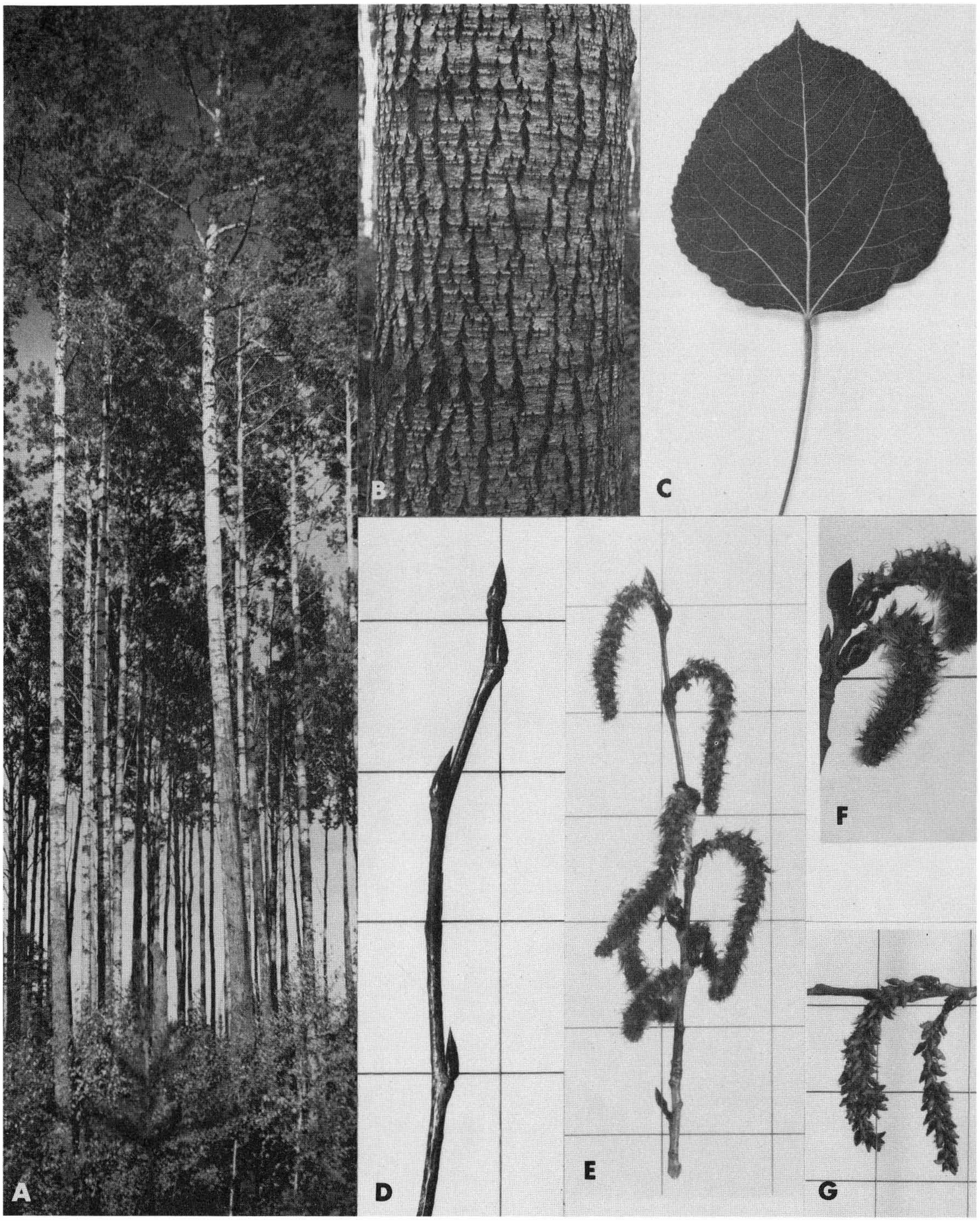


Figure 3. Morphological features of P. **tremuloides**: *A, typical stand; B, mature bark; C, leaf; D, winter twig; E, female catkins, F. male catkins; G, capsules.*

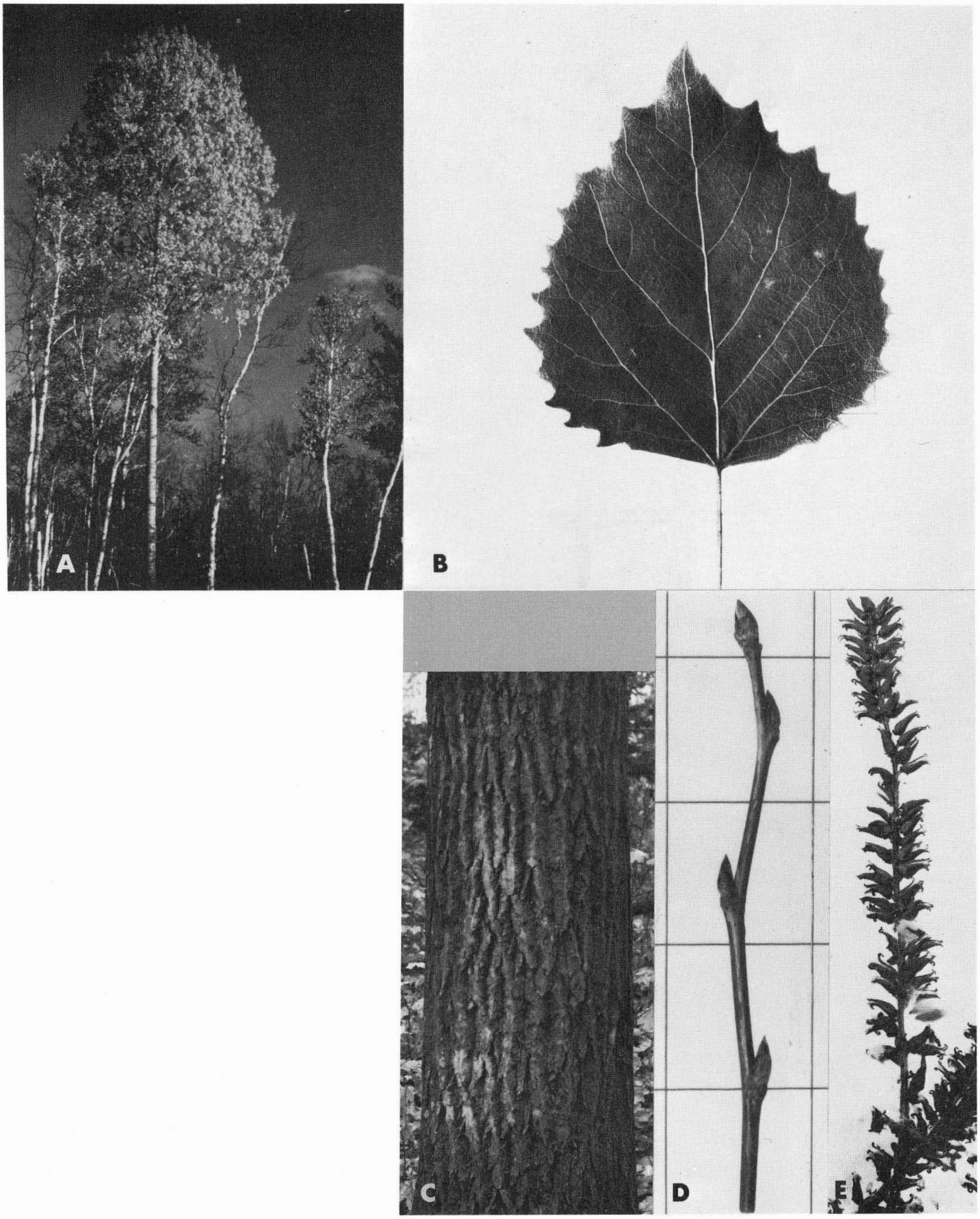


Figure 4. Morphological features of P. **grandidentata***: A, typical stand; B, leaf; C, mature bark; D, winter twig; E, capsules.*

unequal deltoid teeth. Aments coarser and larger than in *P. tremuloides*; bracts 5-7 cleft; ovary and capsules puberulent on a pubescent pedicel.

P. balsamifera L. (syn. *P. tacamahaca* Mill.)

Tree usually develops a long cylindrical trunk and a columnar open crown composed of a few stout, mostly ascending branches; bark at first smooth, greenish to reddish-brown, darkening and furrowing with age (Fig. 5); twigs lustrous, bright reddish-brown, terete; vegetative buds with 5-7 very resinous, pubescent and ciliate scales, fragrant. Leaves 5-10 cm long, glabrous, dark green above, pale green, generally with rusty-brown resinous blotches below; broadly lanceolate to ovate, acuminate, rounded to subcordate at the base, margins coarsely crenate-serrate; petioles terete. Bracts of aments fringed at broad summit by many flexuous bristle-like segments; stamens many on an oblique entire disc; ovary and glabrous capsule subtended by a symmetrical, persistent, saucer-shaped disc; stigmas sessile with coarsely toothed rounded lobes; capsule thick-walled, ovoid.

Variety *subcordata* Hylander has cordate to subcordate leaves, often strongly asymmetrical at the base, slightly pubescent at the veins beneath, petioles puberulent.

P. trichocarpa Torr. and Gray

Tree with a straight trunk often clear of branches for more than half the total height; in dense stands narrow crown composed of short limbs; bark smooth, greenish-yellow to gray on young stems, dark gray and furrowed on old stems; twigs smooth or hairy, red-brown or gray, round or slightly angled, terminal vegetative bud curved, long pointed, about 2 cm long, orange-brown, resinous, larger than the laterals (Fig. 6). Leaves 6-12 cm long, broadly ovate to ovate-lanceolate, acute, finely crenate, dark green and smooth above, paler, silvery-white or rusty-brown below, usually hairy when young but soon glabrous. Aments more or less hairy; stigmas 3; capsule subglobose, sessile or nearly so, densely pubescent, 3-valved.

Variety *hastata* (Dode) Henry has glabrous capsules and somewhat narrower leaves than the typical species.

Recently, Brayshaw (1965b) has analysed the taxonomic status of *P. balsamifera* and *P. trichocarpa* and their varieties. He has suggested the following revisions in the nomenclature of poplars of section Tacamahaca in the Cordilleran and adjacent regions:

P. balsamifera L., subsp. *balsamifera*, var. *balsamifera* L.

P. balsamifera L., subsp. *balsamifera*, var. *subcordata* Hylander

P. balsamifera L., subsp. *trichocarpa* (Torr. and Gray) Brayshaw var. *trichocarpa*

P. balsamifera L., subsp. *trichocarpa* (Torr. and Gray) Brayshaw, var. *hastata* (Dode) Henry.

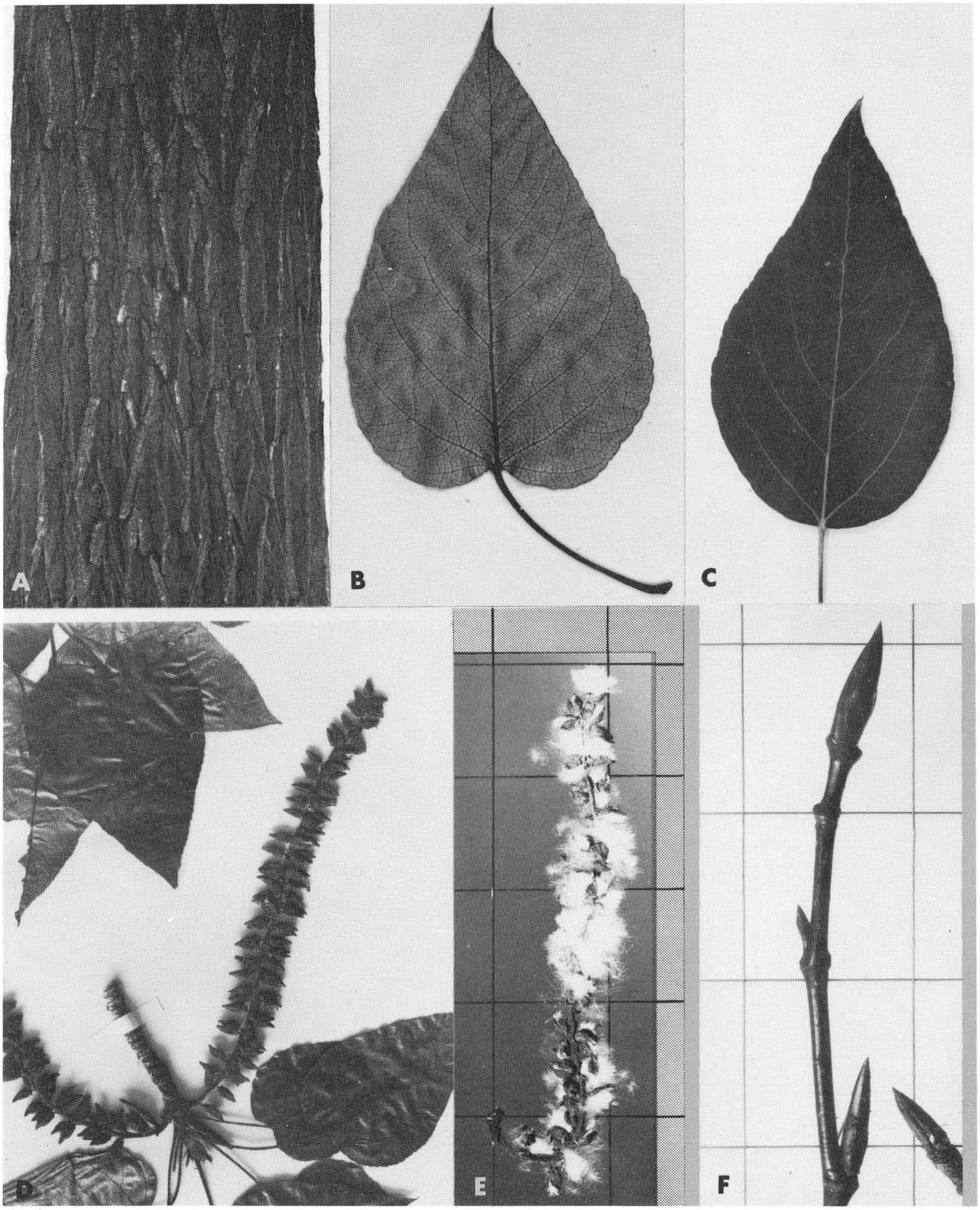


Figure 5. Morphological features of P. balsamifera: *A, mature bark; B, leaf --* P. balsamifera *var.* subcordata; *C, leaf --* P. balsamifera; *D, capsules; E, open capsules; F, winter twig.*

Figure 6. Morphological features of P. trichocarpa: *A, mature tree; B, mature bark; C, fruit; D, winter twig; E and F, leaves. (A, B, and C, courtesy B.C. Forest Service).*

P. angustifolia James

Usually slender tree, having a somewhat willow-like aspect with ascending branches (sometimes drooping at the ends) forming a narrowly pyramidal crown; bark usually smooth, yellow-green becoming shallowly furrowed at the base of old trunks; twigs slender, at first yellowish-brown, becoming bright white to ivory-colored by the second or third year. Bud scales glabrous, eciliate and moderately resinous. Leaves short-petioled, 5-6 cm long, acute to obtuse, cuneate at base, narrow, margin finely but sharptly glandular-serrate to apex (Fig. 7); light yellowish-green above, slightly if at all paler beneath; a further yellowish cast often produced by the sulfur-yellow resin secreted by the marginal glands; petiole semicircular in section and flattened above, rather stiff, glabrous and eglandular. Aments dense, smooth, drooping; fruit an ovate, glabrous, rugose, 2-valved capsule on a pedicel 4-5 mm long.

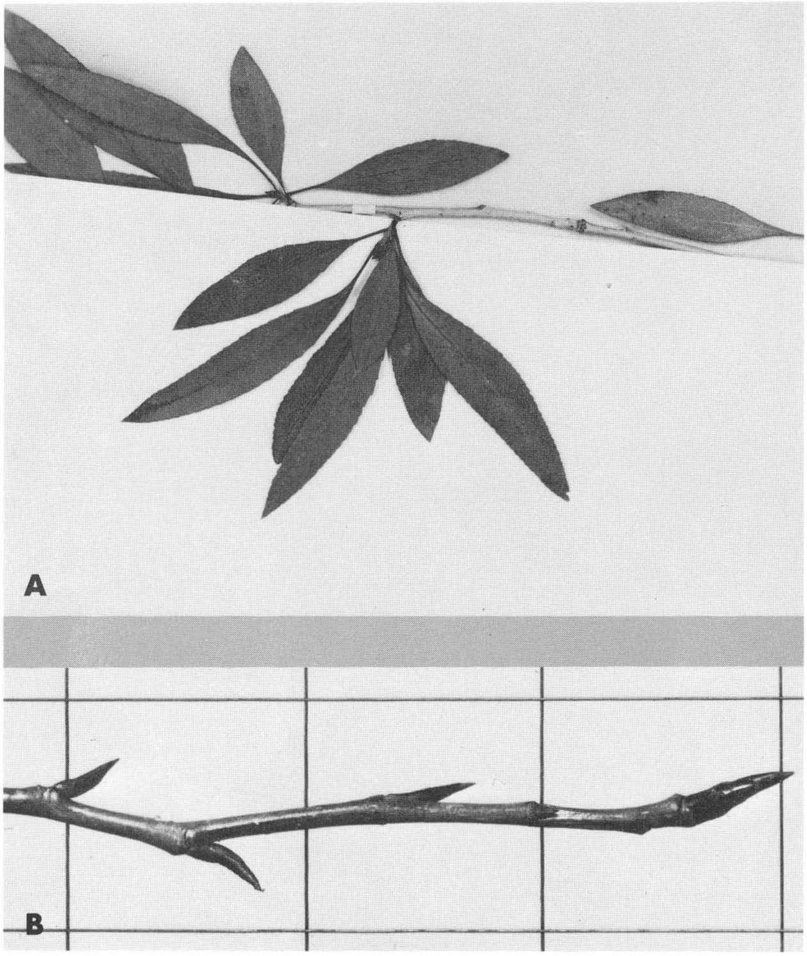


Figure 7. Morphological features of P. angustifolia: *A, leaves; B, winter twig.*

P. acuminata Rydb.

Tree with a rounded compact crown of stout, spreading or ascending branches; bark smooth, almost white at first, becoming gray-brown, deeply furrowed on old trunks; twigs slender, round or slightly angled, glabrous, yellow-brown. Terminal vegetative bud 1-2 cm long, narrow, sharp-pointed, smooth, chestnut brown, somewhat resinous. Leaves often rhombic-lanceolate, abruptly acuminate, cuneate at base, the margin crenate, 5-10 cm long, dark green, shiny above, dull green below; petioles 3-7 cm long (Fig. 8). Aments loosely arranged, smooth, drooping; capsules ovoid, papillose; pedicels 3-5 mm long.

P. acuminata has been included in section Tacamahaca (Smith 1943) and is putatively regarded as a hybrid between *P. angustifolia* and *P. deltoides* var. *occidentalis* (Little 1950, 1953; Brayshaw 1964a).

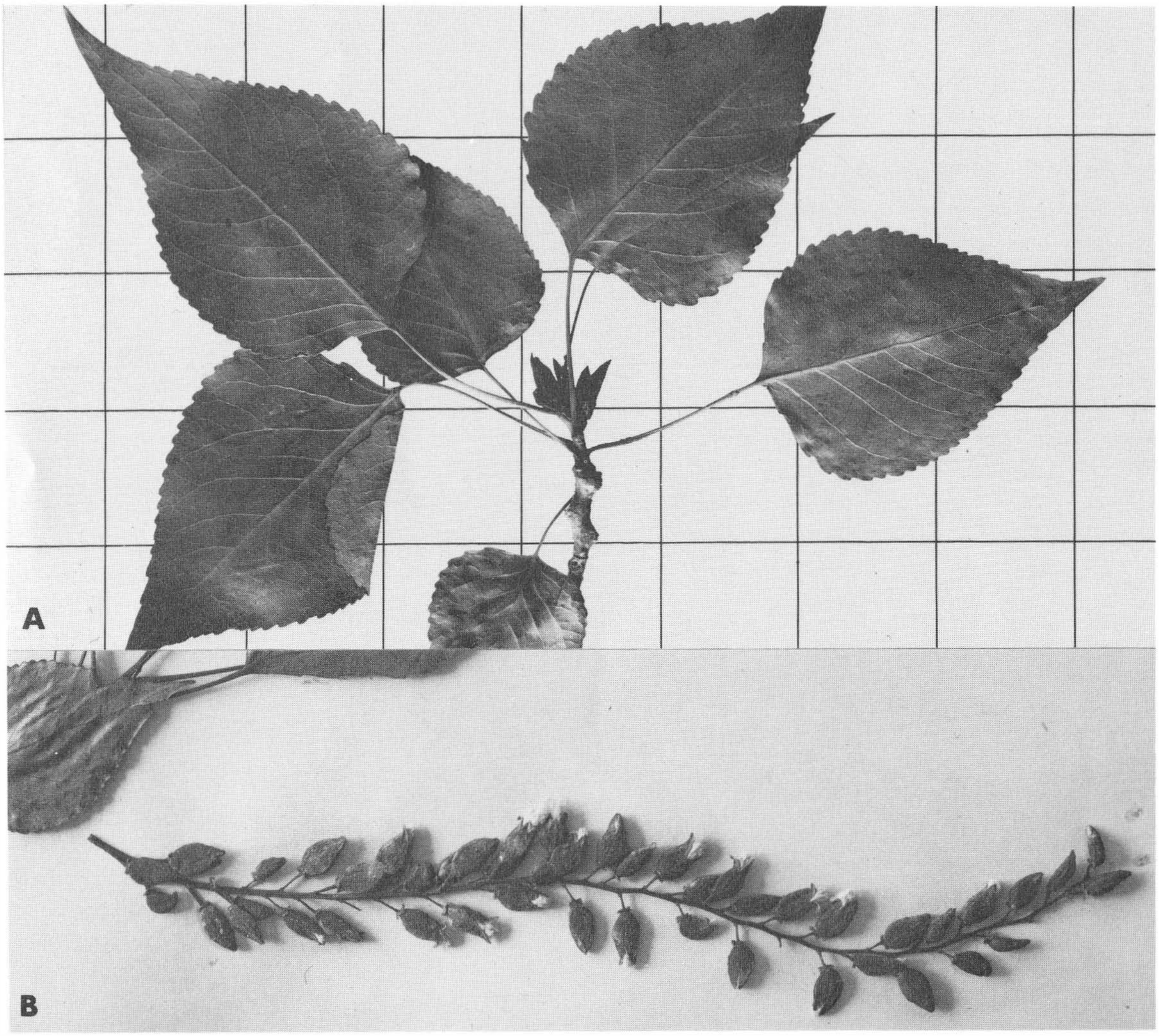


Figure 8. Morphological features of P. acuminata*: A, leaves; B, capsule.*

P. deltoides Marsh.

Young trees with a dense, conical crown of spreading branches; open-grown trees develop massive trunks which are sometimes divided near the ground into several stout, gradually spreading limbs and very broad, open crowns; bark smooth, greenish-yellow on young stems, dark gray, deeply furrowed and scaly on old trunks (Fig. 9); vigorously growing twigs, sprouts angled. Terminal vegetative bud about 1.5 cm long, sharp-pointed, heavily glutinous, glabrous, chestnut-brown, with 6 or 7 scales, outer scales puberulent; lateral buds similar to the terminal, smaller. Leaves triangular ovate, 6-12 cm long and broad, subtruncate to subcordate at base, acuminate, coarsely crenate-dentate, glossy green above, paler below, ciliolate, bearing 2-3 basal glands; petiole flattened at summit. Bracts of ament marginally fimbriate with many flexuous thread-like, beardless segments; stamens up to 60 or more; ovary and capsule glabrous, stigmas widespreading with broadly dilated lobes toothed; capsule ovoid, borne alternately along the catkin axis.

P. deltoides Marsh. var. *occidentalis* Rydb. (syn. *P. sargentii* Dode)

Tree with a straight massive trunk and stout, strong widespreading branches; bark at first gray and smooth, later deeply furrowed into broad rounded scaly ridges; twigs stout, smooth, often angled, light yellowish-brown becoming paler and yellowish-gray, often angled on vigorously growing shoots and saplings. Terminal bud about 1.5 cm long, hairy, olive-green to brown, resinous; lateral buds similar; bud scales pubescent and ciliate. Leaves coriaceous, broadly deltoid, truncate at base, finely and abruptly acuminate or attenuate at apex, 5-10 cm long, short-acuminate, light green, very shiny and glabrous above, paler below; the margin variable, from finely glandular-serrate to coarsely sinuate, the prominent teeth often slightly hooked and glandular at apex (Fig. 10). Aments glabrous, drooping catkins; capsules narrowly ovate tapering at both ends, 3-valved, glabrous, 9-14 mm long, on pedicels 5-7 mm long. Distinguished from *P. deltoides* by its pubescent and ciliate bud scales, the usually more coarsely-toothed leaves, and slightly puberulent young petioles.

PAST AND PRESENT DISTRIBUTION

Pre-Pleistocene

Available fossil records of the genus *Populus* have been attributed to a tendency of the various species to occur on moist soil, where plant remains are preserved readily, and to the firm texture of the leaves (Benson 1957). Thirty species have been described from the Upper Cretaceous period when they were ubiquitous in North America, especially along the borders of the Upper Cretaceous sea in the west (Berry 1917). *Populus* along with *Salix* and *Quercus* was an important constituent of the Arcto-Tertiary boreal flora which was widespread north of 75°N lat. (Campbell 1926). Leaves of more than 50 species of *Populus* have been reported to be preserved abundantly in the

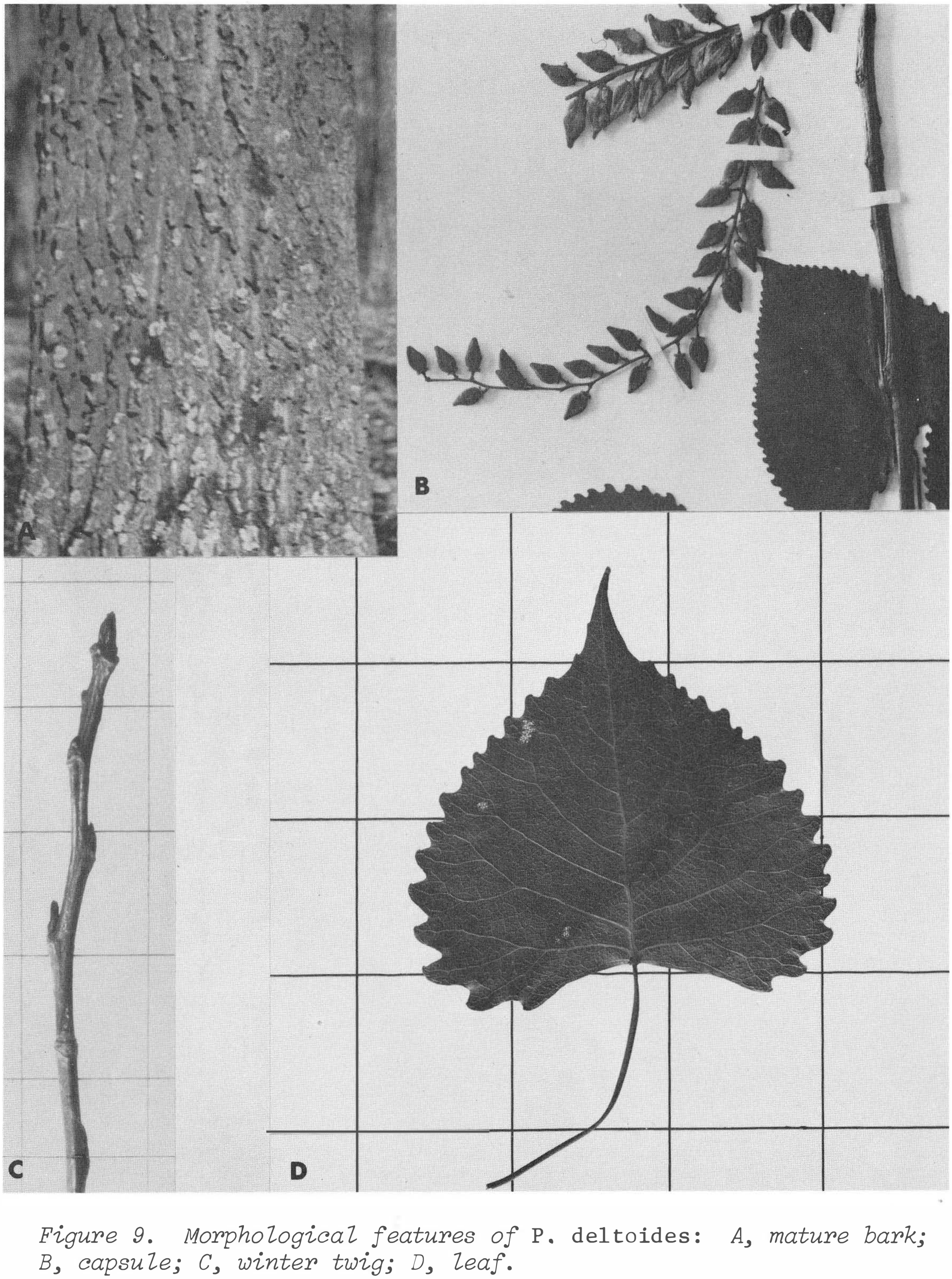


Figure 9. Morphological features of P. deltoides: *A, mature bark; B, capsule; C, winter twig; D, leaf.*

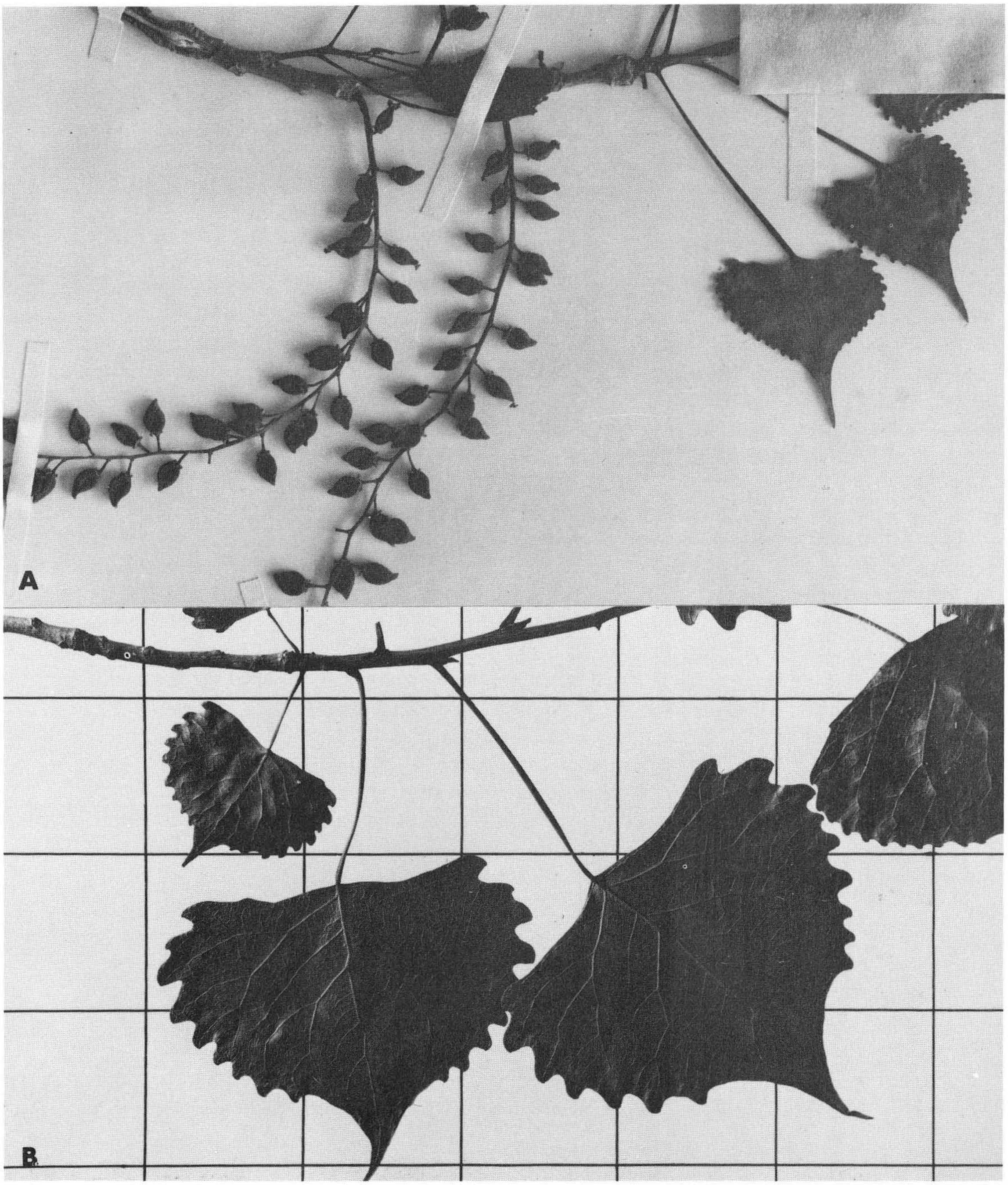


Figure 10. Morphological features of P. deltoides *var.* occidentalis: *A, capsules; B, leaves.*

continental deposits of the Eocene (Berry 1917). During this time *Populus* occupied all the plains and mountain country of western North America, extending northward to the mouth of the Mackenzie River and encircling the globe at high latitudes, while the climate further southward was too warm for *Populus*. Three species from the Oligocene have been described from western North America and 30 species from the Miocene flora have been described from along the Pacific in western North America, Greece and Spain. In North America they were found along the Pacific but none along the Atlantic or Gulf coast (Berry 1917). Fossils attributed to *Populus* in Canada have been discussed by Dawson (1853).

Pleistocene and Post-Pleistocene

Pollen of *Populus* spp., with delicate exine, is poorly preserved, therefore, it is difficult to reconstruct a reliable post-glacial record of the genus. In Alberta and Manitoba, *Populus* pollen was either absent or represented by less than 2% of the total samples from recent sediments in the areas where *Populus* was well represented in the surrounding vegetation (Erdtman 1943; Ritchie and Lichti-Federovich 1963; Lichti-Federovich and Ritchie 1965). Near Guelph, Ontario, Sangster and Dale (1961) traced decomposition of *Populus* pollen through the summer and autumn of two seasons and found that the pollen decomposed at all four habitats studied; the pollen disintegrated earlier in a farm pond, a lake and a swamp than in a bog. *Populus* pollen were recorded in two out of seven peat sections sampled in the vicinity of Alberta (Hansen 1949a), in two out of four sections sampled in west central Alberta (Hansen 1949b) and in three bogs on Vancouver Island (Hansen 1950a), but pollen were absent in the similar samples elsewhere in British Columbia (Hansen 1950b) and Alberta (Hansen 1952). Recently, Ritchie and his co-workers have investigated palynological problems related to *Populus* and they analysed the position of the genus in Holocene pollen spectra in west central Canada (Ritchie and Lichti-Federovich 1963; Ritchie 1964; Ritchie and de Vries 1964; Lichti-Federovich and Ritchie 1965). Other Pleistocene deposits of *Populus* are represented by wood, leaves, bud scales and catkins; macrofossils of trembling aspen, eastern cottonwood and balsam poplar were reported in a late-glacial deposit from the Missouri Coteau, Saskatchewan (Ritchie and de Vries 1964). Remains of largetooth aspen and balsam poplar were reported from the interglacial beds of the Don Valley in Ontario (Berry 1917) and in the nodules of calcareous matter from Green's Creek on the Ottawa River (Dawson 1893). Largetooth aspen was also reported from Leda clays of Montreal (Dawson 1893). Fossil wood of trembling aspen dated 5,130 ± 130 years was found in Ontario near Little Cypress River, on the northern shore of Lake Superior (Zoltai and Harrington 1966).

During Pleistocene glaciation, the genorheitra (Genorheitra: "streams of plant life laden with evolutive potential ..." Croizat 1952: p. 48), comprising sections Leuce, Tacamahaca and Aigeiros apparently survived in the various refugia located on the Appalachian land-mass, the Cordilleran land-mass around the Bering Sea, and in the southern part of the Bering Sea area (Maini 1960). Following glaciation, the ancestral populations of *Populus* seem to have invaded the denuded land from more than one direction.

In section Leuce (Fig. 11), largetooth aspen and the eastern lowland form of trembling aspen were probably components of the eastern biota while *P. tremuloides* var. *aurea* perhaps evolved from the populations that survived in the Yukon valley and other refugia south of the ice sheet (Maini 1960).

One part of the genorheitron comprising section Tacamahaca (Fig. 12) perhaps survived in the east and the second part on the Cordilleran landmass; these ancestral populations segregated into (i) balsam poplar distributed extensively in the cooler northern latitudes east of the Rocky Mountains, (ii) black cottonwood mainly restricted to the lower elevations between the Pacific Coast and the western part of the Rockies (Maini 1960), where there is high humidity, moderate temperature, long growing season and abundant moisture (Smith 1957) and (iii) narrowleaf cottonwood, a southern and continental species, restricted east of the Rocky Mountains. Lanceleaf cottonwood, inhabiting sandbars and river banks, is putatively regarded as a hybrid between narrowleaf cottonwood and plains cottonwood (Brayshaw 1965a), both of which also inhabit the same habitat.

The ancestral population of section Aigeiros (Fig. 13) apparently survived south of the ice sheet and during its northward migration along river courses, it segregated into eastern cottonwood of relatively eastern distribution and plains cottonwood commonly distributed along banks of streams and rivers in the western prairies.

Colored maps on following pages:

Figure 11. Distribution of Populus *species constituting Section Leuce in Canada (After Maini 1960).*

Figure 12. Distribution of Populus *species constituting Section Tacamahaca in Canada (After Maini 1960).*

Figure 13. Distribution of P. acuminata *and* Populus *species constituting Section Aigeiros in Canada (After Maini 1960).*

Present

Maps showing distribution of species within each of the three sections of *Populus* represented in Canada, namely, Leuce, Tacamahaca and Aigeiros (Figs. 11-13) have been synthesized (Maini 1960) from those prepared by Bell (1882), Sudworth (1934), Munns (1938), Halliday and Brown (1943, showing population intensity), Raup (1947), Anon. (1961) and Fowells (1965). These three maps illustrate some aspects of the phylogenetic and ecological relationships between the species within a section.

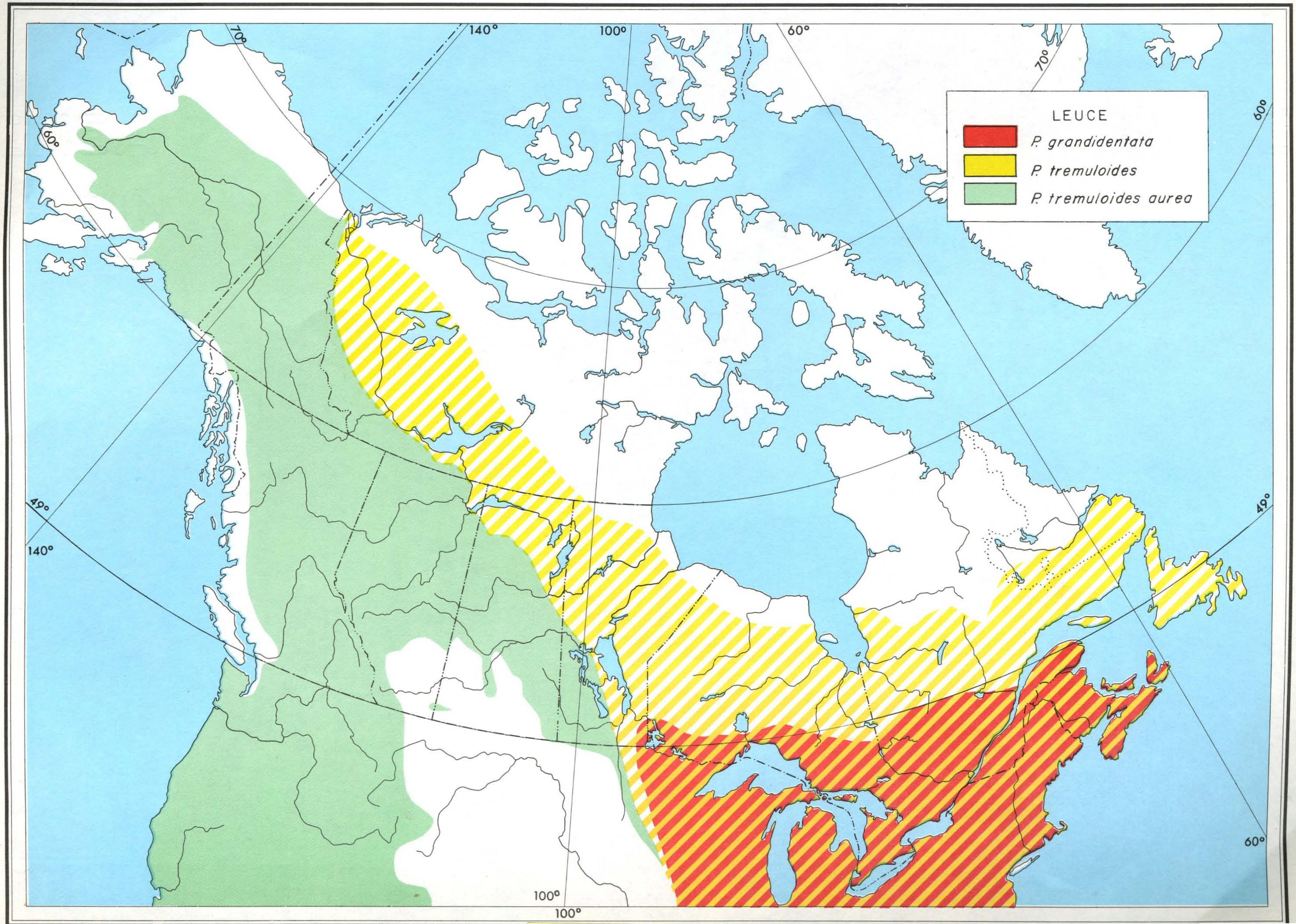
Section Leuce

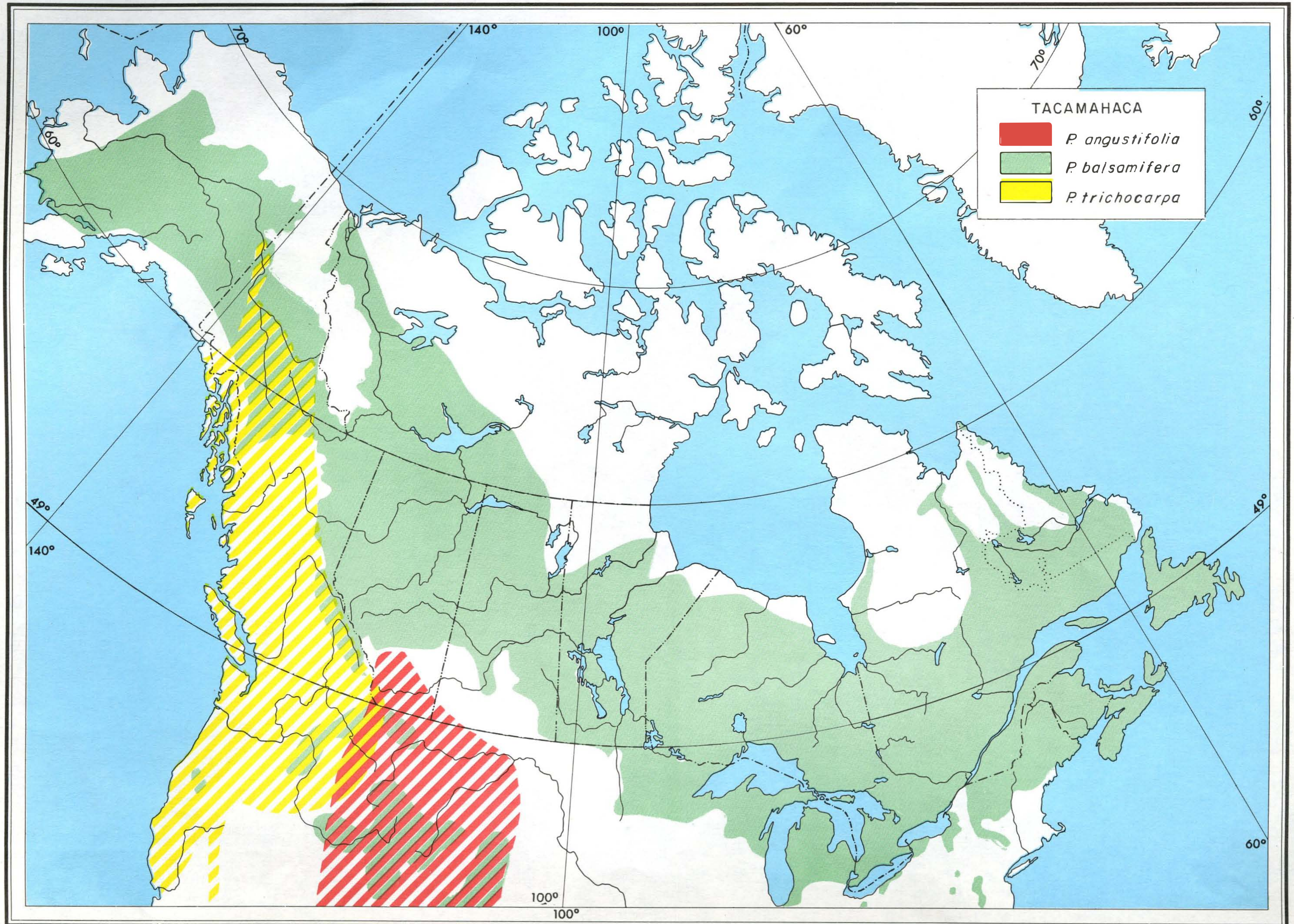
P. tremuloides Michx. (trembling aspen, quaking aspen, asp, aspen poplar, white poplar, popple, smooth-barked poplar, peuplier faux-tremble) including (i) typical form widely distributed in the east, (ii) western mountain variety *aurea* (Tid.) Dan., which has been found associated with the typical (Brayshaw 1965a), (iii) eastern form *pendula*, (iv) eastern form *reniformis*, and (v) variety *Magnifica* Vict. reported from Quebec and Ontario, and (vi) a coastal form *vancouveriana* (Trel.) Sarg. confined to Vancouver Island. This ubiquitous species extends across Canada from the Atlantic coast and Hudson Bay to the Mackenzie River delta, but is absent along the west coast (Fig. 11). Its northern boundary roughly approximates the 13C July isotherm (Halliday and Brown 1943) and is close to the forest-tundra ecotone (Hustich 1966). In the Prairie Provinces (Manitoba, Saskatchewan and Alberta) stands and groves of trembling aspen constitute the Aspen Grove Region (Maini 1960) which forms a transition between the Boreal Forest in the north and grassland in the south.

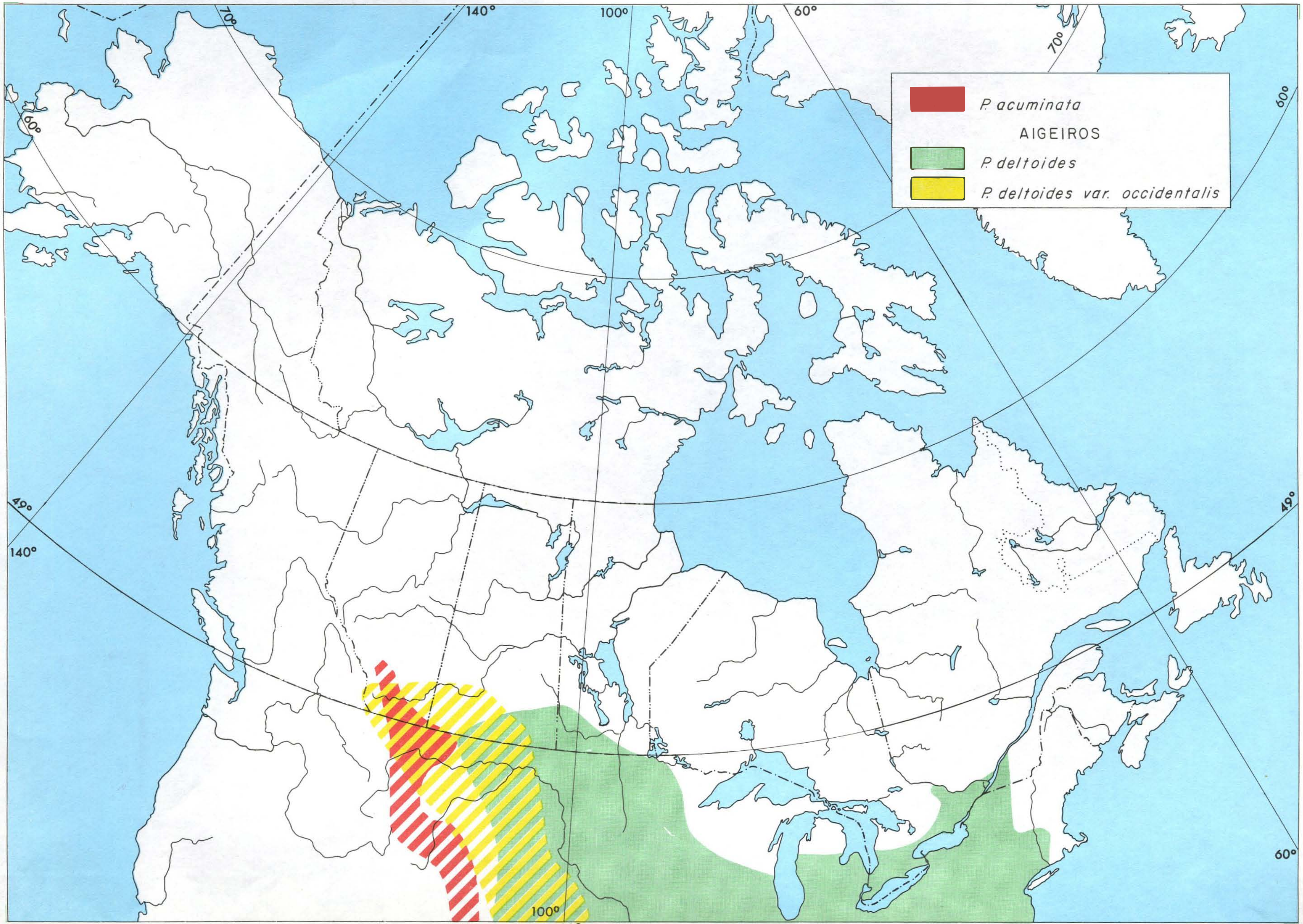
P. grandidentata Michx. (largetooth aspen, bigtooth aspen, largetooth poplar, peuplier a grandis dents). This species is restricted to eastern Canada, extending from Nova Scotia and Prince Edward Island, throughout southwestern Quebec and southern Ontario (Fig. 11), south of the height of land which divides the basins of the Great Lakes and Hudson Bay (Anon. 1961); also reported from the southeastern corner of Manitoba (Scoggan 1957).

Section Tacamahaca

P. balsamifera L. syn. *P. tacamahaca* Mill. (balsam poplar, balm poplar, balm of Gilead, balm, black poplar, rough-barked poplar, tacamahac, peuplier baumier) including var. *subcordata* Hylander, extends along the tree line from the Atlantic Coast and northern Quebec to the Yukon and northern and eastern British Columbia (Fig. 12). According to Hustich (1966) it extends to the forest-tundra transition "along river banks and southern slopes with good soil and less permafrost than the surroundings and it goes beyond the coniferous tree-line in westernmost Canada and Alaska". At one point on the shore of Baretooth Island in Lake Athabasca (northwestern Saskatchewan) Argus (1964) found shrubby specimens of balsam poplar growing on a submerged gravel beach. The species is sparsely scattered throughout the Aspen Grove Region where it occurs in the form of groves and is confined to moist depressions and margins of sloughs (Maini 1960).


LEUCE
P. grandidentata
P. tremuloides
P. tremuloides aurea
140°
100°
60°
70°
49°


TACAMAHACA
P. angustifolia
P. balsamifera
P. trichocarpa
140°
100°
60°
70°
49°


P. acuminata
AIGEIROS
P. deltoides
P. deltoides var. occidentalis
140°
100°
60°
70°
49°

P. trichocarpa Torr. and Gray (Black cottonwood, balsam cottonwood, balm cottonwood, western balm, cottonwood, western balsam poplar) including variety *hastata* (Dode) Henry, occurs mainly from the Rocky Mountains westward (Fig. 12), found in southern Yukon, throughout British Columbia (Anon. 1961) and southwestern Alberta (Moss 1959; Smith 1957; Brayshaw 1965b).

P. angustifolia James (narrowleaf cottonwood, willow-leaved cottonwood, bitter cottonwood, black cottonwood) is confined to stream banks in southern Alberta (Fig. 12).

P. acuminata Rydb. (lanceleaf cottonwood, Rydberg's cottonwood, smooth-barked cottonwood) is restricted to stream banks of southern Alberta (Fig. 12).

Section Aigeiros

P. deltoides Marsh. (eastern cottonwood, cottonwood, common cottonwood, peuplier a feuilles deltoides) is found scattered along stream banks and river valleys in southern Quebec, southern Ontario, southern Manitoba and in southern Saskatchewan (Fig. 13).

P. deltoides Marsh. var. *occidentalis* Rydb. syn. *P. sargentii* Dode (plains cottonwood, river cottonwood, Great Plains cottonwood) is restricted to southern Alberta and in southern Saskatchewan where its range overlaps with that of eastern cottonwood (Fig. 13).

ECOLOGICAL LIFE HISTORY

Phenology

Floral buds of *Populus* swell and extend before the foliar buds. Chilling requirements to break dormancy were apparently satisfied by mid-January and both male and female twigs of trembling aspen brought indoors and maintained at room temperature (about 72F) flowered in 10 days; however, in one exploratory observation, when twigs were brought indoors during the second week of November, the flower buds extended but the male flowers did not shed any pollen (Maini 1960). Mild periods in February initiate extension growth of flower buds of trembling aspen near Edmonton, but growth ceases during subsequent cold weather (Moss 1960). Dates of flowering, foliation and seed dispersal in 1959 were collected from about 30 localities in southern Saskatchewan. In southern Saskatchewan, the female trembling aspen flowered and foliated 4 to 5 days earlier than the male; towards the end of the growing season, the leaves on the female trees also turned yellow earlier than the leaves on the male trees (Maini 1960). Along the southern part of their range, most poplars flower in early April and foliate in mid-May. Towards the northern latitudes and higher altitudes, the phenological events in the spring are delayed and in the autumn they initiate earlier than the populations at southern latitudes (Maini 1960). Air temperature seems to be the principal factor affecting the time of flowering and the duration of the flowering period (Maini 1960; Moss 1960; Ritchie and Lichti-Federovich 1963) and a "daily mean maximum temperature exceeding 54F, over a period of about six days" appears to be necessary for the flowering of trembling aspen (Moss 1960). At Edmonton, Alberta (near 54°N lat.) the average date of flowering (Moss 1938, 1960) of trembling aspen is 25 April (based on 32 annual observations) and balsam poplar flowers on 5 May (based on 24 annual observations). At Winnipeg, Man., anthesis of *Populus* coincides with day and night temperatures of approximately 50F and 32F (Ritchie and Lichti-Federovich 1963). At Ottawa, Ont., (about 45° 30' N lat.) the apparent maximum and minimum threshhold air temperature for trembling aspen flowering (mean date: 16 April) was calculated as 27.9F and -9.2F, respectively, and for largetooth aspen (mean date: 24 April) it was 39.6F and 9.3F, respectively (Bassett, Holmes and Mackay 1961). In Saskatchewan growth activity of balsam poplar initiates about 10 days later and ceases earlier than that of trembling aspen. In Ontario, largetooth aspen flowers, foliates and sheds seeds about 10 days later than trembling aspen. The pollen dispersal may occur over distances of 3-500 miles (Ritchie and Lichti-Federovich 1963).

Sexual Reproduction

Flower and seed production

Populus is normally dioecious; however, abnormal floral organisation in a trembling aspen clone, comprising monoecious and polygamomonoecious stems (trees with bisexual and unisexual flowers on the same or different individuals but in the main monoecious), was reported near Saskatoon, Sask., (Maini and Coupland 1964a).

Flowering age in *Populus* is usually 15 years. The author has observed a few flowers on 10-year-old trembling aspen. Most flower buds are borne laterally on short shoots which terminate into foliar buds. A 23-year-old, 33-feet tall, female trembling aspen located about 60 miles north of Toronto, Ont., bore about 900 productive shoots, 2,200 catkins, 170,000 capsules and 1,625,000 seeds (Maini, unpublished data). The number of capsules per inflorescence and the number of seeds per capsule recorded in the above study was similar to that reported from Saskatchewan (Maini and Coupland 1964a) but the percentage of abortive seeds in Ontario was higher.

The seeds are pear-shaped and discharged from the capsule with a tuft of long silky hair attached to the proximal end. These hairs are not an outgrowth of the seed coat, therefore not truly seed hair. Good seed crops may be expected every second or third year and during seed dispersal, the ground is covered with white fluffy seeds (hence the name "cottonwood"). Seeds are very light and are dispersed long distances from the mother tree; one thousand trembling aspen seeds with hair weigh 0.1768 g and the seed hairs constitute 38% of the total weight (Maini and Coupland 1964a); one million seeds with hair weigh about 180 g (about 6.5 oz) and nearly 2.5 million seeds with hair weigh 1 lb. (Maini 1960).

Seed germination and early development of seedling

Taxa comprising sections Aigeiros and Tacamahaca (cottonwoods, black poplars, and balsam poplars) inhabit moist habitat and seedlings of these species and of their hybrids apparently establish naturally on moist freshly exposed soil (Smith 1957; Brayshaw 1965a). However, the establishment of seedlings of section Leuce (aspens) is rare and restricted to moist freshly exposed mineral soil[1] (Maini 1960). In central Alberta, natural longevity of seeds of trembling aspen and balsam poplar is 2 to 4 weeks; however, the germinative capacity may be prolonged by storing seeds on calcium chloride at -5C (Moss 1938). In laboratory tests, germination of freshly collected trembling aspen seeds was over 95% (Maini 1960) and laboratory tests on largetooth poplar and balsam poplar show similar levels of percentage germination. Paucity of trembling aspen seedlings in nature was due to (i) short seed viability, (ii) presence of a water-soluble germination and growth inhibitor in the "seed hair", (iii) occurrence of unfavorable moisture conditions during seed dispersal on upland sites that aspens usually inhabit, (iv) susceptibility of seedlings to high temperatures that occur on soil surfaces blackened by fire, (v) susceptibility of seedlings to fungal attack, (vi) adverse influence of diurnal temperature fluctuations on initial seedling growth, and (vii) unfavorable chemical nature of some substrates on which the seeds are likely to fall (Maini 1960). In northeastern Nova Scotia, Martin (1955) recorded establishment of largetooth aspen seedlings on mineral soil the second year after forest fire. The author has observed trembling aspen seedlings established on freshly-exposed, moist mineral soil near Lac la Ronge, Sask.

Largetooth aspen seeds, placed on moist sand at 75F and under an 18-hour photoperiod, showed over 80% germination after 1 day. Within the first 24 hours of the study, the radicle emerged from the seed, came in contact with the substrate, and a brush of fine hairs developed at the junction of hypocotyl and the radicle. These delicate hairs elongate and come in very close contact with soil particles and anchor the seedling to the soil surface. According to Moss (1938), these hairs are absorptive in function. After 48 hours, elongation of hypocotyl had raised the cotyledons from the ground. When the seedlings were 144 hours old, the radicle penetrated the substrate while the cotyledons expanded and shed the testa (Fig. 14).

Tricotyledonous seedlings and one seedling with two hypocotyls have been recorded in trembling aspen (Maini 1960). Morphological characteristics of largetooth aspen seedlings have been illustrated by Brayshaw (1959).

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[1]Horton, K.W. and J.S. Maini. 1964. Aspen reproduction: Its characteristics and control. Can. Dep. Forest., Forest Res. Br. Rep. 64-0-12. 85 p. (Mimeograph). Limited distribution.

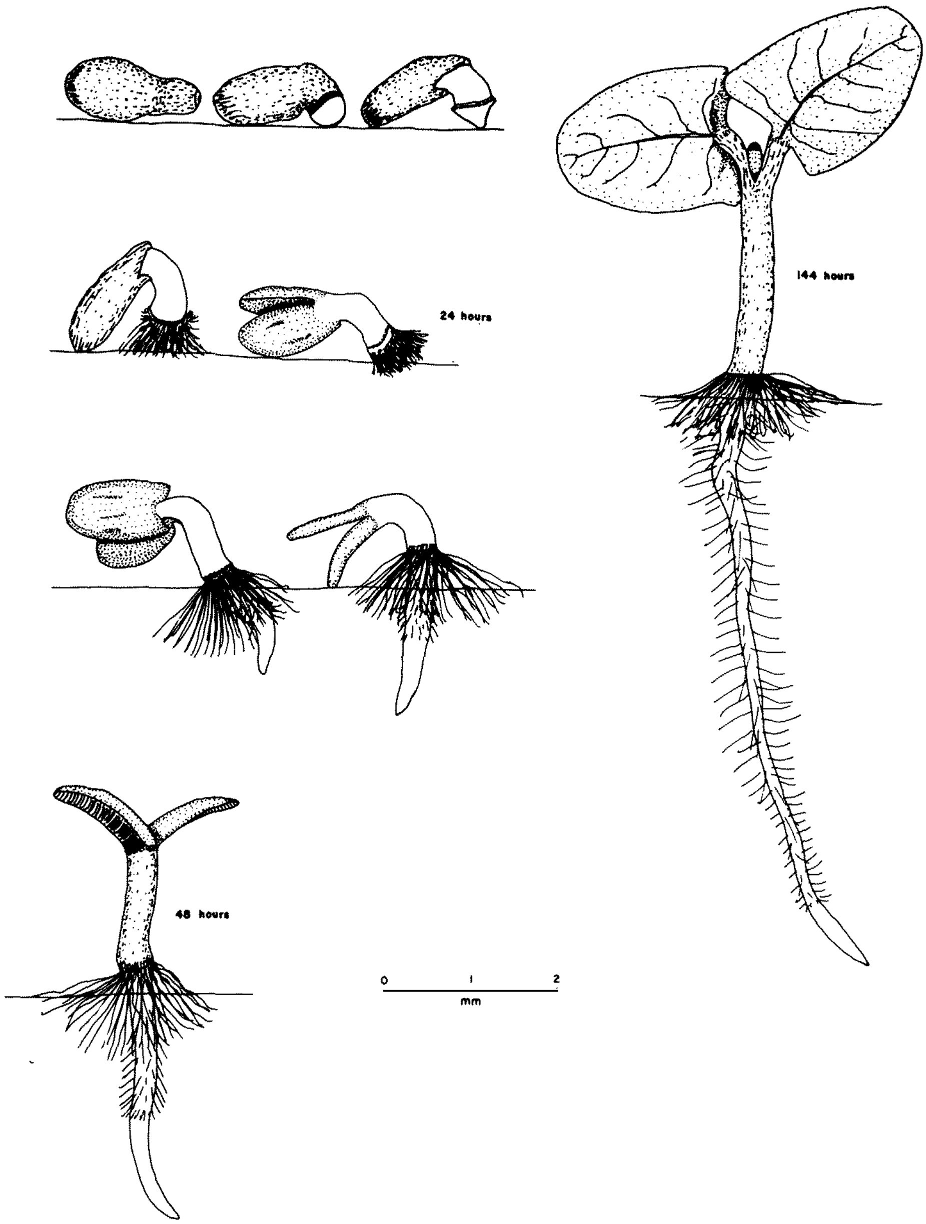

Figure 14. Various stages in germination of P. grandidentata *seedlings.*

Asexual Reproduction

Stem cuttings

Stem cuttings from the species comprising sections Tacamahaca and Aigeiros root with relative ease; however, rootability of aspen stem cuttings is extremely poor. Rooting is mostly restricted to the basal end and is better on the cuttings bearing expanding foliar buds.

Smith, Haddock and Hancock (1956) investigated the influence of age, length, diameter, depth of planting and tropophysis on the growth of stem cuttings obtained from 3-year-old black cottonwood. They concluded that survival and growth of cuttings is influenced by tropophysis; while 6-inch long cuttings obtained from a 1-year-old leader were preferable, similar growth may be expected from cuttings taken from primary and secondary branches and both 1- and 2-year-old leaders. When shoots of 1-year-old black cottonwood were divided into quarters and maintained in an atmosphere of 100% humidity at 4C, roots on the lowest quarter were the longest and most numerous (Bloomberg 1959). Cuttings obtained from the base of black cottonwood shoots produced a larger number of longer roots than cuttings from the top; rooting improved with an increase in the moisture content of cuttings, temperature, and with age of parent shoot up to a maximum of 10 months (Bloomberg 1963; also see Bloomberg 1962). In black cottonwood stem cuttings, the production of basal callus and the associated wound roots decreased when the relative turgidity of the bark was below the 80% level (Bier 1961).

Adventitious roots on the basal end of black cottonwood stem cuttings developed mostly from the callus tissue surrounding the cut surface (Bloomberg 1963) and callus production increased with temperature and moisture content of the cuttings (Bloomberg 1964); cuttings from the basal region produced more callus than those from the apical region, and the latter cuttings produced more callus on the basipetal end than the acropetal end (Bloomberg 1964).

Stem cuttings of balsam poplar grown in distilled water produced more roots and the callus masses that developed on these cuttings were larger, more irregularly shaped and softer than those on the cuttings grown in saturated CaS_4 maintained at pH 6.0 to 11.0; callus masses as well as emergence and subsequent growth of adventitious roots decreased with increasing alkalinity (Cormack 1965). The growth of new roots ceased when the cuttings, first grown in distilled water, were transferred to $CaSO_4$ solution (pH 11.0). However, when the procedure was reversed, almost every rootless callus mass, originally produced in saturated $CaSO_4$ solution, formed at least one root and the roots grew several inches during the first of 10 days (Cormack and Lemay 1966).

Stump and collar sprouts

Sprouts from stump and root collar, have been occasionally reported on young aspen up to sapling size[1] but not from older trees (Maini 1960).

An increase in sprouting with increased stump height[1] is perhaps related to acropetal increase in bud length (Maini 1966a). In lightly, as well as in moderately burnt aspen forests, sprouts were less abundant than suckers of both aspen species[1].

Root suckers

Reproduction by formation of adventitious shoots on roots (suckers) is the most common phenomenon among poplars. However, plains cottonwood does not form suckers as readily as other poplars (Anon. 1961), particularly aspens. When a 5-year-old stand of trembling aspen was slashed, the stand regenerated vegetatively and the regeneration comprised 82% suckers, 12% collar sprouts, and 6% stump sprouts[1].

Factors influencing root suckering

Commercial importance of aspens, which commonly regenerate by root suckers (Maini 1960), has prompted investigations on various ecological and physiological aspects of suckering under field and controlled conditions[1]. For laboratory studies[2], optimum length of cuttings of aspen roots was found to be 10 cm. The results of various studies on suckering of aspens are synthesized below.

Polarity in sucker formation: The number of suckers and buds formed on the proximal half is significantly greater than that on the distal half of 10 cm long root cuttings; this polarity is independent of light and gravity (Maini 1968a). Similar observations were made in field studies when portions of roots were severed from trees and retained *in situ*[1].

Clonal variation: Repeated vegetative reproduction of dioecious *Populus* has resulted in the formation of male and female clones of a few to several hundred trees (Maini 1960). When suckers were stimulated on root cuttings from four clones each of trembling aspen and largetooth aspen maintained at 60, 75, 85 and 95F (Maini 1967), the clones of both species had a significant to highly significant influence on the production of suckers and buds at all temperatures except trembling aspen at 95F (Fig. 15). Boekhoven[3] compared suckering response of one male and one female clone of each of the two aspen species; his results suggest that female aspens out-produced the male in the number of stems, buds and shoots, and new roots. However, in view of the clonal variability described above, a larger number of clones should be investigated to arrive at a valid conclusion.

[2]Maini, J.S. 1965. On the organization and growth of aspen roots. III. Relationship between length of root cutting and production of suckers. Can. Dep. Forest., Forest Res. Br. Rep. 65-0-10. 5 p. (Mimeograph).

[3]Boekhoven, L.W.D. 1964. Relative suckering capacity of male and female aspens. Can. Dep. Forest., Forest Res. Br. Rep. 64-0-5. 6 p. (Mimeograph).

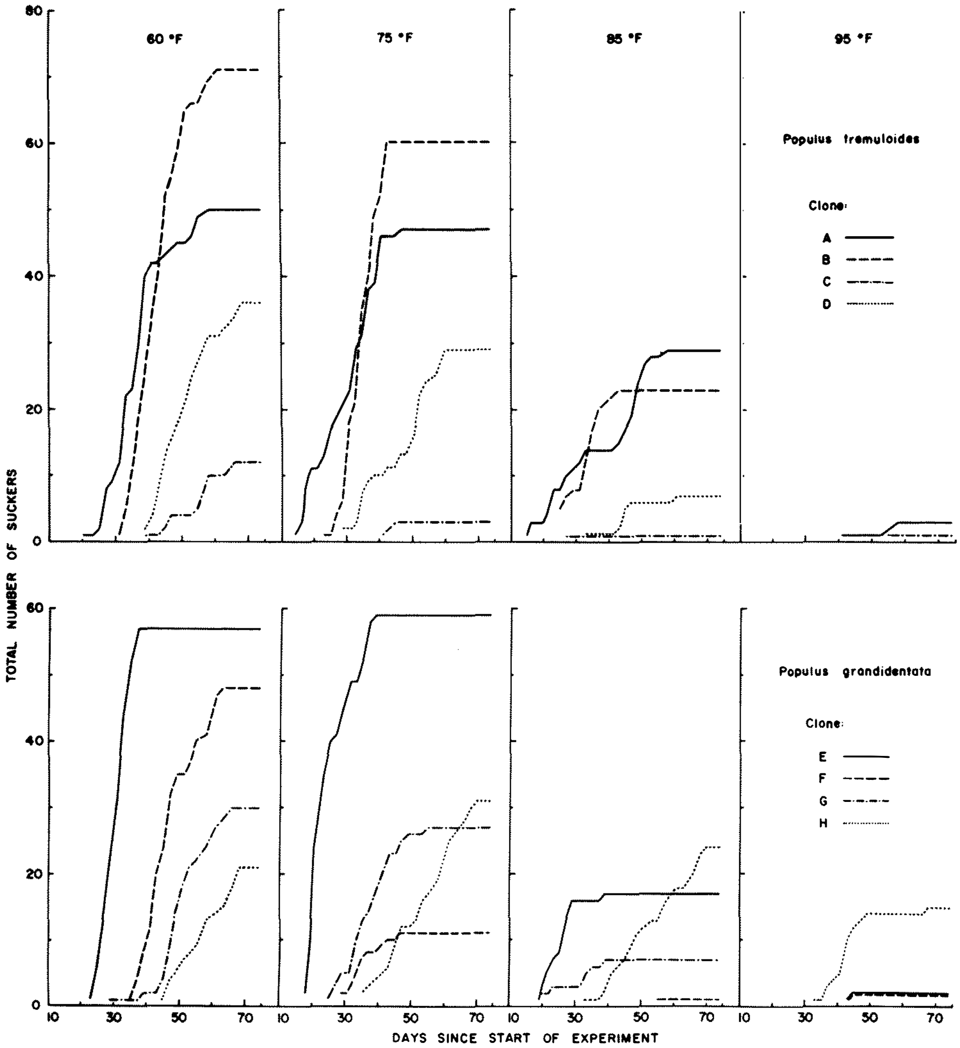

Figure 15. Variation in sucker formation on root cuttings obtained from four clones of each of the two aspens, maintained at four temperature regimes (After Maini 1967).

Age and vigor: Field observations by Rowe (1955) suggested that aging aspen stands decrease in suckering capacity. In experiments under controlled conditions, suckering was similar in chronologically comparable root cuttings (with 7-15 growth rings) obtained from 20- and 150-year-old trees[1].

Root thickness and depth: Suckers usually originate on shallow, cord-like lateral roots (Maini 1960). Sucker-bearing roots of trembling aspen range from 0.2 to 2.0 inches in thickness and those of largetooth aspen range from 0.2 to 4.5 inches; greatest proportion of suckers originate on roots less than 1 inch in diameter[1]. Most sucker-bearing trembling aspen roots are located in the upper 2 inches of soil (range <1.0-4.0 inches) and those of largetooth aspen are up to 3 inches deep in the mineral soil (range <1.0-7.0 inches).

Temperature: Field observations and studies under controlled conditions show that temperature is the most significant factor in sucker formation (Maini and Horton 1966a). Minimum, optimum, and maximum temperature for sucker formation in a clone of trembling aspen was 60, 75 and 95F, respectively. However, significant variation in suckering response to four temperature regimes (Fig. 15) was recorded among four clones of each of the two aspen species (Maini 1967).

Soil aeration: Only well-aerated root cuttings of aspens form suckers; cuttings placed in soil saturated or flooded with water were not productive and rotted. However, members of section Aigeiros may have an inherent capacity to sucker under relatively wet conditions.

Vegetation competition: Since insolation-induced increase in soil temperature favors sucker production (Maini and Horton 1966a), shade from trees and underbrush canopy is unfavorable for suckering (Maini and Horton 1966b). Maini and Horton (1966b) reported that in some aspen stands growing on sandy outwash, the dense canopy of *Pteridium aquilinum* (bracken) is a severe hindrance in suckering. Reproductive response and competition between aspens and associated bracken to various silvicultural treatments was evaluated by employing Reproduction Index where equal significance was attributed to number, stocking and size of aspen suckers and bracken.

Ecological disturbances: Any disturbance that results in an increase in soil temperature will stimulate aspen suckering. Common disturbances, favorable to suckering, include cutting of trees, removal of associated vegetation, fire and scarification[1,4,5] (Horton and Hopkins 1965; Maini and Horton 1966b). Prolific suckering after cutting of aspen trees was mainly attributed to the resultant change in ecological conditions, i.e., increased insolation and resultant increase in soil temperature (Maini and Horton 1966a). Suckering response increased with an increase in the intensity of fire (Maini and Horton 1966b) and intensive burning was ineffective for the elimination of suckers (Horton and Hopkins 1965). Suckering may be minimized by poisoning aspen trees[6] and by application of suitable cultural operations which result in a minimum increase in soil temperature (Maini and Horton 1966b).

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[4]Waldron, R.M. 1961. Poplar suckering increased by basal spraying of underbrush. Can. Dep. Forest., Forest Res. Br. Rep. MS-147. (Mimeograph).

[5]Horton, K.W., J.S. Maini and E.J. Hopkins. 1962. Soil temperature under different forest seedbed conditions. Can. Dep. Forest., Forest Res. Br. Rep. Ont. 62-18. 18 p. (Mimeograph). (Presented at Symp. Forest Meteor. and Microclimate, Cowichan Lake, B.C.).

[6]Waldron, R.M. 1963. Observations on aspen suckering in Manitoba and Saskatchewan. Can. Dep. Forest., Forest Res. Br. Rep. 63-MS-22. 18 p. (Mimeograph).

Development and Growth

Stem growth

Poplars are very intolerant of shade and grow best under full sunlight. Black cottonwood, a pioneer on river banks, shows a very rapid initial growth, and is therefore able to survive the competition from relatively slower-growing associated species (Anon. 1961; Brayshaw 1965a). Aspen suckers originate singly or in clumps; the height of dominant shoots in a clump increased with an increase in the number of shoots per clump[1]. Height growth of trembling aspen suckers was initially faster than that of the seedlings; this is apparently due to an already well-developed root system on which the suckers originate. Differences between the height of suckers and stem sprouts were non-significant[1]. High mortality, recorded among the sucker stems, was largely among suppressed stems[1].

Form of young individuals of trembling aspen is determined by the sequential pattern of buds (Fig. 2) and of internodes on the leader; branch length is related to the length of the bud from which it developed (Maini 1966a) and growth potential of some of the lower buds on aspen leaders is greater than that of the apical (Maini 1966b). Light browsing and pruning of lower branches of 3-year-old aspen suckers, debudding lower half to three-fourths of the 1-year-old suckers during the dormant season, and decapitation of suckers a few days-old had no adverse effect on subsequent height growth (Maini 1966b, c; Maini and Dance 1965). Apical injury extended the growth period and in some cases the height increment of the injured suckers exceeded that of the uninjured suckers. Records of seasonal extension growth of buds on leaders of several young trembling aspen (Fig. 16), growing 60 miles north of Toronto, Ont., showed that the growth of the basal branches ceased about 7 weeks earlier than the apical (Maini, unpublishe data). At Cedar Lake, Ont., (50° 15' N long., 93° 15' W lat.), the radial growth of trembling aspen commenced at the end of May 1950, ceased on September 11 and 50% of the seasonal growth had been laid by about July 12 (Belyea, Fraser and Rose 1951).

Poplars grown in closed stands have clear boles which are branchless for more than two-thirds of their height. The crown is usually conical on the younger trees but round-topped in the older trees. When growing in exposed conditions strong basal branches develop on the stem of trembling aspen (Maini 1960) as well as on other poplars.

Clonal variation: Intraspecific genetic diversity is manifested in variations in growth and reproductive response of *Populus* clones growing within a given locality and between widely separated populations. As described earlier, repeated vegetative propagation results in the formation of male and female clones of variable size and the stems constituting a clone are genetically identical. Field observations showed clonal variations in phenology (Maini 1960), growth, form and disease resistance[1] and in reproductive response of aspens (Maini 1967). This variation of aspen clones is used in breeding programs and possibly to encourage superior clones over the inferior

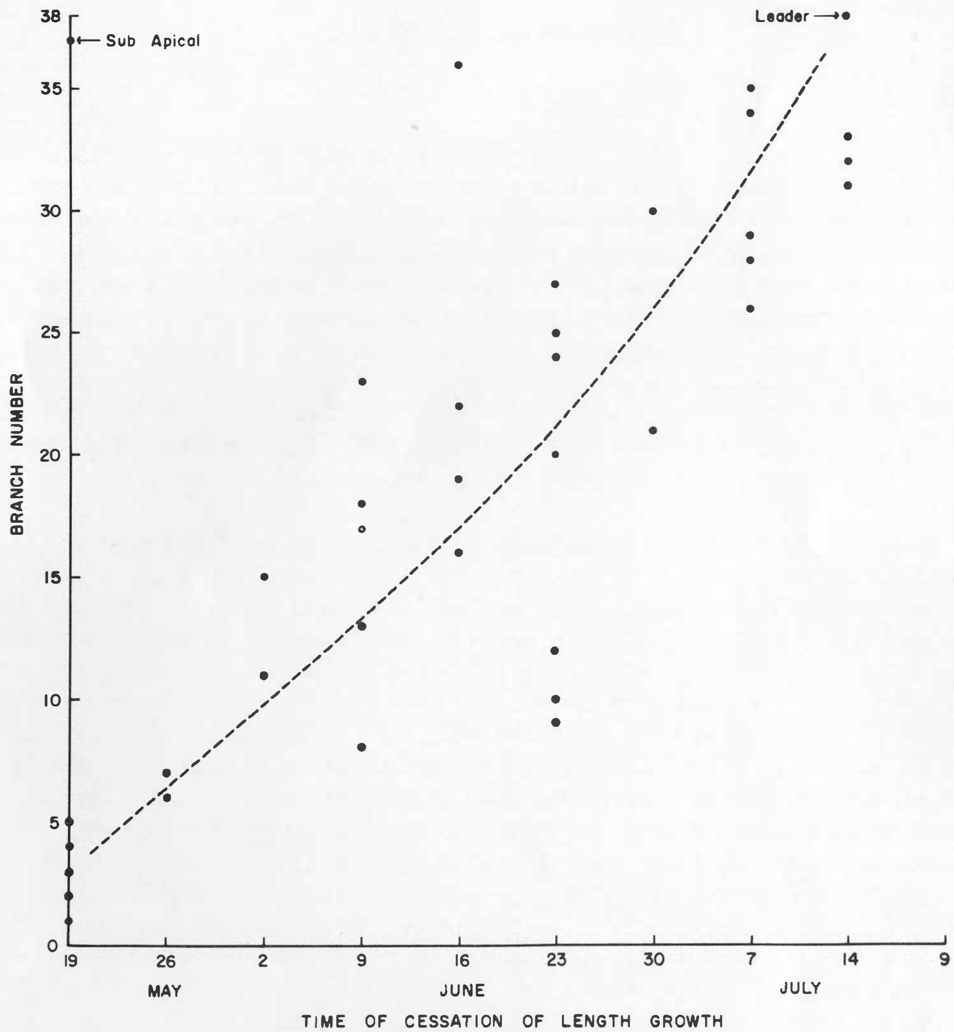

Figure 16. Time of cessation of length growth of branches and the leader on a young individual of P. tremuloides.

by employing suitable silvicultural techniques to promote suckering from "root trees"[7]

Photoperiod ecotypes: Vaartaja (1960) obtained trembling aspen seeds from Prince Albert, Sask. (54° N lat.) and Eagle River, Wisc., U.S.A. (46° N lat.) and compared growth response of the seedlings grown under a variety of photoperiods. His results demonstrated that photoperiodic ecotypes have evolved in the populations of latitudinally distant sites; he also demonstrated a similar phenomenon in eastern cottonwood seedlings. Pauley and Perry (1954) grew many clones of black cottonwood from cuttings obtained from British Columbia and the western United States; the time of

[7]Maini, J.S. 1965. "Root trees" for aspen silviculture. Unpublished Manuscript. 6 p.

height growth cessation was correlated with the origin of the source as follows: (i) different latitudes and (ii) different altitudes (and corresponding length of the growing season prevailing in the native habitat) but at the same latitude. These authors also recorded observations on the occurrence of photoperiodic ecotypes in clones of eastern cottonwood and balsam poplar.

Growth-ring analysis: In studies on growth-ring analysis of trembling aspen, difficulties were encountered due to inaccurate counting of growth rings (Maini and Coupland 1964b). According to Kirby (1953) 87% of the field counts on the growth rings in trembling aspen are unreliable. Use of discs (Kirby 1953; Ghent 1953), impregnation of decayed wood with paraffin (Ghent 1954) and replacing air in the increment cores with light oil (Rose 1957) was useful to overcome this difficulty. A simple rapid technique involves water infiltration of increment cores under low pressure (Maini and Coupland 1964b); this treatment would also overcome other inaccuracies in growth measurements similar to those caused by the shrinkage of increment cores from largetooth aspen (Brace 1966).

Root growth

Early development: Little information is available on initial development of roots on *Populus* seedlings; in the case of aspens, it is due to the paucity of seedlings in nature. Two secondary roots were observed on as early as 7-day-old largetooth aspen seedlings grown on moist sand maintained at 75F. The primary root, when only a few days old, is very sensitive to excessive temperatures and drought (Maini 1960). During the first year, the primary root tends to extend deeper into the soil. Subsequently adventitious roots develop near the root collar and extend laterally in the superficial soil.

Adventitious roots on suckers arise at the basal part of the stem or on the parent root near the sucker base. Apparently growth regulatory substances, produced in the leaves, stimulate rooting. The new roots also emerge on the distal end of root cuttings (Maini, unpublished data). Following sucker origin, a thickening develops on the distal side of the parent root besides the sucker[1] (Maini 1960). Development of another type of unusual tuberous root thickening was attributed to root injury[8].

Spatial organization: Root system of aspens is shallow and laterally very extensive (Fig. 17). A comparative study of the root system of trembling aspen and largetooth aspen growing under various ecological conditions showed that largetooth aspen roots were located more deeply than those of trembling aspen; the former were also less branched and with fewer adventitious roots than the latter (Figs. 18 and 19). Strong, vertically

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[8] Maini, J.S. 1965. On the organization and growth of aspen roots. I. Unusual root growth following stem and root injury. Can. Dep. Forest., Forest Res. Br. Rep. 65-0-8. 13 p. (Mimeograph).

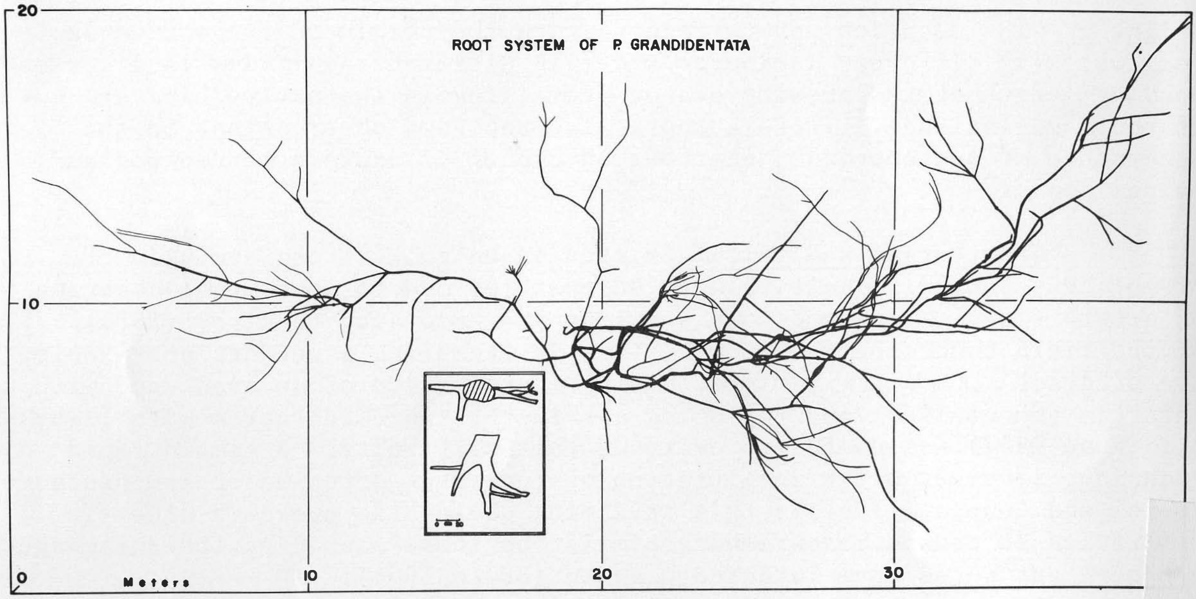

Figure 17. Lateral extension of Populus grandidentata *root system.*

penetrating roots, originating near the tree base and "sinkers" arising
the lateral root system provide a good anchorage to the trees. Usually
or five strongly developed laterals originate from the tree base and br
within 2 ft. Some of the cord-like branch roots, which extend a long d
tance without furcation or reduction in thickness, are particularly sui
for sucker production (Maini 1960). These cord-like roots grow faster
the rapidly-tapering laterals[9]. The root system of trembling aspen growing in the forest grassland ecotone was excavated by the bisect method and its vertical and lateral extension described by Maini (1960). In an 11-year-old aspen stand of sucker origin located in the Boreal Forest of Ontario, the roots were excavated by a hydraulic method and the distribution of root system described (Horton and Maini)[1]. According to Vaartaja (1960), the development of root system in aspen from the northern latitudes is greater than that from the southern latitudes; Vaartaja considered this as an adaptation to cold soils in the north.

Root connections: Suckers originating on a root system (of a parent tree) remain connected by parent roots, even after they have developed their own root systems. Radial growth of the root connection is negligible (Fig. 18) and the connection between the two trees remains alive until one of the two trees dies (Maini 1960). While excavating the root systems of aspens, live connections between 65-year-old trees were observed. Translocation of water-soluble dye was recorded through the root connections which were found to retain their capacity to form suckers (Maini, unpublished data). Root grafting is rare in aspen stands.

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[9]Maini, J.S. 1965b. On the organization and growth of aspen roots. II. Rapidly tapering and cord-like roots. Can. Dep. Forest., Forest Res. Br. Rep. 65-0-9. 10 p. (Mimeograph).

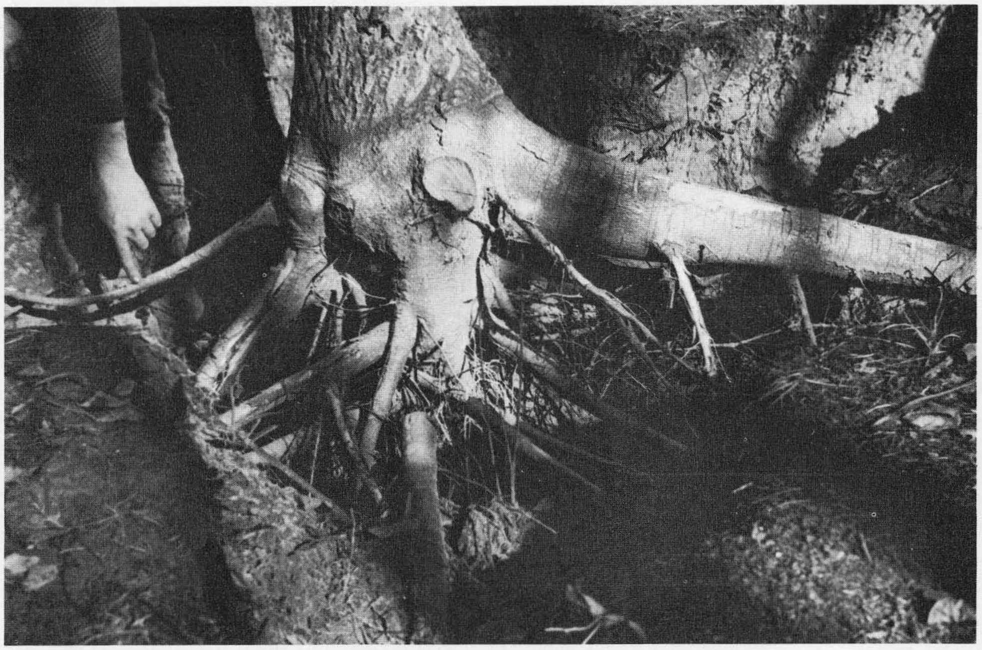

Figure 18. Root system of **P. grandidentata** *showing cord-like root connection on the proximal side of the tree and a thickening of parent root on the distal side. There are only a few, small adventitious roots on the deeply penetrating root system.*

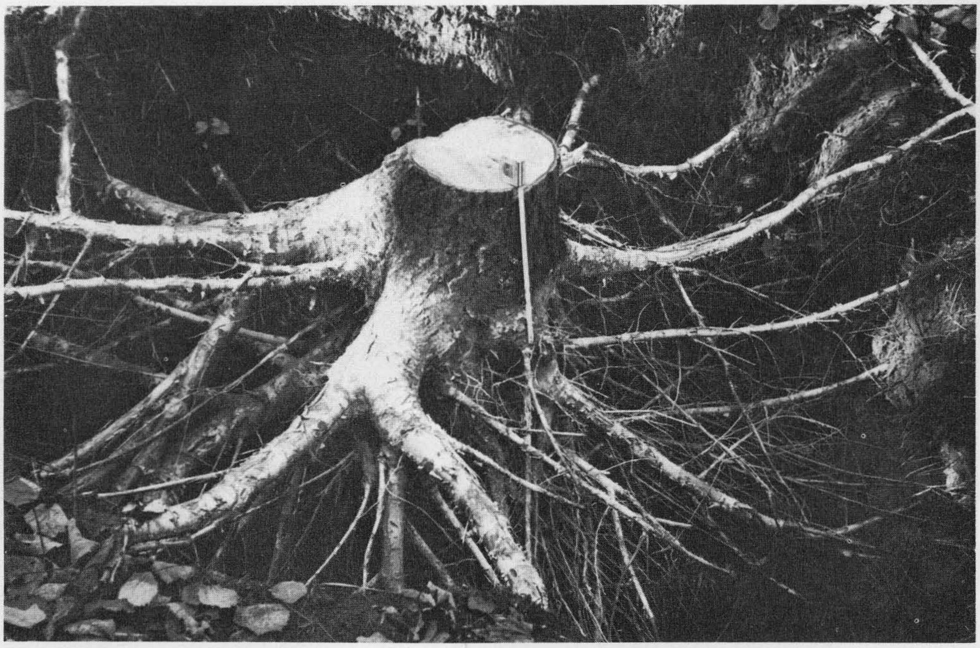

Figure 19. Root system of **P. tremuloides** *showing 5-6 shallow laterals branching profusely to form a well-developed root crown at the tree base.*

BIOTIC, CLIMATIC AND EDAPHIC RELATIONSHIPS

Poplars are intolerant pioneer species colonizing a wide range of habitat conditions. Some members of sections Tacamahaca and Aigeiros (balsam poplars, cottonwoods) colonize wet-mesic to mesic habitats including river banks and freshly exposed sandbars. However, aspens constituting section Leuce commonly occur in burnt, cutover or otherwise disturbed forests located on upland, well-drained sites.

Trembling aspen, largetooth aspen and balsam poplar play a significant successional role in the ecosystems of various sections constituting the Boreal Forest Region. Lacate, Horton and Blyth (1965) have described the role of trembling aspen and balsam poplar in the primary and secondary succession along the Lower Peace River in Alberta and Northwest Territories where repeated fires maintain more or less even-aged stands of *Populus* and retard their replacement by more tolerant white spruce. Along the Lower Liard River in the Northwest Territories, Jeffrey (1964) analysed the forest types in relation to land types and found trembling aspen and balsam poplar as important constituents of forests on flat to undulating terraces as well as on ancient flood plains; both land types were situated at an elevation of 600-700 feet. On these two habitats, 70- to 100-year-old *Populus* may attain a height of 90 to 100 feet.

In the Boreal Forest Region (Rowe 1959; Chap. I), aspens occur on upland sites in the form of pure stands of either species, or mixed stands of the two species or they are associated with spruce, pine, and birch. Light intensity exerts a significant influence on the composition of lesser vegetation under aspen canopy (Swan and Dix 1966). In Alberta, Moss (1932) described 178 vascular plants and 38 mosses and lichens in forests dominated by trembling aspen and balsam poplar. In aspen stands (with characteristically light canopy), located on mesic sites in the boreal forest, common shrubs occurring include, *Symphoricarpos*, *Corylus*, *Alnus*, *Cornus*, *Amelanchier*, *Prunus virginiana* L., *P. pensylvanica* L., *Salix*, *Lonicera*, *Ribes* and *Viburnum*; among herbs, *Aralia nudicaulis* L., *Pyrola asarifolia* Michx., *Cornus canadensis* L., *Maianthemum canadense* Desf., *Smilacina stellata* (L. Desf.), *Fragaria virginiana* Duchesne, *Rubus triflorus* Richard, and *Viola canadensis* are found most commonly (Moss 1932; Bird 1930; Rowe 1956; Maini 1960; Swan and Dix 1966). In dry-mesic areas, the associated ground flora comprises fewer species and on well-drained medium sand in Ontario, the ground may be covered with a dense mat of *Pteridium aquilinum* (L.) Kuhn (Maini and Horton 1966b). Trembling aspen is associated with largetooth aspen on dry-mesic and mesic sites and with balsam poplar on wet-mesic sites. Moss (1932) has described the floristic composition of mixed stands of trembling aspen and balsam poplar in Alberta.

Balsam poplar is more exacting in its ecological requirements and is usually restricted to moist depressions, river bottoms and along the shores of streams and lakes. However, near its northern limit of distribution, Argus (1966) observed balsam poplar growing on a sandy, dry, south-facing esker slope. In pure stands of balsam poplar on wet-mesic sites in Alberta, the ground vegetation is composed of *Cornus stolonifera*

Michx., *Salix, Ribes, Alnus, Lonicera, Mertensia pilosa* (Cham.) DC., *Equisetum, Petasites palmatus* (Ait.) Gray, *Galium triflorum* Michx., *Mitella nuda* L., *Actaea, Hylocomium splendens* (Hedw.) Warnst., *Aulacomnium palustre* (Web. & Mohr) Schwaegr., *Thuidium recognitum* (Hedw.) Lindb. (Moss 1932).

Clumps of trembling aspen and occasionally of balsam poplar constitute the ecotone between the Boreal Forest and Grassland (Aspen Grove Region) in the Northern Great Plain of western Canada. Observation on the dynamics of this ecotone have been recorded in Alberta (Moss 1932, 1944, 1952; Moss and Campbell 1947) and in Manitoba (Bird 1930, 1961). An analysis of the pattern, rate and extent of invasion of grassland by trembling aspen shows that a limited amount of arboreal extension has occurred in grassland since the advent of Europeans and consequent cessation of widespread prairie fires (Coupland and Maini 1959; Maini 1960). In dune sand areas within the grassland region of Saskatchewan, Hulett, Coupland and Dix (1966) have described the phytosociological behavior of trembling aspen. Extension of trembling aspen forest into grassland of north and central British Columbia has been reported (Brink and Farstad 1949).

A wide range of distribution of trembling aspen growing on a variety of habitats, provided an excellent opportunity to study the influence of a range of ecological conditions on its height growth (Maini 1968b). Dominant height of mature trembling aspen trees was measured in 96 stands located in an approximately 750 mile-long south-north transect, starting in grassland from near the southern boundary of Saskatchewan (49° N lat.) and extending across the various vegetation and climatic zones (Chap. I) to the northern limit of the boreal forest near the northern boundary of Saskatchewan (60° N lat.). Aspen was absent at the forest-tundra transition investigated at 61° N lat. (Maini 1966d). The sample comprised 39 stands located in the Grassland, 15 in the forest-grassland transition and the remaining 42 were located in the Boreal Forest Region. Growth of aspen is limited by the moisture towards the south (Maini 1960) and by temperature and other edaphic factors towards the north. Results show that in Saskatchewan, aspen attained maximum height growth in the Boreal Forest between 55° and 56° N lat. (Fig. 20), in the stands located north of the height of land where rivers flow towards Hudson Bay (Maini, unpublished data). Trembling aspen stands showing excellent growth seem to be located north of this height of land in other parts of Saskatchewan, eastern Alberta, Manitoba, and Ontario. The aspen trees are relatively shorter southwards in the forest-grassland transition and in the grassland as well as towards the northern distribution limits of the species near the forest-tundra transition. In the latter ecotone, aspen is stunted and attains a shrubby appearance (Tyrell 1898; Ritchie 1959; Argus 1966). Observations on the distribution limits, growth and reproduction of trembling aspen and balsam poplar in various parts of northern Canada have been recorded by Hustich (1949, 1950, 1954, 1955, 1957, 1965, 1966).

Another interesting feature in the ecology of a widely distributed species is exhibited by the predominant mode of reproduction of trembling aspen in Saskatchewan at its northern and southern limits of distribution and by its regeneration potential at intermediate locations (Maini 1968b).

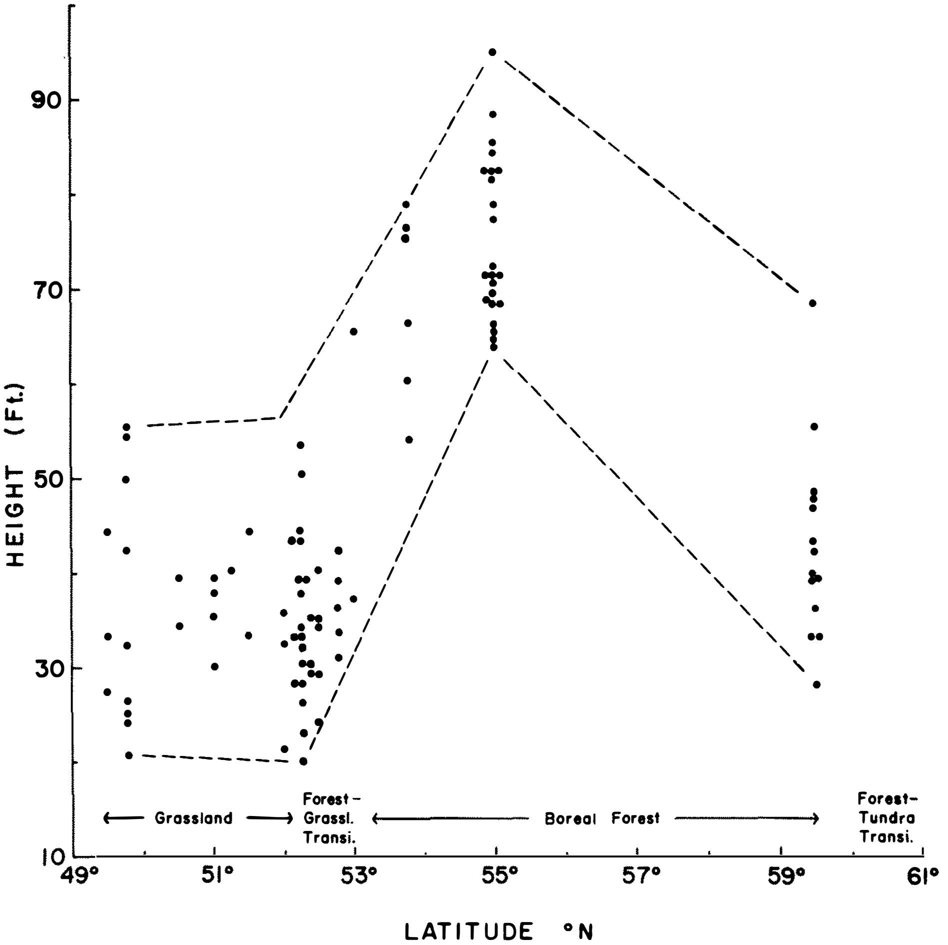

Figure 20. Influence of a climatic gradient (as related to latitude) on height growth of P. tremuloides *in Saskatchewan (based partly on Maini 1960 and partly on Maini 1968b).*

Near the forest-tundra ecotone (e.g. Stony Rapids, Sask., near 60° N lat.) and in the forest-grassland ecotone, the species regenerates vegetatively by formation of root suckers (Coupland and Maini 1959; Maini 1960). Argus (1964, 1966) and Hustich recorded similar observations, i.e., trembling aspen and balsam poplar reproduce vegetatively towards their northern limits. However, in the middle of the boreal forest (e.g., Lac la Ronge, Sask., near 55° N lat.) the author has observed aspen seedlings well established on freshly exposed, moist mineral soil. Apparently trembling aspen survives the adverse conditions at the northern and southern limits of its range by asexual propagation,

In the Great Lakes and St. Lawrence Forest Region (Rowe 1959; Chap. I) located along the Great Lakes and St. Lawrence River valley, *Populus* spp. are a minor component of these forests which are dominated by tolerant hardwoods such as beech, elm, maple, basswood, ash, walnut, yellow birch and by conifers including pine and hemlock.

Eastern cottonwood was the leading dominant in only two stands and trembling aspen in only one stand out of a total of 131 stands sampled in the Deciduous Forest in southwestern Ontario (Maycock 1963). Whereas balsam poplar was distributed on mesic to wet sites and attained the maximum importance at the wet end of a moisture gradient, largetooth aspen was distributed from dry to wet sites and its importance showed a bimodal pattern (Maycock 1963).

In Coast, Columbia, and Montane Forests (Rowe 1959; Chap. I), black cottonwood is a pioneer on freshly exposed soil along rivers and streams and is eventually replaced by more tolerant species. According to Smith (1957) and Smith and Blom (1966), black cottonwood grows best at low elevations and in the more southerly latitudes with a long growing season. Moist rich and well aerated soils with pH 6 to 7 provide optimum conditions for its growth; vigorous growth of *Cornus* spp. and *Sambucus* spp. is apparently associated with excellent growth of black cottonwood. Smith described three broad site classes for black cottonwood in British Columbia. On Site I, black cottonwood is associated with *Rubus spectabilis* Pursh, *Urtica* spp. and with *Polystichum munitum* (Kaulf.) Presl. or *Athyrium filix-femina* (L.) Roth and at age 25, it is about 111 feet tall and 16 inches dbh. Site II may be recognized by the presence of *Cornus stolonifera, Lonicera involucrata* (Richards.) Banks, *Symphoricarpos albus* (L.) Blake, *Rubus parviflorus* Nutt. and *Rosa nutkana* Presl., on this site, 25-year-old trees are 92 feet tall and 12 inches dbh. Site III is usually low-lying and subject to annual flooding for up to 6 weeks; *Equisetum arvense* L. and *E. hyemale* L. are usually found on this site, where at age 25 the trees attain a height of 72 feet and 8 inches dbh.

Palatability and forage value of trembling aspen has been evaluated in Saskatchewan (Clarke and Tisdale 1945). Although cattle do not find aspen palatable, a few domestic and wild animals utilize parts of the tree for food (Bird 1930, 1961). Snowshoe rabbits, which at their peak of abundance may number up to several hundred per square mile of aspen forests, eat the bark and sometimes girdle and kill over 60% of aspen trees (Bird 1930). Considerable damage to young trembling aspen, largetooth aspen, and balsam poplar is common throughout their range and results from browsing of stem and branch apices by deer, moose, elk, and other animals[10] (Bird 1930, 1961; Moss 1932; Banfield 1949; Black and Bourchier 1952; Argus 1966). When available, poplars are the preferred food of beavers (*Castor canadensis*) which have been reported to cause severe damage to various poplar species including black cottonwood by girdling the tree base (Smith and Blom 1966). Poplars are also used in the construction of beaver dams; consequently, the genus is of great significance, not only to beavers, which are among the most important fur-bearing animals in Canada (Harkness 1954; de Vos and Cringan 1957), but also to other fur-bearing animals occupying the habitat created by the beaver dams. Voles (*Microtus townsendi*) damage black cottonwood by eating the roots (Smith and Blom 1966). Buffaloes were once important inhabitants of aspen forest-grassland transition in Manitoba (Bird 1930). The

[10]Pimlott, D.H. 1955. Moose and Newfoundland forests. Can. Dep. Mines Resources, Wildlife Div. Rep. 26 p. (Mimeograph).

aspen forests of Manitoba were divided into six strata and Bird (1930) described the distribution of mammals, birds and invertebrates in each stratum.

Hail storms may strip the leaves and small branches from aspen trees and bruise the bark, thereby stunting the trees as well as creating lesions for entrance of pathogenic fungi and insects (Moss 1930; Riley 1953). Pathogenicity of important insects and fungi on poplars in Canada has been reviewed by Davidson and Prentice (Chap. VII).

Black cottonwood is susceptible to late frosts, sleet storms, and is permanently bent by wind storms (Smith 1957; Smith and Blom 1966). Because of the nature of its natural habitat, soil erosion along waterways may cause considerable damage to black cottonwood stands. Occasionally, young aspens, growing at the edge of a stand are buried under snow drifts and are bent or broken. Trembling aspen is susceptible to atmospheric sulfur-dioxide emitted from petroleum refineries and the injury is evident from foliage discoloration (Linzon 1965). Trembling aspen may be eliminated by girdling at breast height, by applying 2-4-5-T as basal spray or in basal frills (Waldron 1961) and by aerial spraying with 2-4-D (Pratt 1966). Extracts of trembling aspen and largetooth aspen from Nova Scotia, when tested for the presence of antibacterial substances, were inactive against *Staphylococcus aureus* and *Escherichia coli* (MacDonald and Bishop 1953).

CONCLUSION

Populus species deserve consideration in meeting the increasing demand on present and future forest resources. A number of Canadian poplars are particularly suitable because of their wood characteristics, fast growth rate, wide ecological amplitude, ease of sexual and asexual propagation, intraspecific genetic variability, and ease of natural and induced hybridization.

Presently, some useful information is available on the management, silvics and ecology of aspens which are commercially the most valuable native species of *Populus*, as well as the most widely distributed trees of Canada. However, our knowledge on aspen-habitat relationship and on the performance of other poplars is scanty. There is a definite need for defining research and management problems on a regional and country-wide scale and coordinating research activities on various aspects of *Populus* biology in Canada.

ACKNOWLEDGEMENTS

The author is thankful to Mr. Mogens L. Anderson and Miss Jean F. Robinson for preparing the illustrations.

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CHAPTER III

SILVICULTURE AND MANAGEMENT OF NATURAL POPLAR STANDS

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SPECIES, RANGE, VOLUME

The commercially important poplar occurring naturally in Canada are trembling aspen, largetooth aspen, balsam poplar, black cottonwood, and eastern cottonwood.

Trembling aspen and balsam poplar are found in all provinces and extend northward to the limit of trees. The commercial range is restricted, however, to northeastern and central British Columbia, central Alberta, central Saskatchewan, central Manitoba, central Ontario and central Quebec. Largetooth aspen occurs primarily in Nova Scotia, Prince Edward Island, New Brunswick and in the southern and central parts of Quebec and Ontario. The commercial range is mainly in central Quebec and in central and southern Ontario. Black cottonwood is found throughout most of British Columbia but the commercial range is restricted to the central southern parts of the province. Eastern cottonwood is found in the southern parts of Quebec, Ontario, Manitoba, and Saskatchewan but the supply of commercial material is limited (Anon. 1961).

Fitzpatrick and Stewart (Chap. XIV) have estimated that the forests of Canada contain a net merchantable poplar volume of 65.6 billion ft^3 and that the annual allowable cut is 1.5 billion ft^3. Five per cent of the poplar resource is in the Yukon and Northwest Territories, 21% in British Columbia, 26% in Alberta, 13% in Saskatchewan, 3% in Manitoba, 27% in Ontario, 4% in Quebec, and 1% in the Maritime Provinces.

GROWTH AND YIELD

Poplars are small to large, fast-growing, moisture-loving trees. Trembling aspen and largetooth aspen are considered small- to medium-size and under good conditions will attain a height of about 90 to 100 feet and a diameter of about 1-2 feet. Balsam poplar and eastern cottonwood are medium- to large-size trees; they will attain a height of 100 feet or more and a diameter of over 4 feet in favorable locations. Black cottonwood is the largest of the native poplars and trees over 200 feet tall and 8 feet in diameter have been reported.

Young trees grow rapidly and on good sites stands of aspen and balsam poplar will reach minimum pulpwood size (3.6 inches dbh) in 20 to 30 years. Black cottonwood will attain a similar size in about half that time. Volumes of mature stands are comparable to those of the more highly sought-after conifers such as white spruce and jack pine. In Saskatchewan, for instance, the gross volume of aspen stands at 100 years of age and with average stocking and density (empirical yield) is reported by Kirby *et al.* (1957) to vary from about 3,000 ft^3 per acre on poor sites to about 5,000 on good sites (Table 1). Data collected by MacLean and Bedell (1955) in the northern clay belt of Ontario indicate that empirical yield there is similar to that in Saskatchewan. Normal yield tables for aspen in northern Ontario (Plonski 1956) show that volume varies from about 8,500 ft^3 per acre on good sites to about 5,000 ft^3 on poor sites at 100 years (Table 2).

Growth and yield data for black cottonwood are shown in Tables 3, 4 and 5. These data show the yield from black cottonwood stands in British Columbia is greater than that from aspen stands in other parts of Canada (Thomas and Podmore 1953; Smith 1957; Mahon 1966). Smith (1957) concluded that Hesmer's yield tables for German poplar would be applicable in British Columbia. Smith and Blom (1966) observed stands in the lower Fraser and Squamish river valleys equivalent to Hesmer's site I and stands in the Skeena, upper Fraser and upper Thomson river valleys equivalent to sites II and III (Table 6).

Decay

Although gross volumes of poplar stands compare favorably with those of most coniferous stands, merchantable volume is seriously limited by decay. When commercial utilization is attempted gross stand volumes bear little relationship, if any, to those actually utilized. So far there does not appear to be any clearly defined relationship between amount of decay and site (Riley 1952).

In general, as trees get older defect and decay become more prevalent and for most poplar stands rotation age is, in the classical sense, a pathological rotation. In eastern Canada and the Prairie Provinces rotation age for largetooth aspen and trembling aspen varies from about 65 to 80 years and for balsam poplar from about 80 to 100 years. For black cottonwood in British Columbia rotation age varies generally from about 80 to 120 years. However, under management it may be possible to reduce rotations for black cottonwood to between 40 and 60 years in the Skeena river valley and to about 25 years in the lower Fraser river valley (J.H.G. Smith, personal communication).

Data from cull studies carried out in Manitoba and Saskatchewan have been selected to illustrate (Fig. 1) general trends of cull development

TABLE 1. EMPIRICAL YIELD PER ACRE FOR TREMBLING ASPEN IN SASKATCHEWAN[1]

Age (years)	Height (feet)	DBH (inches)	Number trees	Basal area	Gross Volume Cubic Feet	
					Total	Merchantable[2]
			Site I (good)			
20	33.5	2.2	2,237	58.5	948	-
30	45.3	3.0	2,094	90.7	1,889	266
40	55.0	4.0	1,261	109.5	2,711	916
50	63.6	5.2	774	122.2	3,392	2,093
60	71.8	6.6	538	131.6	3,938	3,020
70	79.2	7.8	404	138.4	4,358	3,539
80	85.4	9.2	307	143.2	4,707	3,893
90	90.5	10.4	244	147.3	4,962	4,145
100	94.2	11.3	210	150.1	5,215	4,354
			Site II (average)			
20	26.5	1.9	2,687	53.3	657	-
30	36.9	2.6	2,515	82.6	1,453	102
40	45.7	3.5	1,515	99.7	2,158	511
50	53.6	4.6	929	111.3	2,747	1,280
60	61.0	5.8	646	119.9	3,200	2,256
70	67.8	6.9	485	126.0	3,544	2,775
80	73.4	8.1	369	130.4	3,805	3,109
90	77.8	9.1	293	134.1	4,002	3,306
100	80.7	9.9	252	136.7	4,158	3,451
			Site III (poor)			
20	19.5	1.7	3,011	46.0	384	-
30	28.5	2.3	2,819	71.3	1,044	31
40	36.4	3.1	1,698	86.0	1,639	262
50	43.6	4.0	1,041	96.1	2,142	720
60	50.2	5.1	724	103.5	2,509	1,480
70	56.4	6.0	543	108.8	2,779	2,009
80	61.4	7.1	413	112.5	2,959	2,346
90	65.1	8.0	328	115.7	3,083	2,516
100	67.2	8.7	283	118.0	3,166	2,612

[1]Data from Kirby, Bailey and Gilmour 1957.
[2]Trees 6 inches dbh and over.

TABLE 2. NORMAL YIELD PER ACRE FOR TREMBLING ASPEN IN ONTARIO[1]

Age (years)	Height (feet)	DBH (inches)	Number trees	Basal area	Gross Volume Cubic Feet	
					Total	Merchantable
			Site I (good)			
20	38.7	3.5	1,022	68.5	1,308	420
30	53.8	5.0	698	95.0	2,620	1,604
40	66.7	6.5	508	116.2	4,067	2,903
50	77.1	7.9	389	132.6	5,413	3,932
60	85.0	9.3	307	144.5	6,530	4,694
70	90.7	10.5	253	152.4	7,375	5,213
80	94.4	11.5	217	157.3	7,953	5,524
90	96.4	12.3	193	159.8	8,301	5,684
100	97.5	12.8	179	161.0	8,479	5,757
			Site II (average)			
20	30.8	3.1	1,236	62.9	997	159
30	43.9	4.3	884	90.3	1,983	942
40	55.2	5.3	667	110.2	3,175	2,150
50	64.6	6.6	520	124.9	4,355	3,203
60	72.1	7.8	412	135.5	5,350	3,962
70	77.6	8.8	334	142.7	6,103	4,464
80	81.1	9.8	280	146.7	6,620	4,761
90	82.9	10.5	246	148.4	6,930	4,896
100	83.8	11.0	225	148.8	7,087	4,915
			Site III (poor)			
20	22.6	2.2	1,667	42.2	562	-
30	33.9	3.3	1,200	71.6	1,182	223
40	44.0	4.3	905	92.7	1,978	834
50	52.3	5.3	698	108.0	2,842	1,693
60	59.3	6.3	550	118.7	3,604	2,611
70	64.6	7.2	447	125.3	4,179	3,109
80	67.9	7.9	377	128.4	4,561	3,346
90	69.5	8.5	331	129.1	4,784	3,420
100	70.2	8.8	302	128.7	4,888	3,375

[1]Data from Plonski 1956.

TABLE 3. YIELD PER ACRE, BLACK COTTONWOOD SKEENA RIVER VALLEY, BRITISH COLUMBIA[1]

Age (years)	Net volume[2] bd ft per acre
20	4,700
30	10,000
40	16,700
50	22,800
60	27,800
70	29,400

[1]Data collected in Skeena River Valley of British Columbia (Smith 1957).

[2]Trees more than 11 inches dbh.

TABLE 4. EMPIRICAL YIELD PER ACRE FOR BLACK COTTONWOOD IN THE LOWER FRASER VALLEY[1]

Age (years)	Site class		
	I	II	III
	Volume cubic feet		
20	2,892		
30	3,564	3,383	3,315
40	3,348	3,314	3,599
50	3,564	3,564	3,499
60	3,865	3,727	3,727
70	3,839	3,343	3,931

[1]Data from Mahon, J.E. 1966, includes only trees 8 inches dbh and over.

TABLE 5. GROWTH AND YIELD CHARACTERISTICS OF BLACK COTTONWOOD, QUESNEL REGION, BRITISH COLUMBIA[1]

Total Age (years)	DBH (inches)	Height to Base of crown (feet)	Gross volume from stump to a 10-inch top	
			bd ft	cu ft
80	15	52	235	44
90	17	56	295	54
100	19	60	365	64
110	20	62	450	76
120	22	64	545	89
130	23	67	655	105
140	25	69	780	123
150	26	70	935	146
160	28	71	1,110	173
170	29	72	1,310	200
180	31	73	1,520	225
190	32	73	1,720	250
200	33	73	1,920	273

[1]From Thomas and Podmore 1953.

TABLE 6. BLACK COTTONWOOD SITE CLASSIFICATION[1]

Age (years)	Site Classes					
	I		II		III	
	Height (feet)	DBH (inches)	Height (feet)	DBH (inches)	Height (feet)	DBH (inches)
5	25	-	21	-	16	-
10	47	5.7	43	4.8	33	3.6
15	72	9.5	59	7.1	46	5.9
20	95	12.5	79	9.0	59	6.5
25	111	16.0	92	12.0	72	8.0
30	118	20.0	102	14.5	82	10.5
35	125	22.0	108	17.0	89	12.0

[1]Data from Hesmer, *Das Papelbuch* cited by Smith 1957.

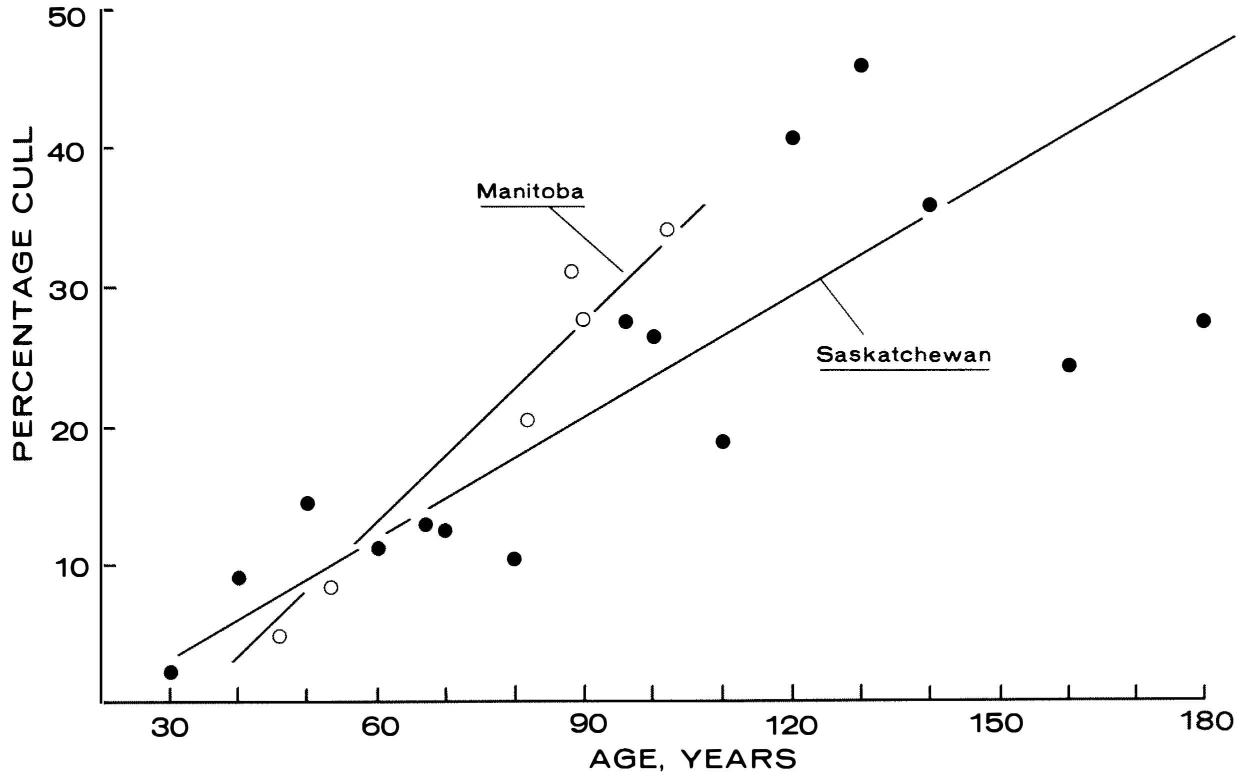

Figure 1. Percentage of cull in aspen in relation to age of tree.

in poplar stands (Kirby, Bailey and Gilmour 1957; H.A. Peacock, unpublished data). Studies in British Columbia show that decay in black cottonwood with no external sign of defect ranges up to 35% and for trees with defect showing up to about 45%.

The foregoing shows that Canada has an overabundant supply of a low quality resource. Low quality, resulting mainly from decay, has had a significant and retarding effect on its past development and will have a significant influence on its future. For instance, Thomas (Chap. VIII) stated that in Alberta the poplar-based industry will have to make greater use of small-size logs, such as those from trees 50 years of age or younger, if the problem of decay is to be overcome.

SILVICULTURE AND MANAGEMENT

Utilization

In spite of the many uses of poplar (e.g. construction lumber, veneer, particle board, boxes, crates, pulpwood, poles, posts, fuel-wood) the amount being utilized at present is negligible in relation to the amount available. In Ontario, British Columbia, the Prairie Provinces, Nova Scotia and New Brunswick the combined average annual harvest of poplar from Crown lands is less than 1% of the estimated annual allowable cut. However, in some local areas utilization is quite good. For instance, in southeastern Manitoba the actual cut in 1966 was within 20% of the annual allowable cut for that part of the province.

Stand management

Because of the low interest and almost insignificant utilization of poplar, scarcely any stands in Canada have been managed. Generally the poplar-based industry may be divided into two categories -- users of large-dimension logs, and users of small-dimension logs. In the former category, woods operations are highly selective. Since large logs are needed operations are carried out in stands of advanced age and many of the trees are so defective they cannot be utilized. Cutting is usually "from above" and to certain diameter limits. In some operations, trees are selected for cutting by trained tree markers but more often they are selected by the cutters. Because cutters are usually paid on a net scale basis they must be carefully supervised or they will cut only the very best trees. Adequate diameter, branchiness, knot size, number of logs per tree and absence of visible defects are the main criteria in selecting trees for cutting.

In poplar plywood logging operations in Alberta, only those trees which will yield two or more suitable peeler logs, each 8 ft 8 inches long with a diameter of 9 inches inside bark at the small end, are felled. Trees are usually cut by power saws, then skidded in long lengths to bush landings where they are bucked into standard lengths and sorted for loading. In some operations, trees are bucked where they fall and the merchantable logs are skidded to decking areas and piled for truck loading. Skidding may be done with horses, crawler tractors or rubber-tired tractors. The latter are a more recent innovation and this type of machinery is becoming more widely accepted for skidding. Along with the increased use of rubber-tired tractors there is also a trend to logging longer lengths (Jackson 1966).

Woods operations for the second category, users of small-dimension logs, are less selective. For the most part stands are designated for merchantable clear cutting and, if a stand is reasonably sound, most of the trees will be taken. However, in many instances trees are very defective, hence these operations, like the first category, tend to be of a high-grading nature. In some pulp operations in British Columbia, cutters resist felling black cottonwood trees smaller than 20 inches dbh; they claim that felling smaller trees increases production costs excessively (Smith and Blom 1966).

Because of poor utilization practices, young growth which may be present after logging is suppressed by the residual trees. Shrub species monopolize the openings created by logging and poplar suckering is inhibited. The net result is that many cut-over areas, even on the best sites, support second-growth stands of a lower quality than that of the original stand.

Figure 2. Selectively cut poplar stand, southeastern Manitoba.

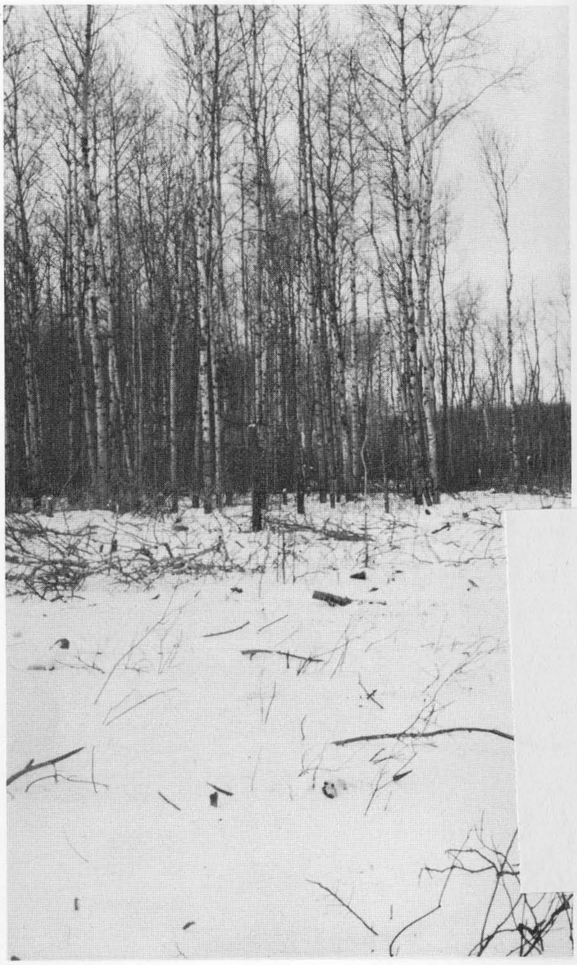

Figure 3. Clear-cut area foreground; uncut poplar stand background; southeastern Manitoba.

Although poplar stands in Canada have received little attention in the past, expanding markets, scarcity of other species within economical hauling distances, and improving technology are causing managers to focus more attention on poplar. Some provinces and some industries are undertaking poplar silviculture. For example, the Ontario Department of Lands and Forests has started trials in cut-over stands on the better sites to promote suckering. Treatment consists of felling all residuals left by the loggers so that solar radiation will warm the soil and induce the formation of sucker buds (Maini and Horton 1966a). Also, some thinning trials are being undertaken in some of the most promising young stands.

The province of Saskatchewan requires operators cutting poplar for chipboard on Crown land to do a thorough clear-cut on their designated areas. The aim is also to promote suckering. Until recently, poplar woods operations in southeastern Manitoba were highly selective (Fig. 2) but stands are now being clear-cut and skidding is being done in full tree lengths (Figs. 3 to 5).

Figure 4. Clear-cut area foreground; uncut poplar stand background; southeastern Manitoba. Note whole trees have been skidded to central location and bucked into log lengths.

Figure 5. Close-up of logs bucked and piled for loading; note defect on ends of logs.

Figure 6. Aspen suckers on cut-over area, 1 year after logging.

This type of operation almost completely removes the aerial portions of the competing vegetation and creates favorable environments for poplar suckering. Observations show that most of the clear-cut areas are well stocked to thrifty aspen suckers (Fig. 6).

SILVICULTURAL RESEARCH

Studies to eliminate poplar

Most of the silvicultural research undertaken by the federal government has been concerned primarily with coniferous species. Much of the early work was designed to eliminate poplar, establish conifers on treated areas and to study the effects of intermediate and release cutting on the growth of the conifers (Daly 1950, 1951; Robertson 1935, 1939; Steneker 1963). In the first studies, axes and saws were used for felling trees, but with the introduction of chemical herbicides, studies were carried out to determine their effectiveness. The aerial portions of aspen suckers and trees may be killed successfully by foliage sprays applied from the ground or from the air and by basal bark spraying with or without axe frilling (Sutton 1958; Waldron 1961; Pratt 1965). Of the various foliage sprays tested, 2,4-D and 2,4,5-T mixed with water appear to be as good as any. For instance, good kills of aspen suckers have been obtained with spray applied from the ground at concentrations as low as 1,000 ppm. Good top kill of aspen trees has also been obtained by aerial spraying at the rate of 5 gal of aqueous solution (48 oz acid equivalent of 2,4-D) per acre. Basal spraying in sufficient quantity to drench the stem with 2,4-D and 2,4,5-T in diesel oil (8 to 16 lb. acid equivalent per 100 gal) has produced good results. Applying ammonium sulphamate to the sapwood region of stumps at the rate of one tablespoon of ammate crystals for each 3 inches of stump diameter has been effective in killing roots and preventing suckering (Quaite 1953).

Thinning and pruning

Studies have been initiated at the Petawawa Forest Experiment Station and in Manitoba to determine whether intermediate cutting and thinning would improve the yield and quality of poplar stands. Thinning cannot increase the growing capacity of any given acre but it can increase production through utilization of the anticipated mortality. It will also affect the size of trees in the final crop, since growth that would have occurred on the thinnings is transferred to the trees that are left.

Studies have shown that poplars respond exceptionally well to thinning, especially during their early life. Diameter growth increases rapidly and in direct relation to thinning intensity. Trees of all sizes are affected but the larger ones maintain a greater rate of growth than the smaller ones. These points are illustrated in Fig. 7, which shows the 10-year diameter increment (1950 to 1960) by diameter class for trees on unthinned plots and on plots thinned to spacings of 8 x 8 feet and 12 x 12 feet. At the time of thinning in 1950 the stand was 23 years old. Trees on the more heavily thinned plots grew faster than those on the less heavily thinned plots; also on each plot the larger trees grew faster than the smaller ones.

Figure 8 shows that growth of residual trees is better on good sites than on poorer ones. The top curve shows the periodic annual basal area increment of the 200 largest trees per acre by residual basal for good sites in Manitoba; the bottom curve is for medium sites. Only the 200 largest trees are used for comparison since this is roughly the number that may be expected to be in the final stand at maturity. Also, considering the silvics of aspen, the largest trees are the ones most likely to reach maturity.

Thinning studies in Manitoba and Saskatchewan have shown that total cubic foot volume production can be increased by 25% with light to moderate thinning at 5-year intervals (Steneker and Jarvis 1966). To achieve the fastest per acre growth rate 10-, 20-, 30-, 40-, and 50-year old

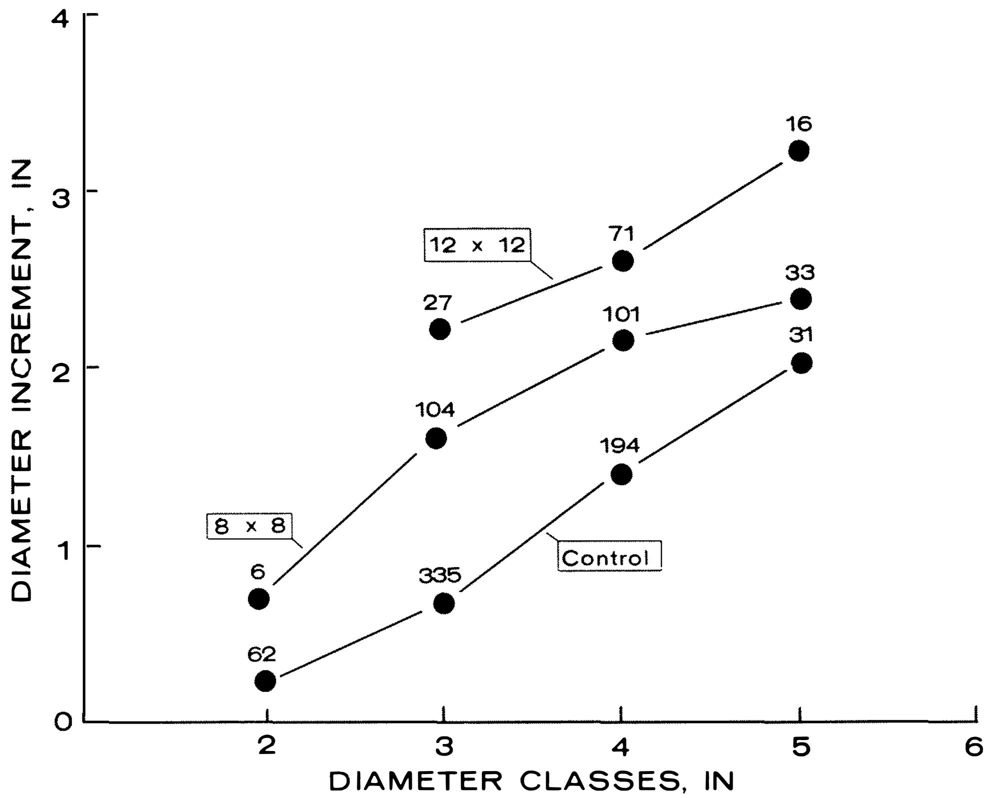

Figure 7. Ten-year diameter increment (1950-1960) by diameter classes (Steneker and Jarvis 1966).

stands should be maintained at about 30, 50, 65, 85 and 100 ft^2 of basal area per acre, respectively. However, at such stocking levels the maximum diameter rate of individual trees is not reached. This is illustrated by Fig. 9, which shows gross and net basal area increment and annual diameter growth of the 200 largest trees per acre by residual basal area for the period 1950 to 1960. The data are for a stand which was 23 years old in 1950. As can be seen, gross basal area increment reached a maximum at about 50 ft^2 of residual basal area. Below that stocking level growth was less because of understocking. Net basal area increment also reached a maximum at about 50 ft^2 of residual basal area; it was less at higher densities because of mortality and at lower densities because of understocking.

The top curve in Fig. 9 shows that the diameter increment of the 200 largest trees per acre continues to increase at basal area levels less than that which produced the maximum basal area growth per acre. This indicates that if thinning is to be undertaken for lumber or veneer, stands should be maintained at basal area levels below those that are optimum for total volume production. Data indicate that by adopting a heavy thinning schedule, and beginning treatment at age 10, crop trees should average at least 8 inches dbh by age 40. With no thinning, crop trees will average about 6 inches dbh at the same age (Steneker and Jarvis 1966).

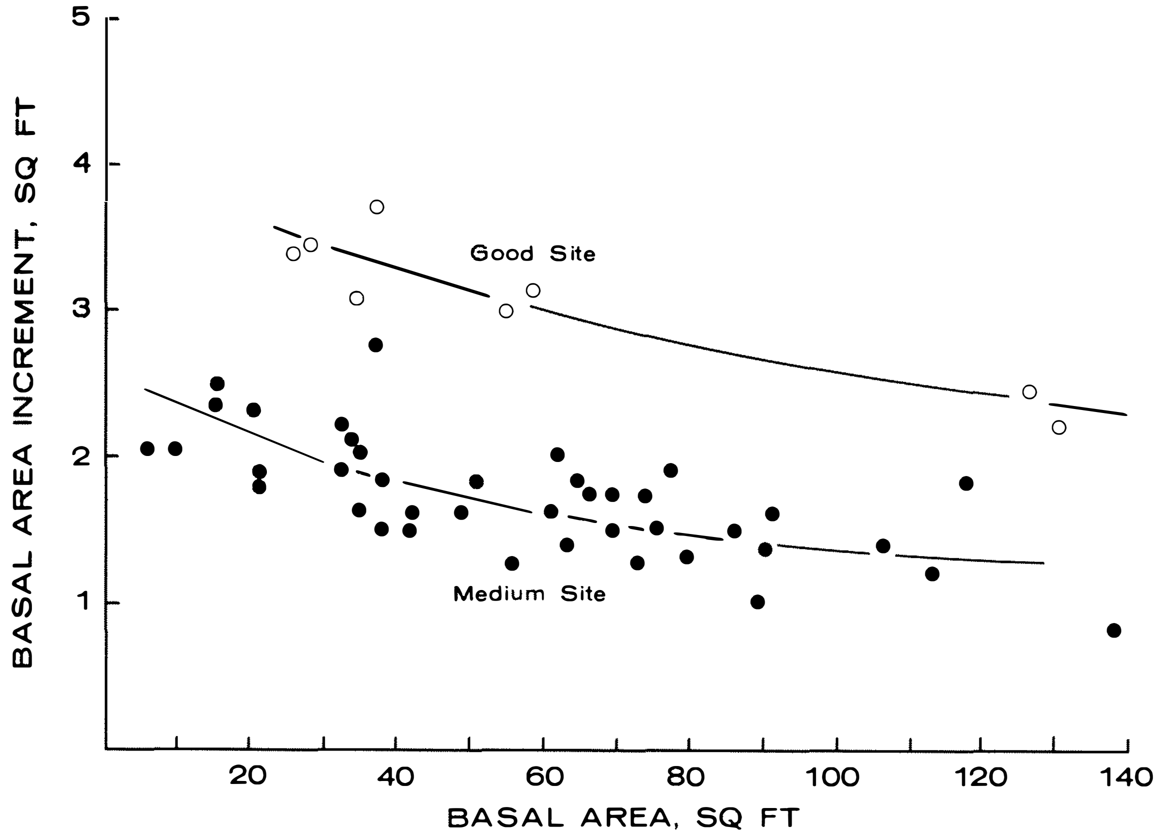

Figure 8. Periodic annual basal area increment of the 200 largest trees per acre by residual basal area per acre (Steneker and Jarvis 1966).

Smith in his paper dealing with the silviculture and management of poplar plantations (Chap. V), discusses relationships between individual tree growth and per acre growth. Also, he shows what spacings are likely to be necessary to produce specific growth rates and desired end products.

Some of the major pathogens causing heartwood decay in poplar, enter the trees by branchwood infections and often the fungi require a number of years to become established. This suggests that branch pruning at an early age might substantially reduce the amount of decay in trees at maturity or time of cutting. Therefore, in 1964 a study was started in Manitoba to determine whether pruning in 10- to 15-year old stands would reduce the amount of decay in the stem. In addition, pruning of young trees may improve their form and perhaps increase their height growth (Maini 1966).

Regeneration studies

The first information on poplar regeneration was obtained on pine sites at the Petawawa Forest Experiment Station. In the 1920's studies were initiated to determine the retarding effects of 20- to 50-year old poplar and white birch on the establishment and growth of conifer seedlings. Plots were established in the stands then thinned by various amounts.

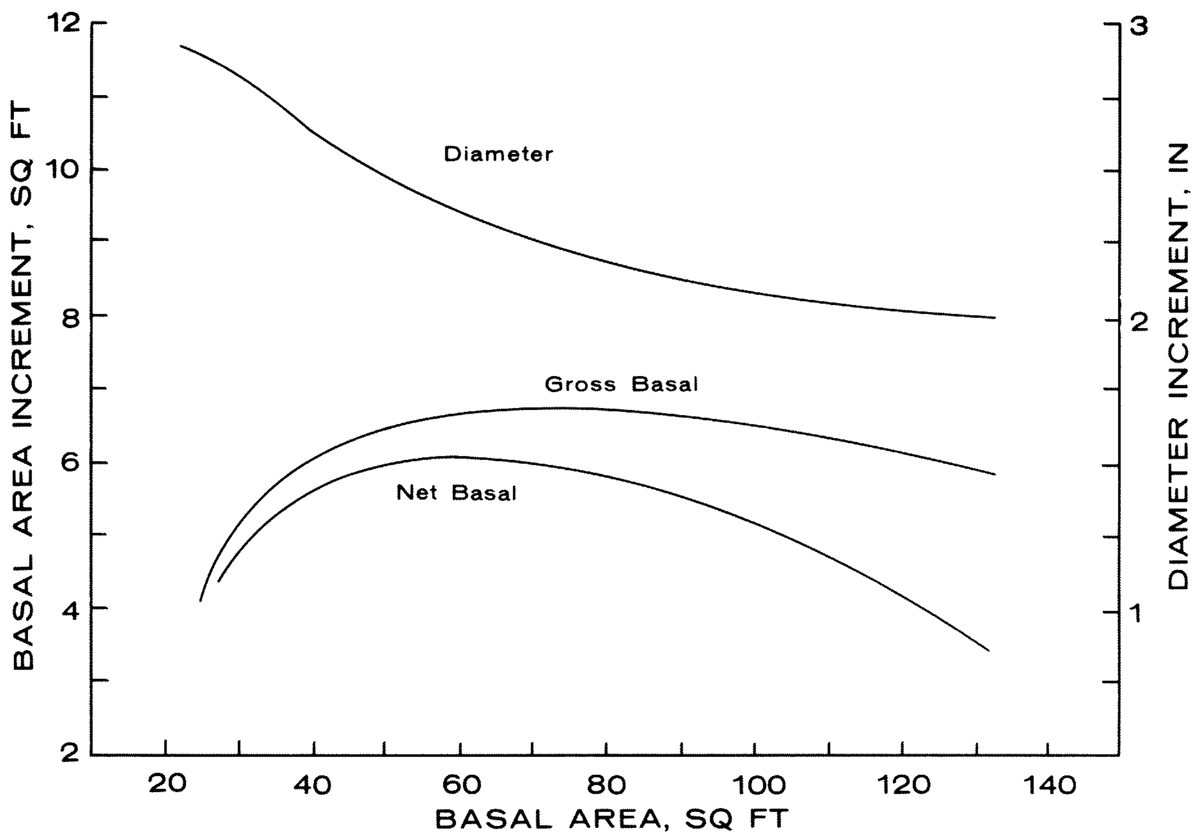

Figure 9. Annual periodic net and gross basal area increment of the 200 largest trees per acre by residual basal area (Steneker and Jarvis 1966).

Results indicated that the number of suckers arising was directly related to the intensity of the thinning (Robertson 1935). Observations indicated that suckering occurred generally within 1 year after cutting and that most stems died the same year they originated. On one plot, as many as 43,000 suckers per acre developed but after 10 years only about 1,000 per acre remained.

Additional studies have been undertaken in Ontario both in the laboratory and in the field to determine the influence of fire, cutting, and scarification on aspen suckering (Horton and Hopkins 1965; Maini and Horton 1966b). Results of the work support the earlier studies and show that a disturbance which will kill the tree canopy and undergrowth and eliminate the litter and part of the duff will effectively stimulate suckering. The less intense the disturbance the less dense and vigorous will be the suckering.

Much genetic variation exists within natural poplar stands due to their clonal nature arising from the species' ability to regenerate vegetatively. Clonal variation is manifested by differences in phenology, form, growth, disease resistance, and reproductive ability. Recently studies have been undertaken to explore the clonal structure of various poplar stands in Manitoba because the possibility exists (J.S. Maini, personal communication) that management practices could be developed to improve stand quality by favoring the regeneration of good clones and preventing the regeneration of poor clones in particular stands.

In 1966 a study was established in Saskatchewan to determine the effects of various stocking densities (500 to 20,000 stems per acre) in 1-year old sucker stands on the subsequent form growth and quality of young trees. Another study was started in 1967 to determine the total dry matter production of young (5 to 20 years) trembling aspen stands at various levels of density on different sites and to study the effects of clonal variation on stand development and productivity. Preliminary results indicate that total productivity of such stands is high and that growth rates are in excess of 100 ft^3/acre per year (Bella and Jarvis 1967).

FUTURE OF POPLAR

World demand for wood is rising rapidly and it has been estimated that by the year 2,000 the amount of fiber used by the pulp and paper industry in Canada will have risen five-fold (Fowler 1966). Unfortunately, production costs are continually rising as well, partly because of the nomadic character of woods operations and partly because of rising labor costs. It has been suggested that a major harvesting break-through will be needed shortly to keep present Canadian fiber crops competitive. However, even with a major harvesting break-through the industry will probably run out of economically harvestable natural stands and will be forced to grow its raw material in managed forests.

Rapidly advancing technology makes forecasting difficult. The uncertainty of future needs dictates shorter planning periods and on an investment basis shortens economically acceptable rotations. Large dimension stock for veneer or lumber will probably be grown in plantations using fast growing hybrids or superior clones of natural stock. In British Columbia some poplars set out in plantations have reached a height of 85 ft and a diameter of 14 inches in 10 years (Smith and Blom 1966).

For fiber production some people are questioning the continuing place of the log as a unit of harvest. If this unit becomes uneconomical then one alternative may be to utilize whole trees (bark, stem and branches) grown on very short rotations. Studies currently in progress in Georgia indicate that sycamore is a promising species for fiber production on short rotations in parts of the United States (McAlpine *et al.* 1966). It is estimated that young sycamore planted and cut at 5-year intervals will produce 25 cords per acre every 5 years. Thus, during the 30 years now required to grow a rotation of pine pulpwood a total of 150 cords of green sycamore wood could be produced from each acre. Pulping studies carried out using whole young trees, i.e., limbs, leaves, bark and stem, have been most promising.

Poplars may well be a suitable species for short rotation management in Canada. They regenerate easily and will tolerate a wide variety of sites. Furthermore, juvenile trees have thin bark and, as indicated earlier, they grow rapidly. Mature poplars are presently being used for the manufacture of pulp, fiberboard and chipboard and authorities have indicated that juvenile trees are also suitable for such products (H.B. Marshal and J.L. Keays, personal communication).

The future for poplar management in Canada is most promising. However, research is needed to obtain basic information on the mechanical, physical and chemical properties of poplars so that new and better uses can be found for the species. Also, research is needed to obtain more information on the biology of the species as a base for the development of economical management and harvesting procedures.

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CHAPTER IV

POPLAR BREEDING IN CANADA

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INTRODUCTION

Poplar cultivation in Canada can be classified into the following three main groups of projects: (1) The growing of poplars in shelterbelts and windbreaks in the southern prairies, based on the adaptability of some poplars for these purposes. (2) The growing of poplars in the northern prairies, in Ontario, and other climatically suitable parts of Canada, for high quality plywood and match stock. (3) The growing of poplars for the manufacture of pulp, utilizing the rapid growth and high yield of good quality pulp.

In these three phases recent advances in the techniques of poplar breeding, propagation, establishment of plantations, stand treatment and greatly increased knowledge regarding the merits of existing poplar species and varieties, have now reached a stage where nearly every step in further research yields very encouraging results (Heimburger 1937). Written 30 years ago, this is still largely applicable to poplar breeding and poplar growing in Canada.

POPLARS FOR SHELTERBELTS AND WINDBREAKS IN THE PRAIRIES

The late Dr. F.L. Skinner, famous plant breeder of the prairies, was the first to produce new poplar varieties by means of hybridization and selection. I first visited his nursery at Dropmore, Man., in the summer of 1939. The so-called duck pond method of producing poplar hybrids was then in operation. Seedlings of eastern cottonwood were being grown for shelterbelts and windbreaks in southern Manitoba although stem cuttings root poorly. One such female seedling was planted near a small creek on the property of Dr. Skinner. This creek was dammed to create a pond and ducks were used to keep the area free from weeds. When the poplar was shedding seeds, the water was lowered and the ducks removed, and poplar seedlings established on the clean, muddy bottom of the pond. In the fall, the poplar seedlings were pulled out and heeled-in for lining out in the nursery during the following spring. The pond was refilled, the ducks reintroduced, and the whole operation was repeated.

This female eastern cottonwood, the only one of its kind on the property, yielded numerous natural hybrids with the native trembling aspen and balsam poplar. The hybrids of trembling aspen were not promising and none are surviving at present. The cross with balsam poplar yielded a number of hybrids (*P. jackii*) of which one female seedling was outstanding in growth rate, form, and freedom from Melampsora leaf rust. It has since been used in several crosses with exotic species such as *P. tristis*, *P. laurifolia*, and *P. songarica* obtained from Kew Gardens, England. The latter is a tree of upright growth habit, similar to *P. berolinensis* but free from cankers caused by *Septoria musiva* Peck.

The following are the main poplar hybrids produced by Dr. Skinner (Skinner 1956, 1967):

Parentage	Year	Results
P. deltoides x *balsamifera*	about 1935	one good female, *P. jackii*, selected.
P. deltoides x *tremuloides*	about 1935	weak, none surviving.
P. balsamifera x *tristis*	1940	resistant to canker and leaf rust.
P. tremuloides x *tristis*	1940	weak, discarded.
P. jackii x *tristis*	1952	variable, immune to leaf rust.
P. jackii x *laurifolia*	1954	patroclinous, uniform, resistant to leaf rust.
P. balsamifera x *laurifolia*	1954	no information, probably not promising.
P. jackii x *songarica*	1962	very diverse seedlings, some promising.

In 1938 some crosses were made in Ottawa and seedlings raised at the Petawawa Forest Experiment Station, Chalk River, Ont. (Heimburger 1940). The following are of possible use on the prairies.

P. canescens x *tremuloides* var. *aurea*. The seed parent is derived from a hybrid of silver poplar and European aspen. The pollen parent material was collected from two poplar bluffs near Calgary, Alta., in a very exposed and dry situation. This cross yielded a great number of seedlings, most of which were highly susceptible to Melampsora leaf rust under the growing conditions at Petawawa. The growth has, for a number of years, been slow with early lignification and leaf-fall. None of the seedlings rooted from stem cuttings and, in subsequent years, all were gradually discarded. However, with the recently acquired knowledge in the production of aspen-like hybrids with satisfactory rooting ability from stem cuttings this, or a similar cross, might well be repeated. The hardiness and well established chinook and drought resistance make *P. tremuloides* var. *aurea*, the western form of trembling aspen, a potentially valuable parent in the production of aspen-like poplars for the prairies.

P. acuminata x 'Eugenei'. The seed parent (lanceleaf cottonwood) is native to southern Alberta where it is quite drought resistant and not damaged by chinooks to the same extent as introduced poplars. The pollen parent is a derivate of one of the many hybrids between eastern cottonwood and European black poplar originated in western Europe. This cross yielded about a dozen vigorous seedlings with great variation in susceptibility to leaf rust and in rooting ability from stem cuttings. They were rather late in maturing their shoots and in their leaf-fall and are probably suitable for growing in the southern prairies only.

Brayshaw (1966) believes that lanceleaf cottonwood is a derivate of narrowleaf cottonwood from natural hybridization with plains cottonwood. Hybrids of this kind could well be used in poplar breeding for the southwestern part of the prairie region, where drought and chinook resistance are as important as hardiness and good rate of growth. There is also the possibility of selection for good rooting ability from stem cuttings within such hybrids.

P. berolinensis x 'Northwest'. Both parental forms are hybrids involving balsam poplars and eastern and plains cottonwoods. *P. berolinensis* is a hybrid of *P. laurifolia*, a balsam poplar from Siberia, with Lombardy poplar and *P.* 'Northwest', the latter being a natural cottonwood x balsam poplar hybrid from North Dakota. The seedlings of this cross showed marked variation in growth rate and in their leaf and stem characters, as was expected from a cross of two intersectional hybrids. About one-half of the plants showed the strong juvenile branchiness of the *P. berolinensis* parent. This, in turn, is inherited from Lombardy poplar and may be a desirable character for shelterbelt materials. Only 26 seedlings were selected and this number did not represent the numerous possibilities from such a cross. Cuttings of some of the most promising seedlings were later sent to the Forest Nursery Station at Indian Head, Sask., for testing and one *P.* 'BNW #4', has recently been used in crosses there (Cram 1960, 1963). For the purposes of breeding valuable poplar materials for shelterbelts in the prairies, this cross appears to be very promising and warrants repeated production on a larger scale than was possible in 1938.

In 1944 seeds were collected from some *P. rasumowskyana* at the Petawawa Forest Experiment Station. This poplar belongs to the group of the so-called "Russian" poplars, introduced by early settlers to the prairies and representing various hybrids between European black poplar and *P. laurifolia*. The seeds yielded numerous natural hybrids with native balsam poplar. Several of these hybrid seedlings were inoculated with *Septoria musiva* by Dr. L.P.V. Johnson, then of the National Research Council of Canada, to test their resistance to this pathogen. About one half of the seedlings so tested proved to be resistant (Johnson 1942a). This may indicate that a single dominant gene for susceptibility is carried by *P. rasumowskyana* in heterozygous condition and thus the breeding of "Russian" poplars for resistance to *S. musiva* would be relatively simple.

For a number of years, numerous poplar clones have been grown and tested at the Forest Nursery Station (since 1963, designated as Tree Nursery, P.F.R.A.), Indian Head, Sask., for propagation and distribution to prairie shelterbelts and windbreaks. Several of these, such as the *P.* 'Northwest' and *P.* 'Saskatchewan' are natural hybrids (*P. jackii*) of eastern cottonwood and balsam poplar taken into cultivation. Others, such as *P.* 'Brooks' and *P.* 'Bassano', are natural hybrids of native eastern cottonwood with the "Russian" poplars. The clones *P.* 'Volunteer' and *P.* 'Dunlop' are reported to be open-pollinated seedlings of the "Russian" poplars. *P.* 'F.N.S. #44-52' is a selected seedling of eastern cottonwood and *P.* 'Sutherland 4' a selected clone of native balsam poplar. The more recent results of such tests included several clones obtained from Petawawa and Maple (Cram 1960). Artificial poplar hybridization started there in 1962 and was continued in 1963. The clones *P.* 'F.N.S. #44-52', *P.* 'B.N.W. #4, *P.* 'Northwest', *P.* 'Saskatchewan', and *P. tristis* were used as parents (Cram 1963). The resulting seedlings are being evaluated in respect to vigor, rooting ability from stem cuttings, growth habit, disease resistance, and suitability for shelterbelt planting. The cross *P.* 'F.N.S. #44-52' x 'Saskatchewan' has yielded some seedlings with good rooting ability from stem cuttings (Cram 1965).

POPLARS FOR HIGH QUALITY PLYWOOD AND MATCH STOCK

The main objective of poplar breeding initiated in 1935 at the Petawawa Forest Experiment Station and continued since 1946 at the Southern Research Station, Maple, Ont., has been to develop high quality poplars for plywood and match stock. The work has been summarized by Heimburger (1956, 1958) and only the most important recent developments are described in the following.

The production of aspen-like hybrids suitable for growing in southern Ontario, having good growth rate and growth form, good wood and ease of vegetative propagation, are aims of the poplar breeding project. The problem of raising aspen seedlings on an industrial scale under our climatic and soil conditions has not yet been solved. Therefore, the main objective has been the production of new hybrids with good rooting ability from stem cuttings. Although some poplar species of the sections *Aegeiros* (cottonwoods) and *Tacamahaca* (balsam poplars) with very good rooting ability from stem cuttings can be crossed with aspens, they have not, until very recently, yielded any promising hybrids. Moreover, the fertility of such hybrids is not known. Therefore, European white poplar is, for the time being, the only source of material with good rooting ability from stem cuttings available for transfer into aspen-like types. The fertility of its hybrids with aspens has been established (Peto 1938). Great variation in rooting ability has been found among the European white poplar acquisitions tested in this respect. The best rooting has been found in the southwestern part of its range, in southern France, Spain, and North Africa. Good rooting is also found in materials from northern Italy. Unfortunately, most of the good rooters have very poor growth form and several are lacking in winter-hardiness at Maple, Ont. The best growth forms were found in

Figure 1. A gray poplar of Polish origin, male parent in recent crosses, Maple, Ont. Height - about 33 ft, age 9 years.

eastern Europe -- Poland, Austria, Hungary, Czechoslovakia and Yugoslavia. Their rooting ability is usually much poorer than in the western forms, although they are better adapted to our climate. Crossing western and eastern forms of European white poplar to combine good rooting ability with good growth form and better climatic adaptation has yielded some hybrids with a rooting ability superior to that of both parental forms. This is interpreted as being due to complementary genes for rooting ability in western and eastern forms of European white poplar and is probably related to the evolutionary history of this species during the Pleistocene.

Most European white poplar planted in eastern Canada appear to be of Normandy origin, i.e., they belong to the western form. Some of their hybrids with aspens in western Europe and eastern North America root reasonably well. This rooting ability is assumed to be derived from the European white poplar parent but is also influenced by the aspen parent. The rooting ability of artificial hybrids of certain good-rooting European white poplar with different aspens was found to differ according to their aspen parentage. Hybrids with trembling aspen root rather poorly in comparison with hybrids

Figure 2. A natural European white poplar x largetooth aspen on property of Rosedale Golf Club, Toronto, Ont. Male parent in recent crosses. Height - about 37 ft, age 10 years.

of the same European white poplar with largetooth aspen and European aspen. Hybrids with *P. davidiana* (Asiatic aspen) occupy an intermediate position in this respect between the two American aspens. The hybrids with *P. sieboldii* (Japanese aspen) obtained thus far, root even better than hybrids with largetooth aspen.

Occasionally hybrids with trembling aspen with very good rooting ability can be obtained. These exceptions apply also to the strong photoperiodic reaction of most northern aspens, which are dominant in hybrids with European white poplar. It is probable that such exceptions are caused by occasional recessive genes found within the very heterogeneous populations of native aspens.

The poor rooting ability of the eastern forms of European white poplar is also found in their natural hybrids with European aspen, the so-called *P. canescens* (gray poplar). By crossing gray poplar types from

Figure 3. Trembling aspen (Maple) x European aspen (Italy) in arboretum at Maple, Ont. Height 28 ft, age 9 years.

eastern European with natural European white poplar x aspen hybrids of eastern Canada, it is possible at one and the same time to combine the rooting ability of the eastern and western forms of European white poplar and to obtain hybrid vigor from a combination of different aspen species of the original hybrids.

This is the present explanation of the breakthrough in 1963. At that time, some aspen-like seedlings with rooting ability of over 90% were obtained from a cross of a female gray poplar from Czechoslovakia with pollen of one of our natural European white poplar x largetooth aspen hybrids, both parents rooting below 20%. Later, the combination of a female European white poplar x largetooth aspen with a male gray poplar from Poland has yielded comparable results. As some of our first-generation European white poplar x aspen hybrids of known parentage and rooting performance are beginning to flower, we can expect gradually improving results from this method. The seedlings obtained by means of such double crosses are extremely heterogeneous and are, at present, being propagated and screened in respect to their nursery performance prior to field testing.

Figure 4. Trembling aspen (Maple) x P. davidiana *(Asiatic aspen) (Korea) in arboretum at Maple, Ont. Height 30 ft, age 9 years.*

The poplar materials are tested by planting 7-inch cuttings in the fall. By following a planting plan that includes replication and randomization of the clones tested, a reasonably reliable indication of the total rooting ability of the tested materials is obtained. Total rooting ability in such tests constitutes, not only root formation by the cuttings, but also the ability to survive and to grow into an acceptable plant during one growing season. The results vary with the original position, physiological age, and size of the cuttings, and with the weather during the year of testing.

To estimate the genetic component of rooting ability, it has been necessary to repeat the tests of any given clone for 3 years, and to use cuttings of comparable size and physiological age. The performance of the clones tested is compared with that of standard clones with known rooting ability. Such standard clones also serve in the evaluation of the growing conditions of any given year in relation to the overall performance of the materials tested in that year.

Figure 5. Gray poplar (Czechoslovakia) x (European white poplar x largetooth aspen) Toronto in poplar plantation, Wainfleet Township, Ontario. Height 29 ft, age 7 years.

Seedling populations of aspen hybrids are screened for rooting ability by planting one cutting from the basal part of each seedling of acceptable size at the end of the second growing season. The seedlings are then at the 1-1 stage. The remaining stumps of such seedlings are used for evaluating the field performance of the populations in test plantations. The cuttings are bulk-planted at a rather close spacing in the fall and the number of acceptable plants in the following year are tallied in relation to the total number of cuttings originally set out. Cuttings are again made from all acceptable plants, and the process is repeated for 1 year. During this period there is a steady increase in the proportion of cuttings yielding acceptable plants within populations containing good rooting ability. In other populations there is a steady decrease in the total number of plants, until after 3 years of such mass selection, there are either no plants left or the few remaining plants show poor rooting ability when tested individually. After 3 years of mass selection in the above manner, the rooted cuttings from promising populations are made into clones.

There are several other methods of breeding superior aspens for plywood and match stock. In Europe, hybrids between trembling aspen and European aspen of suitable origin show distinct hybrid vigor and a wider site adaptation than their parental forms. In Sweden, some of the best such first-generation hybrids have eight times the current annual increment of native aspens. This method is undoubtedly simpler than the cumbersome introduction of European white poplar with its high site requirements, often poor growth form and climatic adaptation into a breeding program.

The trend in intensive silviculture is towards wider spacing in plantations to avoid the expensive and unproductive early thinnings. This, in turn, raises the demands for quality, especially in respect to growth form and growth rate of the planting stock. Even the most promising progeny-tested aspen clones with good specific combining ability are so heterozygous that a great proportion of their hybrid seedlings are of poor growth form and otherwise not acceptable as planting stock. Inbreeding of one or both parent species will undoubtedly result in more uniform hybrid offspring, but this will also be time-consuming and have its pitfalls. Under our present condition a preferred planting stock would be a mixture of thoroughly tested hybrid clones, slightly varying in their site requirements and all of acceptable growth form and growth rate and be easily propagated on an industrial scale.

POPLARS FOR PULPWOOD

Very little poplar breeding specific for pulpwood has been done in Canada. It is implied that poplar plantations established for shelterbelts and for plywood will produce pulpwood from intermediate cuttings. If and when the more specific requirements of superior poplar pulpwood are known, it is quite possible that poplar with these qualities could be developed through appropriate breeding programs. Poplars are so diverse in their wood quality that several possibilities exist in this respect.

During the last war, a series of poplar hybrids were produced at the Petawawa Forest Experiment Station having as their female parent, *P. angulata*, a southern form of eastern cottonwood. The pollen parent was *P. simonii*, a Chinese balsam poplar. Both parent trees were growing in the arboretum of the Central Experimental Farm, Ottawa, Ont. The resulting hybrid seedlings were extremely heterogeneous. From among these, several clones were selected with good juvenile growth rate, rather wide site requirements and good growth form. Cuttings of these have been distributed to several wood-using industries in Ontario and elsewhere and the results to date, for pulpwood production, have been comparable to those of similar poplar materials produced in Europe and the United States.

With the increasing trend towards pulpwood production, even under intensive forest management conditions, the use of balsam poplars in breeding for pulpwood may be quite promising. The dark core of balsam poplar from the east is less pronounced when it is grown in the west. In northern Alberta, native balsam poplar is used for plywood production and constitutes as yet an untapped source of breeding materials for both plywood and pulpwood production.

OTHER WORK

In the discussion of his work with the *P. jackii* x *songarica* hybrids, Skinner (1967) mentions the application of colchicine to induce polyploidy. It is not known if any of these are polyploid or if the great variation among them is the result of genetic segregation only.

During our work with test plantations in cooperation with the Ontario Paper Company on Manitoulin Island, a trembling aspen clone with abnormally large and thick leaves was discovered. Materials of this clone were later forwarded to the Institute of Paper Chemistry in Appleton, Wisc., where work with triploid aspens is in progress. The triploidy of this clone has been confirmed and it is being used in the breeding work of that Institute.

Johnson (1942b) made a preliminary study of the wood quality of some natural aspen hybrids growing near Ottawa. His results indicate that rapid growth is not seriously detrimental to wood quality for plywood manufacture. Rate of growth was found to have little effect on fiber length, but showed highly significant correlation with fiber diameter.

In another study Johnson (1946) investigated the inheritance of several morphological characters and of rooting ability of some natural European white poplar x largetooth aspen hybrids. An F2 generation and some back-crosses to European white poplar were produced and the resulting seedlings scored in respect to pubescence, leaf color, shape, margin and apex, and rooting ability in a greenhouse test. The good rooting ability of the original European white poplar parent was transmitted as a dominant character. The rooting ability of some hybrids of the same European white poplar parent with trembling aspen were much inferior and it was assumed that the latter species carried some rooting inhibitors. This has been confirmed by our subsequent results from a much wider range of materials.

GROWTH OF HYBRID POPLARS

In the fall of 1959, some height measurements and survival counts were made in the Manitoulin Island plantation of the Ontario Paper Co. on aspen hybrids set out there in 1955 and 1956. The height growth varied from less than 1 foot to about 3 feet a year, and was considerably slower than the height growth of hybrid cottonwoods which can grow up to 6 feet a year during the first 3-4 years. Recent estimates of height growth under more favorable growing conditions in the Wainfleet plantation (Welland County, Ont.) gave averages of up to 6 feet a year for 5-year aspen hybrids; growth rates fully comparable with those of the better cottonwood hybrids. In addition, the cottonwood hybrids planted there are stagnating due to sod formation and other factors that cause an unfavorable ecoclimate. The aspen hybrids are gradually shading the grass out and do not show any signs of height growth retardation. Some height measurements of young plantings of aspen hybrids growing at the Morgan Arboretum, Macdonald College, P.Q., are also available. Their growth is slightly superior to those on Manitoulin Island but not as good as the ones in the Wainfleet plantation. The materials in the latter plantation consist of our most recent and advanced hybrids while those on Manitoulin Island and at the Morgan Arboretum are older materials. Apparently aspen-like hybrids can be produced whose height growth initially is somewhat inferior to that of cottonwood hybrids but with more sustained height growth under conditions unfavorable to cottonwoods. This advantage has been demonstrated in trees at least up to a height of 25-30 feet. Some apparently successful hybrids are shown in Figs. 1-5. Also, the wood quality of such hybrids is much superior to that of the cottonwood hybrids for plywood manufacture.

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CHAPTER V

SILVICULTURE AND MANAGEMENT OF POPLAR PLANTATIONS

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INTRODUCTION

From a world point of view much is known about silviculture and management of poplars (Anon. 1958; Schreiner 1959; Bradley, Christie and Johnston 1966; Prevosto 1966). A vast body of information is potentially available to guide Canadian foresters concerned with improved growth of poplars.

However, the major purpose of this chapter must be to point out the desirability of undertaking the formal experimentation required to develop methods that are efficient for Canadians under Canadian conditions. Only long term and sustained observation of carefully planned and adequately maintained experimental plantations can lead to methods which are likely to be biologically sound. It is equally necessary to develop economic systems of management that pay adequate attention to the high cost of Canadian labor and the need for mechanization of operations. This latter point is especially necessary because such large surpluses of relatively low quality poplar exist in Canada. The British Columbia Forest Service estimated that the gross cubic foot volume of black cottonwood in British Columbia was 10 billion ft^3 in 1957. This was much less than the 17 billion ft^3 of trembling aspen reported for British Columbia. Fitzpatrick and Stewart (Chap. XIV) have estimated that the net merchantable volume of black cottonwood and aspen combined for British Columbia is 14.0 billion ft^3. Total volume of these poplar species utilized in a typical year, is only about 4.5 million ft^3 according to the Annual Reports of the British Columbia Forest Service. Therefore, plantations of poplar can only be justified if they provide something more than a raw material supply. Plantations must produce better wood or more economical wood than that which can be secured by logging of existing natural stands.

PLANTATION EXPERIENCE

The report on Man-Made Forests in Canada (Cayford and Bickerstaff, In press) showed that 10.4 thousand acres of abandoned farmland had been planted with poplar since 1909. Cayford (personal communication) estimated that this included 9,900 acres planted with Carolina poplar in Ontario and 500 acres with various species in Saskatchewan. In addition, 29.2 million poplars have been planted on an estimated 29.2 thousand acres in the form of farm shelterbelts and blocks in the agricultural areas of Manitoba, Saskatchewan, and Alberta. Cram (1960) described growth and survival of 17 poplar clones in Saskatchewan. Aird (1962) summarized his studies of fertilization and weed control to improve establishment and early growth of poplar.

Vezina (personal communication) reported that Dr. Martin Hubbes recently has established 14 experimental plantations along the St. Lawrence River in Quebec. In these up to 40 hybrids are currently being tested for vigor, growth, and presence of fungi and other defects. Some have been planted in cooperation with Canadian International Paper Company at its Harrington Tree Farm. Dr. L. Parrot also has established three small plantations since 1962 with 50 poplar clones from Italy, the United States, Ontario and Quebec. These plantations are located in Matane on the Gaspé Peninsula and in St-Raymond near Quebec City. Hubbes (personal communication) reported:

> "The material we work with comes from Dr. E. Schreiner, Northeastern Forest Experiment Station, U.S.A. From 68 species, hybrids and clones, we planted in five plantations scattered over the Province of Quebec, the following hybrids proved to be the most resistant against pathogens and climatic conditions:
>
> *P. angulata* x *deltoides*
> *P. candicans* x *berolinensis*
> *P. angulata* x *trichocarpa* (6)
> *P. angulata* x *trichocarpa* (34)
> *P. deltoides* x *nigra* var. *caudina* (25)
> *P. deltoides* x *nigra* var. *caudina* (52)
> *P. deltoides* x *nigra* var. *caudina* (53)
> *P. nigra* x 'Eugenei'
> *P. deltoides* x *nigra* var. *plantierensis*
> *P. maximowiczii* x *trichocarpa*
> *P. deltoides* x *nigra* var. *caudina*
> *P. petrowskyana* x *nigra* var. *caudina*
>
> "These results are considered preliminary since the plantations are only 3 years old and each specimen was only five replicates planted in each plantation. But for the time being this type of plantation seems very useful to single out the highly susceptible material. At the moment, we have 14 plantations (trial plots) of 1.5 acres each of these resistant hybrids in the Province of Quebec".

Cayford (personal communication) described the poplar plantations in Ontario as follows: Manitoulin Island, 103 varieties on 40 acres; Wainfleet near Thorold, 100 acres; Grand Bend, 10-15 acres; Elmvale, 20 acres; Petawawa Forest Experiment Station, 10 acres; Coburn Island (near Manitoulin), 4.5 acres not successful. He also said that a number of hybrids have been planted at Dropmore, Man., and there are now about 5 acres in the arboretum in Skinner's nursery. Near Prince Albert, Sask., the Hardply Corporation has 20 acres of poplars, 3-10 years old. Species used are the "Russian poplar" and *P.* 'FNS 44-52'. In Alberta, according to Cayford, 5 acres near the town of Slave Lake have been planted with 35-40 hybrid poplar varieties.

The plantations established by West Tree Farms (2,000 acres) and by Columbia Cellulose (400 acres) in British Columbia are the largest established as commercial forestry ventures in Canada. The first decade of experience with these and other small plantations in British Columbia was described by Smith and Blom (1966). Annual growth rates in excess of 1 inch dbh, 5 feet in height, and 200 ft^3 per acre have been achieved but they concluded that much long term research was needed to reduce the risks involved. Figures 1-3 show typical poplar plantations.

Maini (personal communication) examined the poplar plantations in Wainfleet Township during the summer of 1966. An attempt was made there to field test numerous hybrids and to grow commercially two clones

Figure 1. View of populetum, Gardner Island, B.C. Planted as rooted material in 1959.

Figure 2. Fast growing poplar clone 8 years after planting.

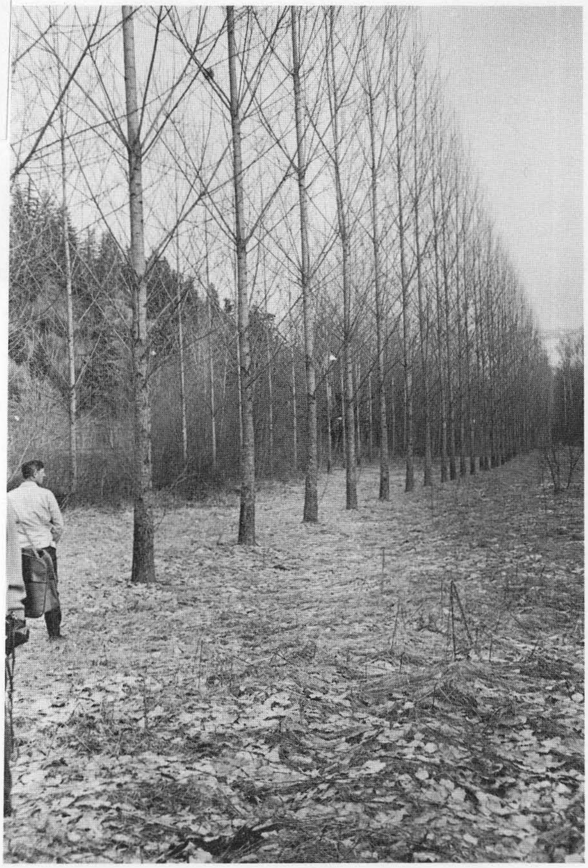

Figure 3. A 1959 planting of 2-year-old P. *'robusta' sets on Harper Mainland Property. Grass sod strip plowed to both sides and trees planted in 4-inch auger holes. Two treatments of Dowpon around base of trees to suppress grass. Trees pruned to 8 feet in 1964. Picture taken in 1967.*

P. 'Raverdeau' and *P.* 'IH-78B'. The first is a clone of *P.* 'Robusta' and the second is a cross between eastern cottonwood (from Mississippi) and European black poplar. His comments were rather discouraging:

> "The plantation is located on poorly drained, fine textured soil with fragipan about 15 inches below the surface and much mottling in the profile. The effect of spacing, fertilizers and other cultural operations was to have been observed in the Wainfleet plantation. Unfortunately the operations were very haphazard and disorganized and the plantation was very much neglected. No valid conclusions could be drawn on the effect of spacing, fertilization or cultivation. Both of these hybrids are unsuitable for the fine textured and poorly drained soils of the plantation. Mortality is high in both hybrids (*P.* 'IH-78B', 55%; *P.* 'Raverdeau', 70%). The roots of *P.* 'IH-78B' penetrate deeper than those of *P.* 'Raverdeau', but the former is more susceptive to sunscald than the latter. Better growth of surviving *P.* 'Raverdeau' trees (than *P.*'IH-78B') was partly attributed to their shallower root system distributed extensively above the fragipan and in the upper 8 inches."

Although the Wainfleet plantations of the Ontario Paper Company Limited have been disappointing, much of value still may be learned from their Gore Bay plantations on Manitoulin Island. Their Chief Forester, J.F. Walker (unpublished data), observed:

> "The basic difference between the hybrid poplar plantations on Manitoulin and in Wainfleet should perhaps be pointed out. The Manitoulin plantation, established in 1955, was designed to field test a large number of the most promising hybrid poplars, either collected (from all over the world), or developed by Dr. Carl Heimburger, Research Division, Department of Lands and Forests of Ontario. Field tests included variations in spacing, cultivation, fertilization, pruning, etc. (Several unpublished reports on this experimental work are available.) About 108 varieties of hybrid poplars are currently growing in the Gore Bay plantations.
>
> "The Wainfleet plantation was designed to explore the economic and silvicultural aspects of growing, on a "commercial" basis, fast growing hybrid poplars on abandoned farm land in the vicinity of the Thorold Mill, to provide a readily available source of acceptable wood fiber for future use."

Heimburger (personal communication) took a pessimistic view of poplar cultivation in Ontario. He said:

> "Poplar growing in eastern Canada is largely a series of frustrations interrupted by a few promising results. Two main trends are in evidence. Some people show great interest and enthusiasm, make good site preparation and plantation establishment, but over-expend their efforts on maintenance. The poplars are pruned, cultivated and variously manicured to death. Somehow, the novelty does not wear off soon enough and this results in bad publicity and frustration. Other people make only fair site preparation and good planting followed by

very poor or no maintenance. Under such conditions, cottonwood poplars grow into large shrubs surrounding a dead stick, but many aspens do quite well. Since there is no pruning, much variation in natural pruning ability of the planted materials can be observed and used as a basis for selection. This is one of the reasons why I am much more interested in aspens than in cottonwoods. Also, the potential growing area for aspens is far greater than the area suitable for cottonwoods in eastern Canada. Many farmer's woodlots, also on relatively wet land, could probably be converted to aspen hybrids with good economic results.

"In our own work, on Crown land, we plant poplars usually at 8 x 8 ft spacing, in the fall when the planting areas are drier and more accessible than in the spring, after one full season of cultivation to eliminate sod. Stump planting, as with teak, is used, to save on packing and transportation. One good sprout is left during the first fall after planting and grows into a tree. We prune in the middle of the summer, leaving everything on the ground. This usually is conducive to good ecoclimate and poplar growth. None of our own poplar plantations have as yet reached thinning age and we have no experience [in this]."

CHOICE OF STOCK

As if the choice between aspen and cottonwood is not sufficiently complicated, the Canadian forest manager is faced with a bewildering choice from many other species and hundreds of hybrids. Usually, if there is any local experience with hybrid poplars, these have been grown as ornamentals often off-site, with a minimum of care, and from highly uncertain sources. Careful study can glean some useful clues from growth of such trees but much risk is involved.

It seems obvious that long-term observation of Populetums such as that established on the University of British Columbia Research Forest (Walters 1963, 1966) and on Gardner Island (Smith and Blom 1966) will be needed to give some assurance that the trees used operationally are among the best. More work of the kind reported by Peto (1938) is needed.

In many situations and especially for growth of pulpwood the safest approach will be to select superior clones from native poplar stands that have already proven their suitability for the sites involved. Cottonwoods should be favored over aspens because they grow faster than aspens and are easier to propagate. Smith (1957) reported from 3 to 5 feet annual height growth for black cottonwood from coastal regions, which is much superior to the 0.8 to 1.6 feet of height growth estimated for trembling aspen by Heinselman and Zasada (1955).

Thanks to the efforts of the late Dr. J.E. Bier and others, e.g. Boyer (1961), it now should be possible to greatly reduce the damage caused by the various diseases which prevented large scale use of black cottonwood stock by West Tree Farms (Smith and Blom 1966). However, considering form, natural pruning, growth rate and resistance to pests *P.* 'Robusta' still seems to be preferable to ordinary clones of black cottonwood for the lower Fraser River Valley.

MANAGEMENT ALTERNATIVES

Once he has decided on a species, the forest manager also has to choose among intensive management of land close to the mill, extensive management of more distant land, or combining one of these with a continual process of improving utilization methods to deal more effectively with grades, sizes, and species of trees that are economically marginal.

This third alternative is seldom open to managers of most intensively managed poplar stands who usually enjoy the benefits of a timber hungry economy. But Canadians have no justification for methods which simply maximize fiber production without regard to costs and alternatives. Instead we usually have difficulty recovering our costs of growing wood because stumpage prices still are limited by those for easily available natural stands.

It will be many years before local data of the kind reported by Prevosto (1966) are available. He selected: "1,223 sample plantations varying in age from 3 to 15 years from time of planting, covering a total of over 5,000 hectares and containing about 2 million plants, i.e. about 10% of the plants of clone *P.* 'I-214' grown in the Lombardy-Piedmont plain". He concluded: "both the rotation of the maximum volume production and the economic rotation are of about 9 years in dense plantations (about 200-400 trees per ~~hectare~~ acre) in all classes taken into consideration. In average, dense plantations (about 120-160 trees per ~~hectare~~ acre) the rotation of maximum volume production is 13 years in good (productivity) classes, and 11-12 years in poor ones; the economic rotation is 11 years in the former and about 10 years in the latter ones. In widely-spaced plantations (about 80-100 trees per ~~hectare~~ acre) the rotation of the maximum volume production is of about 14-15 years while the economic rotation is of about 13 years in all productivity classes".

Maximum annual production of poplar fiber will come from very closely spaced stands grown on short rotations. However, the capital costs involved in establishing such plantations would also be high. West Tree Farms' costs for growing and planting each short cutting were 3.5 cents. Using 10,000 of these per acre would cost $350.00 and impose an annual interest charge of $17.50 at 5%. Stumpage values at current prices on even 500 ft^3 growth per acre/year could barely meet the interest charges. Trees per acre would have to be reduced to perhaps 1,000 before there would be any hope for recovery of minimum capital costs of $35.00 as well as interest. New technologies involving silage (McAlpine *et al.* 1966) and chip groundwood (Eberhardt 1965) methods might improve this situation.

A formula for estimation of tree and stand volume for black cottonwood can be used to illustrate the dimensions within which forest managers can plan their operations. Smith and Munro (1965) observed for black cottonwood that V/B equals 0.36 H, where V is total cubic foot volume inside bark (ib), B is basal area outside bark at breast height, and H is total tree height. For trembling aspen V/B equals 0.42 H. Smith and Kozak (1967) reported that black cottonwood ib volumes must be increased by 22% for bark and that trembling aspen ib volumes must be increased by 19% for bark.

When solving this V/B relationship for the limit of annual height growth, which is about 10 feet for hybrid poplars, it is evident that a stand must have 28 ft^2 of basal area per acre to support an annual growth of 100 ft^3. To grow 500 ft^3 per acre, a poplar stand would have to have 139 ft^2 of basal area at the beginning of the year and gain 10 feet in height during the year. To grow 100 ft^3 per acre when annual height growth is 1 foot, 278 ft^2 of basal area per acre are needed. Early development of the required level of basal area obviously involves many problems.

To provide the 28 ft^2 of basal area per acre needed to support annual growth of 100 ft^3 associated with annual height growth of 10 feet we must have 28 trees 13.5 inches dbh, 280 trees 4.3 inches dbh, or 2,800 trees 1.4 inches dbh. Unless there are well developed markets that will pay for very young, small trees (thinnings) there must be a sacrifice of productive capacity while basal area is being built up to desired levels.

A measure of the loss associated with incomplete stocking of poplars during this juvenile period also exists in the ratio of the crown width (CW) of open grown poplars to their dbh. Expressed as CW in feet to D in inches this ratio averages 1.67 for both open and forest grown black cottonwood ranging from 7 to 25 inches dbh (Pearson 1962). Smith (1966) reported that crown widths of both open and forest grown trembling aspens were 4.0 + 1.30 times dbh. For open grown balsam poplar CW = 3.0 + 1.75 D, and for forest grown balsam poplar CW = 2.5 + 0.95 D. Basal area per acre equals $\frac{15.4^2}{(CW/D)^2}$ for square spacing (Smith 1965). If the desired size at harvest is established by technical or economic considerations that are known, it then is possible to further define the limits within which the species can be grown. For example, 16 inches dbh was considered as the optimum in early plans for development of the West Tree Farms program. Then the forest manager wanting to start production quickly might choose to plant 62 trees or sets per acre and to grow them throughout their life without competition until they reach the desired harvest size of 16 inches dbh. Such trees would produce reduced yields per acre at full stocking but a maximum rate of growth per acre for that size of tree. Alternatively, the manager might choose to force his trees into full stocking and normal density when they are only 2 inches dbh. Then the stand would have 4,000 trees per acre and competition would eliminate the weakest, or less fortunate, naturally as they grew in dbh to the desired 16 inches average. When this stand reached 16 inches it would contain perhaps 67 trees but these would be nearly twice as old and might be nearly twice as tall as the poplars grown without competition (Smith 1966).

One good compromise is to plant just enough trees that the desired average dbh will be achieved by the number of trees required for normal yield. This could be done by planning to plant enough trees to create full stocking and open stand density at 8 to 10 inches dbh. The number of trees or sets required to do this will be about 170 per acre.

There may also be a legitimate desire to sacrifice yield per acre for even lower establishment costs and a high rate of growth per tree. This can be done by planting hybrid poplars or cottonwoods at spacings of 20 x 20 or 15 x 30 feet. The latter spacing facilitates all operations involved in establishment and harvest of the stand. The 97 to 109 trees planted per acre could be harvested when they average 16 inches dbh or be held until they average about 21 inches dbh and achieve normal yields. Mortality of such trees should be low, but long term observations are needed to confirm this opinion.

The wide spacings just discussed apply very well to black cottonwoods capable of growing from 3 to 5 feet in height annually. Much closer spacings are needed to provide the basal area required to utilize the site more fully when planting aspens that may only grow from 1 to 2 feet annually in height.

To use an annual growth capacity of 50 ft^3 per acre with an aspen stand growing 1 foot a year in height $\frac{50}{.44}$ or 113.5 ft^2 of basal area are needed. If the trembling aspen stand were increasing in height by 2 feet annually, only 57 ft^2 of basal area would be needed. Even then, spacing with trees 1 inch dbh would have to be about 2 x 2 feet to fully utilize the site capacity with 10,400 trees per acre. Unless there is an excellent market for very small pulpwood, optimum spacing for trembling aspen will be about 14 x 14 or 10 x 20 feet. This should produce a maximum harvest of 8-12 inch dbh trees at a minimum cost per acre.

OPTIMUM MANAGEMENT CONDITIONS FOR BLACK COTTONWOOD

The system that is most likely to prove profitable in Canada will involve a minimum of hand labor and will aim at rapid production of large sized trees. Strip clearing with a 15-foot bulldozer blade leaving every second strip free facilitates planting of sets at a spacing of 15 x 30 feet. Potentially competitive trees between rows should be killed. Use of sets 10 to 12 feet tall should give high survival and require a minimum of weeding and cleaning. Until superior local black cottonwood hybrids can be developed, well tested European poplars such as *P.* 'Robusta' should be used. Plantations should be inspected periodically in order to detect and plan any necessary action against pests, and reduce the probability of losses caused by trespass, but little maintenance can be afforded. If trees are to be grown for veneer, pruning will be necessary and this may be facilitated by use of "Tree Monkeys" (Fig. 4). (These Sachs tree-pruning machines are distributed in Canada by Vanguard Steel Ltd., Vancouver 1, B.C. They are powered with a power saw motor and are designed to climb and prune 5-10 inch

Figure 4. Tree monkey, used for pruning, costs $1300(US).

dbh trees to a 4 inch top dob. They climb at about 10 feet per minute to a height of 40 feet). It would be most desirable, economically, to prune in one operation to a height of about 30 feet to give three veneer blocks when trees are about 60 feet tall, which is within the present 4-10 inch diameter range of the Tree Monkey. It may be possible to remove every second tree within rows in a thinning or these may be regarded as a reserve against mortality. Probably most cottonwood stands should be harvested when they average about 16 inches dbh.

CONCLUSIONS

A good start on some aspects of poplar cultivation has been made. Much more must be learned, however, about growth and yield from species and spacing trials and about the methods and economics of managing commercial poplar plantations. Formal, large scale, comprehensive, well planned and adequately financed research programs are needed now to secure the basic data required to plan and manage poplar plantations to satisfy increasing needs for high quality poplar in Canada.

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CHAPTER VI

POPLARS FOR GRASSLAND PLANTINGS

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INTRODUCTION

Federal tree nurseries have, since 1901, provided material for some 350,000 acres of shelterbelt plantings in the Prairie Provinces. Eight per cent of this acreage was poplar. Annual plantings of poplar have ranged from 101 to 960 acres or 140,000 to 1,315,000 trees. Climatic and other conditions have affected the annual demand for poplar, thus during the 1930's plantings decreased to 142,000 annually. However, since 1960 the demand for poplars has exceeded the material available so that production is being expanded at Indian Head to permit plantings of 2 million rooted cuttings a year by 1970.

POPLARS IN SHELTERBELTS

Poplars were formerly planted around prairie farm homesteads to provide early shelter, but few persisted beyond 16 years because of adverse effects of drought, site, disease, and possibly insects. They were later planted as a "nurse" or temporary species in mixed shelterbelts alternating in the row with slower-growing but more permanent species of deciduous trees, such as elm and ash. More recently, poplars have been planted as the outside rows in home shelterbelts to provide early shelter and to facilitate removal when the inner rows of the more permanent species afford sufficient shelter.

Before 1940, planting stock of poplar distributed by the Tree Nurseries was limited to three clones, *P.* 'Northwest', *P.* 'Saskatchewan' and *P. petrowskyana*, one of the "Russian" poplars. As new clones became available this number was increased to 13 by 1958 but since 1965 distribution has been restricted to the five clones that performed best in local and regional tests. These clones, now being mass produced and distributed for prairie planting are *P.* 'Northwest', *P.* 'Saskatchewan', *P.* 'FNS 44-52', *P.* 'Gelrica' and *P.* 'Tristis'.

NURSERY PRODUCTION

Before 1963, planting material was produced and distributed as 8-inch hardwood cuttings obtained from stooling or cutting beds. These cuttings were normally stored over winter by heeling-in out-of-doors and packed and shipped in the spring. The production of rooted cuttings, which ensure better stands, has been made possible by the mechanization of all phases of nursery operations. The use of herbicides and irrigation, the development of a hydraulic cutter, and mechanical harvesters and planters have reduced costs per 1,000 rooted cuttings from $23 to $11 since 1964. This cost includes $2.48/1000 for the production of hardwood cuttings, $2.47/1000 for planting, $1.34 for nursery culture and $4.63 for harvesting and storage. It is anticipated that costs will be further reduced to about $7/1000 with refrigerated bin storage.

All poplar planting material was produced and distributed as 8-inch hardwood cuttings prior to 1963 as the most economical method. Nursery production of poplars entails the establishment of stooling or "cuttings" beds, from which shoots of the current growth are harvested each fall and made into hardwood cuttings. Normally, these cuttings are stored over the winter by heeling-in outdoors for the spring packing and shipping operations. With gradual mechanization of harvesting, planting and cultural operations on the nursery, the production and distribution of "rooted" cuttings has proven more practical and economical to ensure better stands. For example, the hand labor required to harvest and make hardwood cuttings has been reduced from 2.4 man-hours per 1,000 in 1964 to 1.6 man-hours per thousand with hydraulic cutters in 1966, or by 65%. Utilization of rooted cuttings would materially reduce the costs of establishing shelterbelts and reforestation operations.

Studies on 17 clones between 1951 and 1956 (Cram 1960) showed one female clone, *P.* 'FNS #44-52', to be outstanding with a survival rate of 94% and a height of 25 feet after 6 years. Six other clones, *P.* '38P38', *P.* 'Tristis #1', *P.* 'Gelrica', *P.* 'BNW #4', *P.* 'Northwest' and *P.* 'Saskatchewan', had survival rates of 75-100% and attained heights of 12-20 feet. Ten clones *P. deltoides* var. *occidentalis*, *P.* 'Incrassata', *P. angustifolia*, *P.* 'Dunlop', *P.* 'Volunteer', *P.* 'Wheeler #4, *P.* 'AS #2' and *P.* 'Brooks #4', *P.* 'Brooks #7' and *P.* 'Brooks #10', were highly susceptible to disease or adverse climatic conditions and were deemed of little value for shelterbelts in the Indian Head area. A breeding program to incorporate the rooting ability, vigor and disease resistance of the seven best clones was initiated in 1962. Hybrid selections from these crosses are now being evaluated.

INVESTIGATIONS

Rooting capacity of hardwood cuttings has been found to increase with maturity of shoots from the clonal material. Cuttings harvested in 1957 from three clones *P.* 'Northwest', *P.* 'Brooks' and *P.* '44-52', on October 9 and 29, had an average rooting capacity of 43 and 53% in 1958, with an average top growth of 30 and 45 cm, respectively. Previous and subsequent studies have confirmed the superiority of cuttings from mature wood.

Storage of hardwood cuttings has also been investigated. In the fall of 1965 outdoor storage of three clones was compared with refrigerated storage at 0, 28, and 34F, with and without polyethylene and vermiculite protective coverings. Average stands of cuttings in 1966 following storage until May 30 were 5% for outdoor storage compared to 44% for "bare", 59% for vermiculite and 75% for poly-covered cuttings. Stands following refrigerated storage at OF were greater than those stored at 28 and 34F. On the other hand, average stands for the three clones following OF storage were 84% for the poly-covered and 80% for the "bare" cuttings. Storage at OF with polyethylene coverings has been accepted as a standard nursery practice. Significant reductions in handling and labor costs are now possible by utilization of refrigerated storage in poly-lined pallets.

Herbicide investigations have demonstrated that Linuron at 2 lb./acre (active) produces good to excellent results throughout the growing season in plantings of rooted poplar. On the other hand, applications of simazine at 3 lb./acre were toxic to established plantings of poplar.

TEST PLANTINGS

Regional test plantings of poplar have been conducted on a cooperative basis since 1964 with the Alberta Department of Agriculture, the Saskatchewan Department of Natural Resources, and the federal Department of Forestry and Rural Development in Manitoba. These tests are planned to evaluate the potential for shelterbelts and pulp of all available poplar clones in the three regions. Some 163 clones of poplar have been acquired at the Tree Nursery to date and will be propagated for inclusion in future regional tests.

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CHAPTER VII

INSECTS AND DISEASES

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INTRODUCTION

The poplars in Canada are host to a wide variety of insects and disease organisms. For example, at least 300 insects and 150 fungi have been recorded by the Forest Insect and Disease Survey on living trembling aspen alone. Many of these cause little, if any, damage and the importance of others is unknown. This paper reviews present knowledge of some of the more important insect and disease problems from the standpoint of hosts, distribution, present or potential impact, life history, and control.

INSECTS

Defoliators

On the basis of feeding habits, the defoliators are by far the largest group of insect species attacking poplar. The extent of damage by this group depends on the severity of defoliation, the time of the year when defoliation occurs, and the frequency of successive defoliations.

The insects defoliating poplar belong mainly to two orders; Lepidoptera (moths and butterflies), and the Coleoptera (beetles). While both the larvae and adults of Coleoptera are leaf feeders, only the larvae of Lepidoptera cause damage.

Outbreaks of defoliating insects can generally be controlled by the application of chemicals such as DDT or malathion. Although small-scale control programs are carried out against these insects in towns, cities, recreation areas, and plantations, the present level of utilization of poplar in Canada does not warrant the spraying of extensive forest stands.

Lepidoptera

Forest tent caterpillar, *Malacosoma disstria* Hbn.: This tent caterpillar feeds on a number of broad-leaved species, but trembling aspen is the preferred host. Infestations occur periodically in trembling aspen stands from the Maritime Provinces to British Columbia. The most extensive of these have developed in central Canada where aspen forms a major component of many forest stands. Outbreaks in this region have covered areas of up to 100,000 square miles. The typical pattern of outbreaks has been described by Sippell (1962) and a number of workers have prepared cartographic histories of infestations in Canada and adjacent areas in the United States (Duncan and Hodson 1958; Hildahl and Reeks 1960; Sippell 1962). High populations of the forest tent caterpillar usually appear suddenly and persist for 2 or 3 years. They frequently cause complete defoliation of host trees by early summer. Fortunately trees that are heavily defoliated at this time of the year usually produce new foliage. Despite the spectacular nature of outbreaks of this insect, there have been few instances of appreciable tree mortality. Some branch mortality may occur but the main effect of outbreaks is the reduction in the annual growth of severely defoliated trees (Barter and Cameron 1955; Hildahl and Reeks 1960; Rose 1958). This reduction in growth may continue for 2 years following outbreaks. The growth reduction from an outbreak in Manitoba and Saskatchewan during the early 1950's amounted to 2 cords per acre over 1.5 million acres (Hildahl and Reeks 1960). During outbreaks, the large number of larvae and the unsightly appearance of denuded trees are a nuisance in resort areas.

Figure 1. Trembling aspen stand defoliated by the forest tent caterpillar.

Figure 2. Larva of the forest tent caterpillar feeding on a poplar leaf.

The time of egg hatch of the forest tent caterpillar is influenced by weather and may occur from late April to mid-May. Young larvae appear on the trees at about the time the buds are bursting and at first feed gregariously. Later they scatter throughout the crown and feed voraciously on the developing foliage until mid-June. Cocoons are spun either on the leaves of the host trees or on nearby shrubs and ground plants. Moths emerge 8 to 12 days later and lay their eggs in conspicuous bands on the twigs of the host. The insect overwinters as a first-instar larva within the egg shell.

The number of egg bands on the trees provide an indication of the intensity of infestation that may be expected the following year. However, the validity of forecasts based on autumn egg surveys can be strongly influenced by the failure of eggs to hatch (Prentice 1954) and extremes of weather immediately following hatching (Blais *et al.*1955).

Outbreaks are usually terminated by natural control factors such as starvation, parasites, predators, disease, and unfavorable weather conditions (Brown 1966). Starvation is a particularly important control factor because the number of insects often increases so rapidly that trees are defoliated and the food supply is exhausted before the caterpillars are fully grown.

Over 40 species of insect parasites attack the forest tent caterpillar; some attack the eggs, some the caterpillars, and others the cocoons. One of the flesh-flies, *Sarcophaga aldrichi* Park, is the most important of these parasites; living maggots are deposited on the cocoons and feed on the body tissues of the insect within.

Unfavorable weather appears to be the only natural control factor capable of bringing an outbreak to an end within the first 3 years. Outbreaks have been terminated by cold spells which occurred immediately before, or soon after, the hatching of the eggs. Cold spells after the caterpillars have hatched may cause their death by freezing the leaves so that the caterpillars cannot eat, or by making them too sluggish to feed.

Large aspen tortrix, *Choristoneura conflictana* (Wlk.): The large aspen tortrix, like the forest tent caterpillar, feeds on a number of broad-leaved trees but prefers trembling aspen. It occurs across Canada but is most common from Ontario west where it periodically causes severe defoliation of aspen (Prentice 1965). Severe infestations covering 10,000 square miles or more have been recorded in Manitoba and Saskatchewan. Generally, severe outbreaks persist only 2 or 3 years in any particular area. Although little is known about the effect of severe infestation on aspen stands, tree mortality to date has been negligible. It may be expected that some losses would occur should aspen stands be successively attacked by tent caterpillar and the aspen tortrix.

The eggs of the large aspen tortrix are laid in flat clusters on the aspen leaves from mid-June to early July, and the larvae hatch 7 to 10 days after oviposition (Prentice 1955). The first-instar larvae are gregarious, congregating between flat surfaces of leaves they web together. The larvae skeletonize the foliage, but feeding damage is not conspicuous at this stage. During the latter part of August the larvae descend to the base of the trunk and overwinter in hibernacula. Second-instar larvae emerge from hibernation in early May. They ascend the trees, mine the swelling aspen buds and again feed on epidermal leaf tissue. From the latter part of the third-instar until pupation, the larvae feed within rolled leaves, eating all but the larger leaf veins. It is during this period of larval development that most defoliation occurs. The larvae pupate from early June to mid-June and the adults emerge 7 to 14 days later.

Second- and third-instar larvae remain in mined buds and developing leaf clusters for a period of 10 to 14 days in the spring. Sampling at this time provides an estimate of the potential population and forms the basis for defoliation forecasts.

The large aspen tortrix has many parasites, some of which attack other common forest insects. Birds and ants also attack the larvae. In one area, hibernating second-instar larvae were infected by a fungus but its impact as a control has not been evaluated.

Satin moth, *Stilpnotia salicis* L.: The satin moth, native to Europe and western Asia, was first discovered in New Westminster, B.C., in 1920 and at several points in the Maritime Provinces in 1930. It has now been recorded in Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, and British Columbia (Reeks and Smith 1956; Prentice 1962). The insect attacks silver poplar, Carolina poplar, trembling aspen, Lombardy poplar, balsam poplar, black cottonwood, and other poplars. Natural stands have been attacked in British Columbia and Newfoundland, but the insect is primarily a pest of planted poplars (Reeks and Smith 1956). Repeated stripping of poplar foliage for four consecutive years may cause limited tree mortality but considerable branch-killing. For example, branch mortality as high as 80 to 90% has been recorded on Carolina poplar in the Maritime Provinces.

The life history of the satin moth varies with climate but in general the moths appear during midsummer. Eggs are laid in masses on tree trunks, posts, buildings, and other objects. After hatching the young larvae skeletonize the foliage. In late summer or early autumn, the larvae move to the stems and branches and form hibernating webs in which they overwinter. The following spring the larvae feed again and consume most of the leaf tissues except the petioles and larger veins. Pupation occurs inside cocoons formed on foliage, buildings, or other sites.

The insect is easily controlled on shade trees by spraying in the spring when the leaves are fully developed or later before hatching is at its peak (Reeks and Smith 1956). With summer spraying it is only necessary to treat the trunk and lower branches; the young larvae are killed by the direct and residual effect of DDT during migration over the bark surface.

Bruce spanworm, *Operophtera bruceata* (Hulst): The Bruce spanworm occurs in Canada from Newfoundland to the interior of British Columbia (Prentice 1963). It feeds on a variety of broad-leaved trees with trembling aspen being the preferred host in western Canada. High numbers sometimes develop locally in the Maritime Provinces and Quebec and fairly extensive outbreaks have been recorded in Alberta and northeastern British Columbia. In 1958, trembling aspen over about 50,000 square miles were moderately or severely infested in Alberta (Brown 1962). As with the forest tent caterpillar and large aspen tortrix, the main effect on trees has been a reduction in growth.

The eggs, laid singly in bark crevices or in other protected locations on the tree, are deposited late in the fall and remain dormant until the following spring. Development is completed early in the spring and young larvae usually hatch when the aspen buds begin to burst. Shortly after hatching many larvae spin down on long strands of silk and are often carried long distances by wind. This is the chief method of dispersal because adult females are wingless. If cool weather delays leaf development, the young larvae bore through the bud scales and feed on the soft tissues in the bud. These buds may be completely destroyed. If rapid bud development begins just after the larvae have entered the buds, evidence of this early feeding appears as holes in the unfolding leaves.

The larval period usually begins in late May and lasts approximately 5 to 7 weeks. The larvae may feed openly on the leaves or within the shelter of loosely rolled or webbed leaves. They spin large amounts of silk, often festooning the trees. Feeding is usually complete about the third week in June. Pupation occurs in thin silken cocoons in the soil or in the duff beneath the trees; the pupal period lasts until late fall. Upon emergence the females ascend the trees. Adults are active at low temperatures and females sometimes lay eggs when there is snow on the ground.

A number of parasites have been reared from the Bruce spanworm in Alberta. None were numerous enough to have had an appreciable effect on host numbers during the last outbreak, but parasites may be important during periods of endemic populations. In Quebec, where the spanworm prefers sugar maple and beech, the population decline in a recent outbreak was caused principally by a virus disease (Martineau and Monnier 1966).

Aspen leaf miners: The aspen leaf miner (*Phyllocnistis populiella* Cham.) has been collected from Newfoundland to British Columbia (Forbes, Underwood and Van Sickle 1962; Martineau and Ouellette 1967; Prentice 1965; Warren 1967). In Canada, only adults reared from trembling aspen have been authoritatively identified as *P. populiella* although the insect (probably undescribed species) has been reported on other poplars (Condrashoff 1964). The insect has been abundant in parts of Alberta and British Columbia (Baranyay and Stevenson 1966a; Molnar, Harris and Ross 1966). Unlike those of the previous species the larvae feed inside the leaf, mining the epidermal layers. Severe attacks may cause leaf discoloration, desiccation and subsequently early leaf-fall. The long-term effect of the leaf miner on trees has not been assessed but some workers attribute the death of aspen trees to severe infestations over several years (Condrashoff 1962).

In spring, when the trembling aspen buds open, the moths deposit eggs on both upper and lower leaf surfaces. Oviposition continues until the leaves reach approximately two-thirds full size. The developing larvae mine the upper and lower epidermis, attaining full size in 4 or 5 weeks, and then spin cocoons. Ninety per cent of the mining occurs in the third or final mining instar; this lasts 4 or 5 days. The fourth instar does not mine. The pupal stage lasts about 2 weeks. New adults are frequently seen resting on trees and shrubs during June, July, and August; they hibernate soon afterwards. There is only one generation per year.

In British Columbia, excellent control of the leaf miner was obtained by spraying the foliage of young trembling aspen with Thiodan (endosulfan) and Rogor (dimethoate) in May. One month later treated trees had grown considerably taller than untreated trees, which suggests that the leaf miners may reduce growth considerably (Condrashoff 1962).

The aspen blotch miner (*Lithocolletis salicifoliella* Cham.) occurs from New Brunswick to western Saskatchewan but is most common in central Canada where it sometimes causes conspicuous damage to trembling aspen foliage (Prentice 1965). In Ontario foliage within 10 ft of the ground on small trees has suffered the greatest injury (Martin 1956).

The insect is similar to the aspen leaf miner in life history but differs from it in feeding habits. Eggs of the blotch miner are laid on the underside of the leaves and the larvae, upon hatching, eat through the lower epidermis and feed on the mesophyll of the leaf.

Two major factors, larval competition and parasitism, have been observed to be operative in the control of the aspen blotch miner in Ontario (Martin 1956).

Coleoptera

The gray willow-leaf beetle, *Galerucella decora* (Say): The gray willow-leaf beetle causes moderate to severe skeletonizing of the foliage of trembling aspen, balsam poplar, and planted hybrid poplars throughout southern Manitoba, Saskatchewan, and Alberta.

The adults of the gray willow-leaf beetle appear first in late summer and fall, and overwinter in the leaf mould and debris under natural stands of poplar and willow. They emerge the following May (Peterson 1949).

The adults are quite gregarious upon emergence in the spring, and are heavy feeders. They frequently migrate in large numbers and may fly long distances to settle *en masse* on farm shelterbelts and shade trees, or on natural stands. Their sudden appearance is due to this migratory habit. Such migrations may occur until early June. Initially no preference is shown for poplar and willow, and trees of all sizes are attacked. By late May when mating becomes common, the smaller second-growth aspen and willow appear to be preferred, and by late June, when the migratory phase is largely over, feeding is limited almost entirely to willow, on which the eggs are laid. Although the adults may be found from early May to early July, they rarely remain in a farm shelterbelt for more than a week or 10 days, unless willow is present.

Oviposition takes place during June and early July, and is believed to occur only on willow. Like the adults, the larvae are gregarious and several feed on one leaf. The larvae skeletonize the foliage leaving only the veins and a thin transparent membranous layer. The damaged leaves turn rusty and if many are affected the willows appear scorched by mid-August. Upon completing their growth in July or August, the larvae leave the foliage and enter the soil where they remain for about 2 weeks and emerge as adults.

Feeding by adults in the fall is usually light, and is confined to poplar. As the adults do not migrate in the fall, but remain in the stand where they emerge, native aspen is chiefly affected. With cooler weather, the adults again go into hibernation as described.

High beetle populations in certain years are due to the high reproductive capacity of the species and to the paucity of natural control factors. Its rapid decline to very small numbers is brought about by a marked increase in natural control factors. Most of this natural mortality appears to be due to parasites which are especially effective against the larvae.

Serious stripping of shelterbelts, shade trees, and natural stands takes place in the interval between peak abundance of the beetle and of the parasites. During this interval the application of artificial control measures may become necessary.

The aspen leaf beetle, *Chrysomela crotchi* Brown: The aspen leaf beetle feeds primarily on trembling aspen but occasionally on largetooth aspen, balsam poplar, and willow. It has been recorded from Nova Scotia to Alberta (Brown 1956) but periodically defoliates trembling aspen in Saskatchewan, Manitoba, and Ontario. An extensive outbreak of the aspen leaf beetle was recorded between 1961 and 1964 in Manitoba and Saskatchewan (Elliott and Wong 1966). At the peak of the outbreak, trembling aspen leaves were moderately to severely skeletonized over some 74,000 square miles. Aspen reproduction was generally the most severely attacked but in some areas the foliage of trees up to 8 inches dbh was completely skeletonized. Extensive areas of heavy infestation occurred on all sizes of trembling aspen in many parts of western and central Ontario in 1964 (Sippell, MacDonald and Rose 1965). These infestations were of particular concern since the beetle skeletonized the second crop of foliage that appeared following complete defoliation earlier by the forest tent caterpillar.

The life history of the insect (Smereka 1965) is similar to that of the gray-willow leaf beetle.

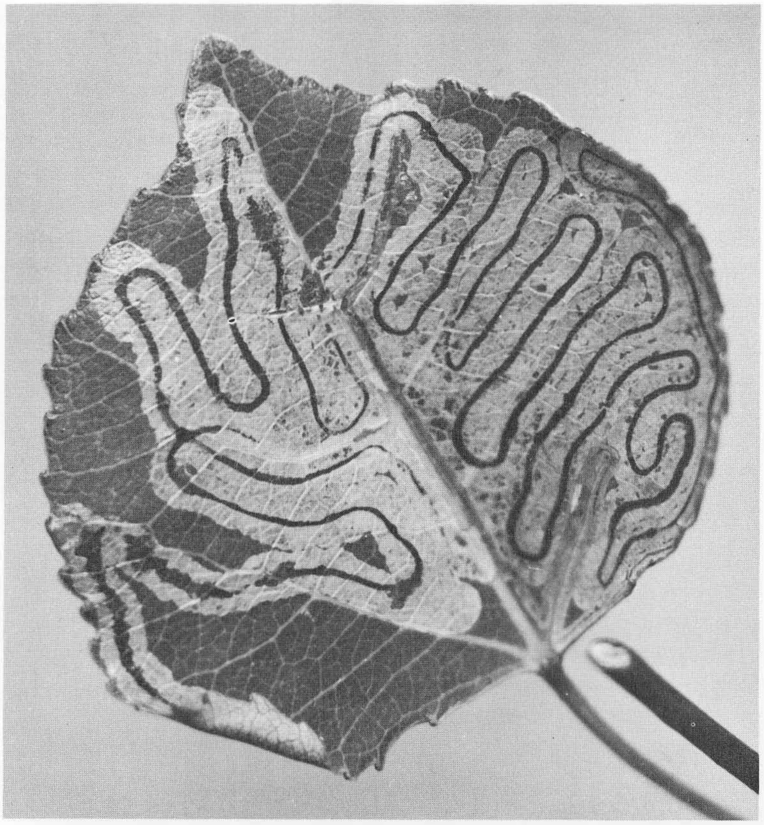
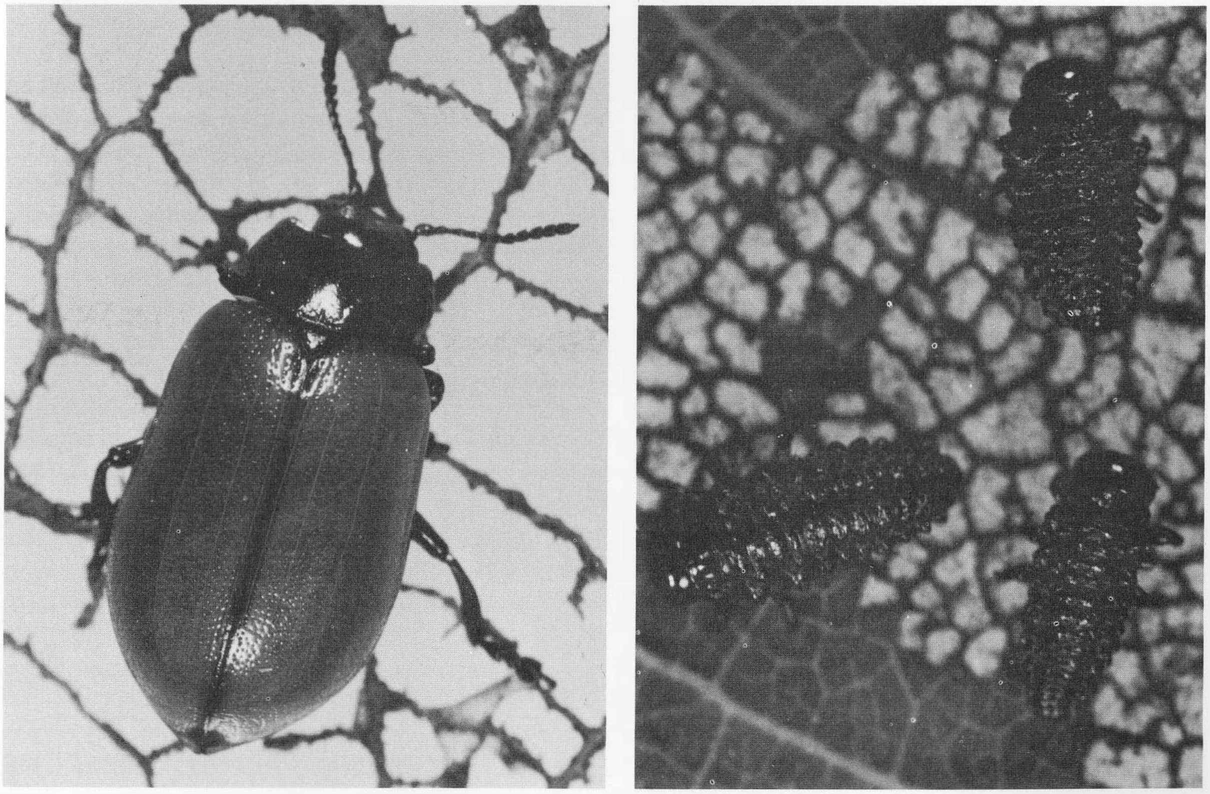


Figure 3 (left). Mined leaf characteristic of the aspen leaf miner feeding.

Figure 4 (below). Aspen leaf beetle: left - adult, right - larva.



Parasites, predators, and winter conditions have some regulating effect on numbers of the aspen leaf beetle. Predators of immature stages and overwintering mortality appeared to be the most important control factors in Ontario (Smereka 1965) and a predator that attacks the eggs and larvae was the main cause of population decline in Manitoba and Saskatchewan (Elliott and Wong 1966).

The American aspen beetle, *Gonioctena americana* (Schaef.): Almost every year this beetle severely defoliates young trembling aspen and occasionally trees up to 6 inches dbh at widely scattered locations in Manitoba, Saskatchewan, and Alberta. However, infestations usually persist for only 1 or 2 years and affected trees readily refoliate. The American aspen beetle is common also in Ontario and Quebec. Its life history (Rose and Smereka 1959) is similar to that of the other defoliating beetles.

Borers

The larvae of a number of Coleoptera bore in the roots, stems or branches of living poplars. The adults of these insects may also feed on leaves and tender bark but most of the damage results from the larval feeding. Two types of borers are recognized (Craighead 1950). The first, including the poplar borer and the poplar-and-willow borer, attacks sparingly over the stem, boring individual galleries under the bark and into the wood of apparently healthy trees; the second type, including the bronze poplar borer, attacks in great numbers over a considerable portion of weakened trees and the larvae mine under the bark of the larger branches or the entire trunk.

The control of borers in living trees is difficult. Many species of borers attack only weakened or dying trees, and after attack the larvae are well protected by a thick layer of impervious bark. In the forest, it is impractical to attempt control except through the sacrifice of the infested tree; and often in shade and ornamental trees, the condition is discovered too late to apply a remedy (Craighead 1950).

Planted trees have been protected from borers by wrapping the trunks with paper or burlap to ward off ovipositing adults until the trees become established and are growing vigorously.

In valuable trees the simplest method of treating some borers is to place one of the common fumigants into the borer tunnel or if the borers are numerous, to spray or paint the trunk with a spray containing the fumigant. With other borers, the application of insecticides when the adults are active will kill the insects before oviposition takes place. Since some borers enter wounds, wounds should be painted or covered with a waterproof dressing until they have healed.

The poplar borer, *Saperda calcarata* Say: The poplar borer occurs throughout most of the range of poplars in Canada. It is known to attack almost all species of poplar (Craighead 1950). Most of the important damage in recent years seems to have occurred in Saskatchewan where the insect has been responsible for heavy root-collar damage to young trembling aspen and balsam poplar (Drouin, McLeod and Wong 1961) and damage to the trunk and branches of living aspen in the parkbelt (Peterson 1947).

Adult beetles feed on poplar and willow, particularly the foliage, petioles, and bark of tender twigs (Peterson 1947). Following mating, oviposition punctures are made in the bark and the eggs are placed between the bark and outer sapwood. In the first season, the larva mines beneath the bark, and in the next, into the sapwood and heartwood where it feeds until mature. The life cycle varies from 3 to 5 years but is usually completed in 4 years.

Small trees are often killed by the larvae girdling under the bark but greater damage results from the decay that becomes established in the abandoned mines and the breaking off of trees where the heartwood has been weakened (Craighead 1950).

The poplar-and-willow borer, *Cryptorhynchus* (*Sternochetus*) *lapathi* (L): The poplar-willow-borer occurs throughout most of southern Canada (Harris 1966) but is important only in British Columbia and Alberta (Baranyay and Stevenson 1966b; Silver and Ross 1965). Although damage caused to wild trees is seldom of economic significance, the borer sometimes becomes a pest by attacking plantations and ornamentals. Trees usually are not killed but may be deformed by severe and persistent attack (Harris 1966).

The borer breeds in willow, poplar, alder, and birch. Young trees, over 1-year old but with thin, smooth bark are preferred. Newly planted trees are particularly susceptible. Willows are the preferred hosts and when these are abundant, poplars or alders are usually free of attack. Attacks are unknown on trembling aspen and most hybrid poplars planted in British Columbia are less susceptible than the native black cottonwood.

The adult feeds on the young succulent bark of branches and the main stem. Eggs are laid in young stems throughout the season but usually in July and August. Newly hatched larvae do little mining before winter; in the spring they mine through the bark and in June bore into the wood.

The bronze poplar borer, *Agrilus liragus* Barter and Brown: The bronze poplar borer, known to occur from New Brunswick to British Columbia, attacks a number of poplar species including trembling aspen, largetooth aspen, balsam poplar, black cottonwood, and eastern cottonwood (Barter and Brown 1949).

The borer weakens and often kills the host through its attacks on the branches and stems (Barter 1965). The larvae make zigzag galleries injuring the phloem and cambium and apparently disrupt the normal translocation of essential plant nutrients. Some chlorosis and abscission of leaves may occur in the year of attack but there is no apparent suppression of increment until the next year. The more numerous the galleries the greater

Figure 5. Damage caused by the poplar-and-willow borer: left - external appearance on black cottonwood stems, right - longitudinal section of stem.

the girdling effect, which intensifies if the attack enters the crown. Other species of borers are usually present in trees heavily infested with the bronze poplar borer (Barter and Cameron 1955).

Studies in New Brunswick (Barter 1965) have shown that survival of the bronze poplar borer is highly dependent on host condition. Any weakening factor predisposes trees to attack and enhances borer survival. One of the most important factors weakening healthy aspen is defoliation by the forest tent caterpillar because it may occur over several consecutive years. Other predisposing factors include Hypoxylon canker, wind breakage, and drought.

The bronze poplar borer reduces tree vigor by destroying the translocation tissues of the tree. This leads to increased borer attack in successive years. In vigorous trees early attacks usually fail because larvae die young, but the trees may be weakened enough to allow later successful attack. Sufficient numbers of beetles to sustain such repeated attacks on healthy trees may result in stands adjacent to or containing several heavily infested trees.

Besides weakening trees and increasing their susceptibility to borer attack, there is evidence that the incidence of Hypoxylon canker is increased by the borer (Barter 1965). In a sample of 50 trembling aspen and four largetooth aspen trees, which supported recent and well-advanced Hypoxylon infections, 13% of the cankers were over borer galleries. Borer injury was invariably involved whenever the cankers were recent enough to determine the exact site of infection.

Adults feed regularly on aspen leaves, usually between mid-June and late August. The eggs are laid in bark crevices and the young larvae bore directly to the cambium where they mine, entering the wood to molt. The larvae mature after 1 or 2 seasons.

The aspen agrilus: *Agrilus granulatus* (Say) occasionally causes damage to planted and native poplars in western Canada (Brown and Stevenson 1965). Its life history and habits are similar to those of the bronze poplar borer.

DISEASES

The most important diseases of poplar are caused by fungi and consequently, this discussion is confined mainly to fungous diseases. In addition, poplars are damaged occasionally by other agencies including drought (Riley and Hildahl 1963), wind (Forbes and Davidson 1962), freezing rain (Davidson and Newell 1957), hail (Riley 1953), frost (Cayford *et al.* 1959), sulfur dioxide (Linzon 1965) and animals (Smith and Blom 1966; Molnar 1963).

Heart Rot

Decay of heartwood by fungi is the most important cause of fiber loss in living poplars in Canada. It is estimated that 20 to 25% of the merchantable volume of poplar is affected by decay. All poplar species are susceptible.

Heart-rotting fungi are transmitted by spores that are produced in specialized fruiting structures developed on decayed trees or slash or on the ground near decayed roots. The spores are spread mostly by air currents but also by insects, birds, or other animals. Upon contacting a suitable substratum and under favorable conditions, the spores germinate. As the germ tube cannot penetrate bark or living sapwood, the spore must come into contact with exposed heartwood or on dead wood directly connected with heartwood for decay to start in a living tree. Heart rot can take place, therefore, in any tree exposed to infection as the result of injury or natural pruning. Some decay fungi grow in roots and may spread from infected roots through the soil to the roots of uninfected trees or through a common root, e.g., between suckers and parent tree. Following establishment, the causal fungi destroy the heartwood and predispose the trees to breakage from winds, ice, and snow. The rate at which decay is initiated and develops depends on the tree species, site, and causal fungus but generally, the volume of decay increases with stand age. In Alberta, more decay is present in trembling aspen than in balsam poplar and more is present in aspen on mesic than on dry sites (Thomas, Etheridge and Paul 1960). In Ontario, trembling aspen stands located on mesic sites are generally less defective than stands located on drier or wetter sites, particularly the former (Basham 1958). However, there is a tendency for trembling aspen to have a greater volume of butt rot, which comprises a smaller proportion of the total heartwood decay than trunk rots, on dry sites.

Many fungi cause decay in poplar but in any particular species, a few cause most of the loss. In trembling aspen the most important fungi are: *Radulum casearium* (Morg.) Lloyd, *Fomes igniarius* (L. ex Fr.) Kickx, and *Peniophora polygonia* (Pers. ex Fr.) Bourd. & Galz. (*Corticium polygonium* Pers.) (Thomas, Etheridge and Paul 1960; Basham and Morawski 1964); in balsam poplar, *Fomes igniarius* and *Pholiota destruens* (Brond.) Quél. (Thomas, Etheridge and Paul 1960); and black cottonwood, *Polyporus delectans* Pk. and *Pholiota destruens* (Thomas and Podmore 1953).

Losses from heart rot can be reduced through various management practices. Bark wounds constitute the main avenue of entrance for *Fomes igniarius* (Etheridge 1961), the most important cause of decay in poplar. Injuries, therefore, should be avoided during logging, and priority in cutting should be given to stands damaged by storms, insects, or other diseases. On the other hand, *Radulum casearium* and *Peniophora polygonia* generally enter through branch stubs. Artificial pruning to reduce trunk rot is therefore an interesting possibility but its use will depend on economic and utilization considerations.

The volume of decay by heart-rotting fungi generally increases with stand age so stands should be cut before decay losses become serious. For example, in Ontario, if trembling aspen is harvested at an age of 80 years or less high losses from decay can be avoided (Basham and Morawski 1964). The average volume of decay in black cottonwood is low (Thomas and Podmore 1953) and at no point up to age 200 years does decay increment exceed or equal gross wood increment. In this species, decay is apparently not important except in trees cut for specialty products such as plywood.

Cankers

Poplars are attacked by a number of fungi that kill areas of the bark causing "cankers". The cankers caused by the most important of these fungi gradually enlarge until they girdle and kill the main stem, or the infected part becomes weakened and breaks off. Several of the more important canker diseases are discussed below.

Hypoxylon canker, *Hypoxylon mammatum* (Wahl.) Miller (*Hypoxylon pruinatum* (Klotzsch) Cke.): Hypoxylon canker is one of the most serious diseases of trembling aspen in Canada. It has been recorded in all provinces with the exception of Newfoundland (Conners 1967).

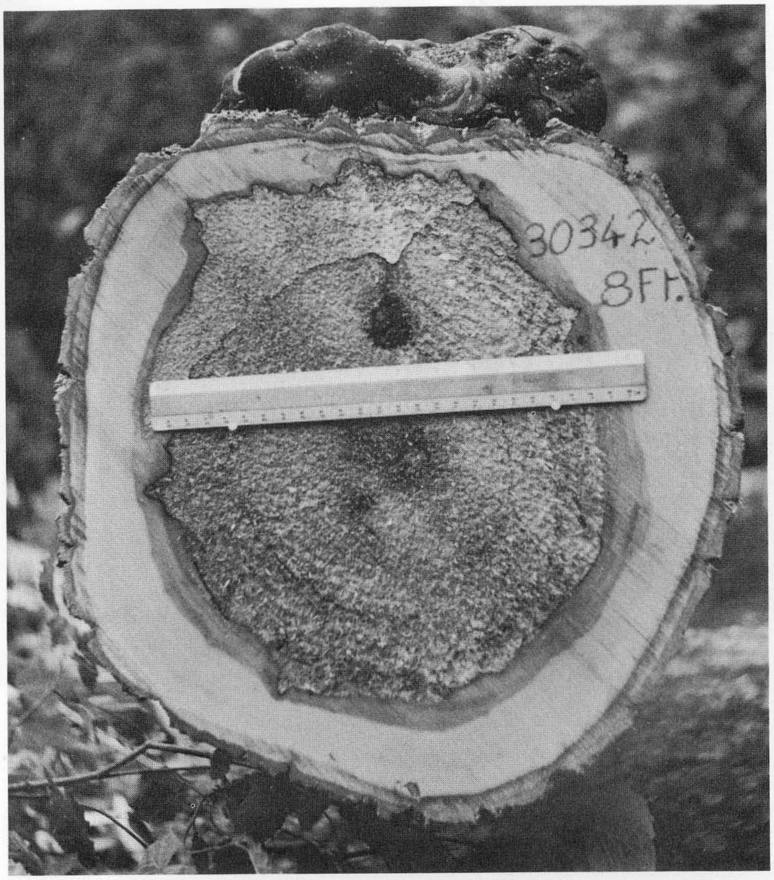


Figure 6. Decay in trembling aspen caused by Fomes igniarius.

Figure 7. Fruiting body of Fomes igniarius *on trembling aspen.*

Although no overall loss figures are available, the following will indicate something of the impact of the disease. Counts in immature stands throughout the Maritime Provinces showed that 20% of the trees were diseased of which 40% were dead or had broken off following girdling by the canker (Forbes, Underwood and Van Sickle 1967). In Ontario, the incidence of the disease varies from less than 10% in the western and northern districts as high as 65 and 77% in parts of the southern districts (Dance and Lynn 1965). Incidence levels ranging from 4 to 58% with a mean of 18% have been reported in Manitoba and Saskatchewan (Elliott, Laut and Brandt 1967).

Of the poplars native to North America, trembling aspen is very susceptible to *Hypoxylon*, largetooth aspen is moderately susceptible, and balsam poplar is rarely infected (Anderson 1956). Stands 15 to 40 years old are most susceptible but appreciable losses also occur in older stands. Both dominant, vigorous and suppressed, weak trees are equally susceptible.

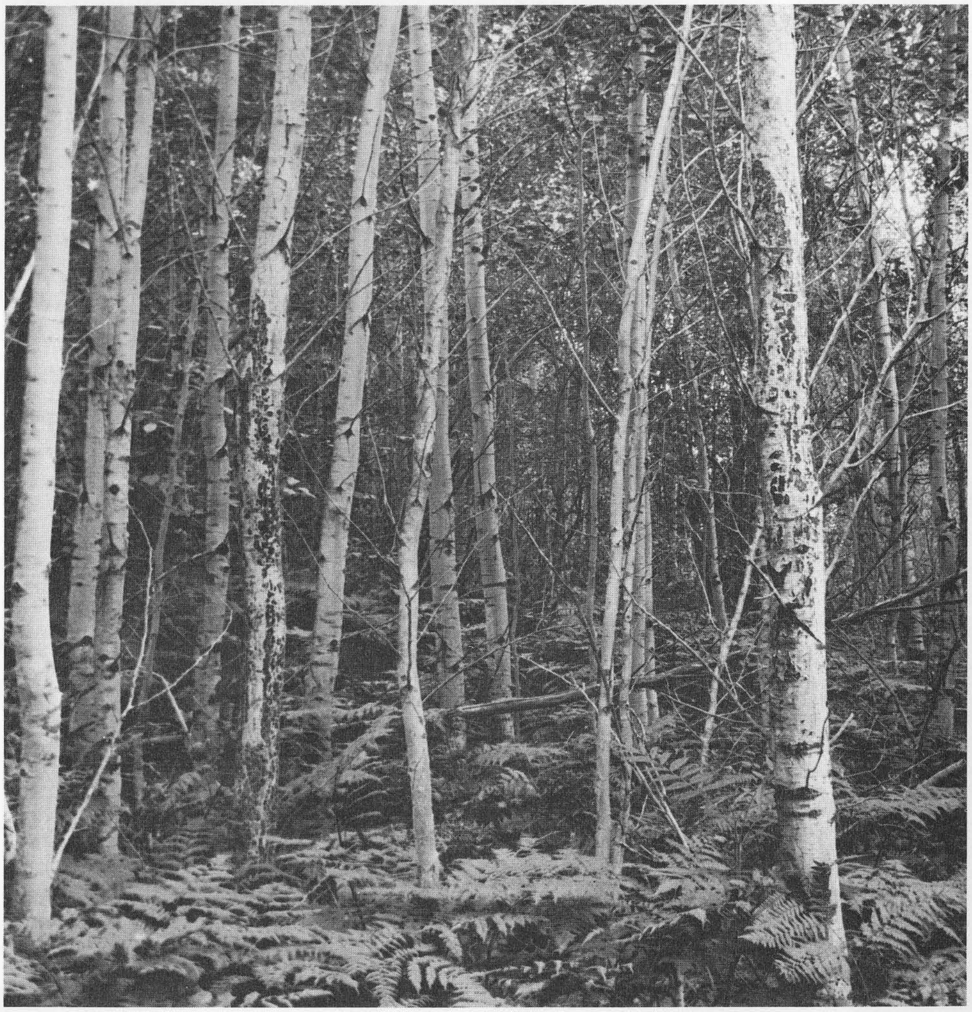


Figure 8. Hypoxylon canker in a stand of trembling aspen.

Poorly stocked stands are more susceptible to infection and serious damage than well-stocked stands.

The means by which the fungus infects aspen is not definitely known (Anderson 1956). Apparently germ tubes of airborne spores enter the tree through wounds in living bark. Insect wounds are reported to be commonly associated with infections. Failure to induce infection artificially by inoculating wounds with spores, however, suggests that factors other than the presence of a wound are important. Most cankers originate in the immediate vicinity of dead branch stubs or old scars, but there is no evidence that entrance was through the dead tissue in such areas. Recently, Hubbes (1966) concluded that *H. mammatum* is a sapwood pathogen and not a typical bark parasite as formerly believed. This conclusion was based on the following facts: (1) living aspen bark is highly toxic to *H. mammatum* and (2) it was demonstrated that the fungus grows in sapwood under sound bark. To successfully infect the tree, the fungus probably enters through a wound or dying bark tissue that has lost its toxicity through oxidation. This would explain why *H. mammatum* can attack aspen in spite of the natural protection provided by chemical inhibitors present in its bark.

No direct control measures are known (Anderson 1956). Poor sites and understocked stands are less able to absorb the impact of the disease and remain productive. It has been recommended, therefore, that poorer aspen sites be converted to other species and that in poplar regeneration, special efforts be made to obtain high initial stocking.

Septoria canker, *Septoria musiva* Pk.: This canker is widely distributed in Canada and is probably transcontinental. It has been recorded on most native poplars and a number of native and exotic hybrids (Bier 1939). The fungus causes a leaf spot of little importance on all poplars; native poplars within their natural range are not subject to cankering. However, certain native hybrids, particularly those with European black poplar, balsam poplar, and eastern cottonwood parentage (e.g. *P.* 'Northwest' and *P.* 'Saskatchewan'), and exotic hybrids, especially those known as "Russian" poplars, are highly susceptible. The incidence and severity of cankering increase greatly when these susceptible hosts are subjected to unfavorable environmental conditions.

In Alberta, Septoria canker was present in 13 shelterbelts examined in the parkland region in 1963[1] (Baranyay 1964). The percentage of infection ranged from 4 to 100. *P. petrowskyana* one of the "Russian" poplars, appeared to be more susceptible than *P.* 'Northwest' as 12 of the 13 infected shelterbelts consisted of the former. In 1962 a moderate occurrence of cankers was reported in Griffin poplar in one shelterbelt (Baranyay and Bourchier 1963). In Saskatchewan, severe to moderate cankering has been reported on Griffin poplar and *P.* 'Northwest' hybrids (Laut and Hildahl 1965).

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[1]Baranyay, J.A. 1964. Report on the condition of shelterbelts in Alberta, with special reference to diseases, insects, and cultural practices. Inform. Rep., Forest Entomol. Pathol. Lab., Dep. Forest., Calgary, Alta.

The fungus overwinters in dead leaves and cankers (Bier 1939; Waterman 1954). Primary infections in the spring originate from ascospores developed in the perithecia of the *Mycosphaerella* stage produced on overwintered leaves or cankers or from conidia produced in pycnidia on cankers.

Initial leaf infections appear 3 to 4 weeks after bud-break, and are mostly confined to leaves on the lower branches. Later infections are general throughout the trees. The fungus causes necrotic spots of various shapes and sizes which often coalesce to involve large areas of the leaf. Individual lesions are brown with yellowish to white centers, and pycnidia develop throughout the lesions on both leaf surfaces.

The canker stage originates in the bark of twigs of the current year, entering the host through mechanical wounds, lenticels, stipules, or leaf petioles. By early summer a very conspicuous symptom is the presence of one or more dead leaves on the leaders, at the ring scars, or on the axillary branches on 2-year-old stems. At the base of the dead leaves cankered bark, usually black, is evident; this frequently encloses yellowish to white areas in which the pycnidia may be found. The cankers may girdle and kill the leader and axillary branches during the first year and later spread from the axillary branches into the main stem. On entering the main stem the pathogen may produce a perennial canker resulting in considerable malformation. Isolations from the diseased bark at the margin of older cankers frequently produce cultures of *Cytospora chrysosperma* (Pers.) Fr., and it is possible that advanced cankers may result from a combined attack of *Septoria* and other fungi such as *Cytospora*.

Septoria canker is difficult to control after it becomes established in a planting. Therefore, measures that will prevent or impede the progress of infections should be adopted in new plantings.

Poplars should be planted under favorable conditions to ensure reasonable health and vigor so that they will not be susceptible to the canker stage of the disease. A number of promising species and clones are quite resistant to the disease (Chap. IV) and these should be favored in planting. New poplar clones should be tested to establish their susceptibility or resistance prior to general distribution.

Although resistant clones only are selected for planting, they should be established in randomized plots or mixed groups, particularly when grown under climatic or soil conditions unlike those in which their resistance was tested. This will minimize losses from infection due to changes in susceptibility that may occur under the new environment. Precautionary measures that will tend to prevent infections in a new planting include surface sterilizing of dormant cuttings with Semesan, spraying stool beds with a fungicide such as Bordeaux mixture to prevent leaf infection, and spacing trees to provide adequate aeration near the ground, thus preventing high humidity favorable for the infection of leaves and stems.

Dothichiza canker, *Dothichiza populea* Sacc. & Briard: Dothichiza canker is unimportant in natural stands of poplars in Canada, but important

Figure 9. Dieback of Lombardy poplar caused by Dothichiza canker.

in nurseries and plantations. In many parts of Europe, this disease is the worst enemy of poplar growing (Anon. 1958).

The causal fungus has been recorded in Nova Scotia, New Brunswick, Quebec and Ontario (Conners 1967). In Canada serious damage occurs primarily to introduced poplars, particularly Lombardy and Carolina, and hybrids with European black poplar ancestry.

In 1959 (Ouellette 1960) *Dothichiza* was associated with dieback symptoms on *P. deltoides* x *P. petrowskyana* hybrids in Quebec damaged by drought and grass competition. In 1962 (Dance and Lynn 1963) the fungus indirectly caused severe damage to most clones in a large plantation of young Italian hybrids. Cankers were apparently induced by severe pruning and the tops of infected trees were broken by winds.

On trees more than 15 years old, stem and branch cankers result in a typical dieback (Waterman 1957), reducing increment and wood quality. Under suitable conditions *D. populea* is an active parasite and may kill younger poplars.

Infection occurs through lenticels, buds, and bark cracks. Infected tissues are at first discolored and sunken. Later, a canker is formed that may girdle and kill the branch or the tree. When conditions favor the host, a cork barrier develops and the fungus becomes inactive. Under less favorable circumstances (low temperatures, drought, transplanting, etc.) resulting in reduced host vigor, the fungus may reach the cambium and the sapwood. Once behind the cork barrier, the pathogen resumes activity during unfavorable periods particularly during the dormant season, and the host has no further means of defence. Fruiting bodies (pycnidia) are produced on the affected parts from early spring to late fall and the fungus is spread mainly by conidia which are produced most abundantly during late spring. The occurrence of the perfect state, *Cryptodiaporthe populea* (Sacc.) Butin, was recently reported for the first time in Canada (Ouellette 1967).

No effective chemical control of the disease is known (Waterman 1957). However, damage can be reduced by careful handling of transplants during transportation, choice of suitable sites for plantations, use of the more resistant varieties, and general sanitation.

Cytospora canker, *Cytospora chrysosperma* (Pers.) Fr.: The fungus causing Cytospora canker occurs on most poplars in Canada. It usually attacks weakened trees and occasionally causes important damage. Trees growing outside their normal range and with consequent low vigor are particularly susceptible[1]. Studies show (Bloomberg 1962) that canker growth varies proportionally with temperature and inversely with shoot moisture content, relative humidity, and soil moisture content. In Alberta shelterbelts, drought, heavy competition from herbaceous vegetation, self competition caused by lack of thinning, and other non-infectious conditions are the predisposing factors. Sixty-four per cent of the shelterbelts surveyed were affected by *C. chrysosperma*, although 26% had only a trace of damage[1]. In 10% of the shelterbelts more than 25% of the crown was dead, usually the topmost branches. This damage greatly reduces the effectiveness of such shelterbelts as wind breaks. Most of the heavily damaged shelterbelts were in the dry prairie region. The warmer climate and low relative humidity and soil moisture in this region provide optimum conditions for *C. chrysosperma*. In the Parkland and Boreal regions, heavily damaged shelterbelts had been predisposed to *C. chrysosperma* by a combination of herbaceous vegetation, hail, frost, and mechanical damage.

Elimination or modification of predisposing factors, e.g., mechanical injury, livestock damage, herbaceous competition, and drought, are important in the control of Cytospora canker. Trees with *Cytospora* infections should be pruned, sometimes to ground level, to remove infected parts. Sprouts from the roots will replace the trees removed. The prunings should be burned to reduce spore sources.

Planting of less susceptible hybrids is the best preventative. Cram (1960) found that 3 of 17 poplar clones tested for survival over a 6-

year period demonstrated resistance to *Cytospora* and provided better survival and height growth than the widely propagated Northwest or "Russian" hybrids.

Galls

In an inoculation test with *D. tumefaciens*, *P.* 'Brooks', *P. cardeniensis*, *P.* 'Northwest', *P. petrowskyana* and *P. tristis* were susceptible, while Plains cottonwood, *P.* 'Vernirubens' and *P.* 'Volunteer' appeared to be resistant (Zalasky and Fenn 1965).

The fungus penetrates the intact cuticle and epidermis and stimulates hypertrophy of the xylem, phloem, and cambium (Zalasky 1964b). Crowns and boles of infected trees may be affected by numerous galls on twigs and smaller branches, and by galls, wart-like swellings and rough bark on larger limbs and boles. Tree thus affected become weakened and subject to infection by canker fungi. Infection at the base of buds may result in dwarfing and brooming or eventual death of the twig. Trees of all ages may be affected. The fungus may persist in the bark for many years (Zalasky 1965).

Poplar bud-gall mite, *Aceria parapopuli* (Keifer): The poplar bud-gall mite is found from Vancouver Island to northern Manitoba. It attacks many poplars including the native trembling aspen, the cottonwoods, and many of the hybrid poplars[2]. In recent years it has caused serious damage to hybrid poplar shelterbelts in southern Alberta.

The mite feeds on the tissue of the galls on the exterior surface and in pockets within the galls. Many insects and other species of mites are found on or in the galls.

Because the mite lives within the gall, control by ordinary chemical sprays is not effective. Several years of mite attack and population build-up are necessary before serious damage occurs to trees. The spread of this mite from tree to tree and from shelterbelt to shelterbelt is slow, so the removal of the galls provides an effective control measure. On small trees the galls should be removed individually during the dormant period. As migration to the new gall sites takes place about the first of June in southern Alberta all pruning must be complete by that date. On larger trees the removal of individual galls is impractical and pruning of infected branches is recommended. This pruning should take place during the winter or early spring to minimize shock to the trees. It is important to prune all infested trees in a shelterbelt the same winter to prevent spread of the mite to newly pruned trees.

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[2] Brown, C.E. Habits and control of the poplar bud-gall mite. Inform. Rep., Forest Entomol. Pathol. Lab., Dep. Forest., Calgary, Alta.

Some hybrid poplars are almost completely immune to attack from this mite; others show varying degrees of susceptibility. *P.* 'Northwest', for example, appears to be more susceptible to poplar bud-gall mites than the Griffin poplar. Further investigations may show that certain more resistant hybrid poplars can be recommended for planting in areas where this mite is abundant.

Foliage Diseases

Many fungi attack the leaves of poplar and may have local significance. These fungi kill small to large areas of leaf tissue but are of consequence mainly when defoliation is moderate to severe. Small trees suffer the most damage and these may be killed. Generally, however, damage from foliage diseases, like that of defoliating insects, is confined to reduced growth of severely affected trees. In forest stands the amount of damage caused does not warrant control. For more valuable trees in towns, cities, nurseries, and plantations, these diseases can be kept under control by destroying diseased material and by several applications of a suitable protectant fungicide.

Ink spot, *Ciborinia whetzelii* (Seaver) Seaver: This disease occurs from Newfoundland to British Columbia (Conners 1967). Trembling aspen is the major host (Baranyay and Hiratsuka 1967) but the disease has also been recorded by the Canadian Forest Insect and Disease Survey on balsam poplar, eastern cottonwood, largetooth aspen, Lombardy poplar, and various poplar hybrids (unpublished data). It periodically causes considerable early defoliation of trembling aspen (Baranyay and Hiratsuka 1967) occasionally over extensive areas (Baranyay 1965). Young trees may be killed (Pomerleau 1940; Reid and Griffin 1960).

Infection takes place in the spring from ascospores produced in apothecia developed on overwintering sclerotia. The only symptom of the disease is a brown discoloration of the leaf at the site of infection, which becomes surrounded by concentric light zones. These early symptoms are most evident on the upper surface of the leaf. The leaves later die and sclerotia appear. Sclerotia drop from the leaves in August (Baranyay and Hiratsuka 1967).

Leaf and twig blights, *Venturia* spp.: Leaf and twig blight caused by *Venturia tremulae* Aderh., imperfect state *Pollaccia radiosa* (Lib.) Bald. & Cif. (Dance 1959), is perennially present on trembling aspen, largetooth aspen, and on various introduced species and varieties of the section Leuce (Dance 1961a) from Newfoundland to British Columbia (Conners 1967). The pathogenic capability of the causal fungus varies with different hosts, and within one species or clone according to the age of individual specimens; larger trees may be relatively unaffected, while seedlings and suckers generally are severely attacked. This results in the loss of established regeneration, in the deformation of saplings, and in a delay of one or more years in establishing new stands. The disease constitutes a problem for tree breeders seeking to create new hybrids which are easily propagated,

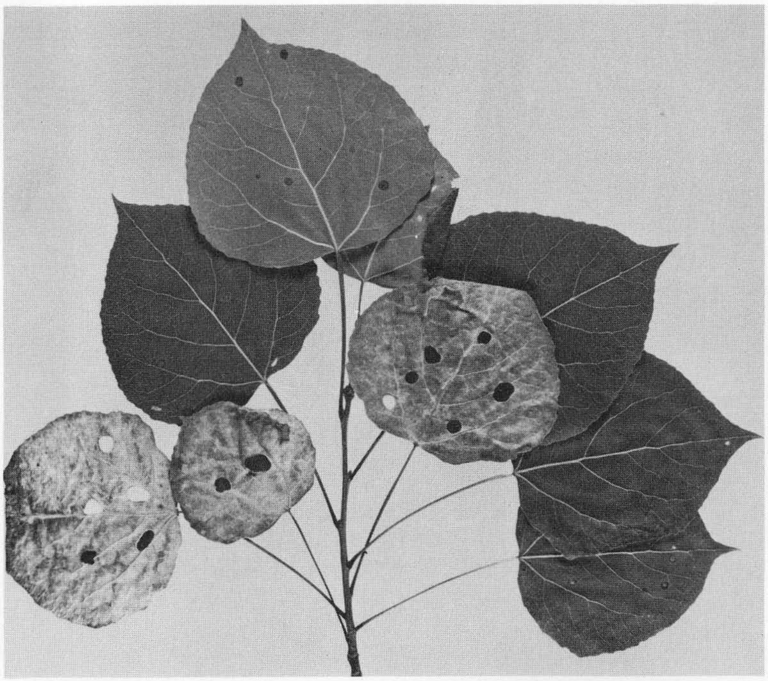

Figure 10. Ink spot of trembling aspen caused by Ciborinia whitzelii.

Figure 11. Leaf and twig blight of balsam poplar caused by Venturia populina.

fast-growing, disease-resistant, and superior to existing species and varieties in silvicultural characteristics (Dance 1961a).

Venturia populina (Vuill) Fabric., imperfect state *Pollaccia elegans* Serv., causes a leaf and twig blight of balsam poplar (Dance 1961b) and black cottonwood (Conners 1967). The fungus may be confined to poplars of the section Tacamahaca, although experimental evidence suggests that poplars of the section Aigeiros also may be susceptible: they are in Europe (Dance 1961b). The most serious danger from *V. populina* lies in the threat it poses to hybrid poplars whose parentage includes susceptible exotic species or varieties. Tree breeders should consider this hazard in selecting material for their crosses.

The blight caused by *V. populina* is recognizable at any time of year. When in the leafless condition, the crowns of affected trees appear closed, stunted, and decadent. In newly infected saplings, the principal disease symptom is the large number of blighted, reflexed shoots or "Shepherd's crooks". Since infections of *V. populina* seem to persist for only a single season, perennial reinfection must occur to ensure perpetuation of the fungus.

Primary infections are initiated by ascospores ejected from perithecia which develop on overwintered, blighted balsam poplar shoots. These infections usually appear in May on whorls of leaves that have emerged from winter buds subjacent to the dead, perithecia-bearing part of the diseased terminal shoots. The tip of each leaf in each whorl is curled, black, brittle, and truncated, whereas healthy leaves have acute or short-acuminate tips. Secondary infections first appear early in June on the leaves and towards the tips of most new shoots arising from, or below, whorls of leaves with primary infections. They are started by conidia from primary infections. The diseased tissues turn black and brittle while the shoots reflex to form characteristic crooks. Shoots and leaves produced subsequently also may be subject to conidial inoculation and infection; if so, the resulting symptoms are indistinguishable from those that appear earlier. While secondary infections may develop on apparently mature leaves of water sprouts and suckers, none will be found on the blades of mature leaves that bear primary infections at their tips. Should this pathogen become locally destructive, as a result of a favorable combination of environmental factors, it probably could be controlled by eliminating the source of primary inoculum through pruning of blighted shoots.

Leaf rusts, *Melampsora* spp.: Leaf rusts caused by *Melampsora* spp. occur sporadically on poplars throughout Canada and heavy infections may develop occasionally, particularly in western Canada (Molnar 1961; Molnar, Harris and Ross 1966). The primary effect of Melampsora rust is premature leaf drop and accompanying loss of vigor (Jokela 1966). Young, susceptible trees may be severely damaged.

A considerable number of species of Melampsora have been recognized (Jokela 1966). All are heteroecious and generally have a conifer as the alternate host. In Canada, valid records have been obtained on four species on poplar, namely *M. abietis-canadensis* Ludwig ex Arth. *M. albertensis* Arth., *M. medusae* Thuem., and *M. occidentalis* Jacks. (Conners 1967). These rusts alternate between poplar and species of fir, larch, spruce, pine, Douglas-fir, or hemlock (Ziller 1965).

In the spring, basidiospores from overwintered telia on poplar leaves infect the needles of nearby susceptible conifers. Pycnia and aecia are produced on these and the aeciospores infect susceptible species of poplar during the summer. They cannot reinfect the coniferous host. Yellowish leaf spots bearing uredia appear as the first symptoms of poplar infection 2 or 3 weeks later. Reinfections of poplar by uredospores and the formation of telia begin in the summer and continue until fall.

To avoid damage to plantings of susceptible poplars, coniferous hosts of the rusts should be removed from the vicinity of plantations or plantations should be established in areas where the coniferous hosts are absent. Since there are many inherently resistant clones of poplar (Schreiner 1959), these should be given consideration when poplars are to be planted.

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CHAPTER VIII

DECAY AS A LIMITING FACTOR ON POPLAR UTILIZATION[1]

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A discussion on the effects that wood decay might have on poplar utilization should be prefaced by a few basic facts concerning decay, otherwise there could be a tendency to overestimate the impact of decay on poplar. We need to keep in mind that wood decay is a completely natural phenomenon that is common to all species of trees, not poplar alone, nor poplar in particular. Decay is potentially, but not always an important factor to the utilization of all species of trees - poplar included, but not poplar exclusively.

Decay is mainly important only when relatively large volumes of wood are destroyed, because it represents a direct loss of timber yield. It costs just as much to grow a defective tree, and to protect it from fire, as it does a healthy tree, and it costs just as much to fell, buck, skid, transport and remanufacture defective wood as it does sound wood.

Under particular sets of circumstances, but not all circumstances, decay losses in any species of tree vary from insignificant to serious, even to the extent of limiting the possibilities for utilization and, in extreme situations, to prohibiting economic utilization. I believe it will be useful to keep these points in mind through our discussions, and also to acknowledge that the long-term solution to the utilization problems caused by excessive decay lies in timber management practices. The cure for decay (like fire) is prevention, and decay prevention is a by-product of timber management.

To return to our topic, which is to consider decay as it affects poplar utilization in Alberta, I believe it would be a serious error from the timber management point of view to ever accept wood decay as a prohibitive factor to poplar utilization. However, let us be frank to admit

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[1]This paper was prepared for the Industrial Wood Products Seminar, November 8-9, 1966, Edmonton, Alberta. It is included here as the problems discussed with reference to Alberta are similar to those faced by poplar users throughout Canada.

that under current conditions in Alberta, decay has become a limiting factor to poplar utilization. Corrective measures are needed to meet this situation, the problem is what measures are needed and how to apply them. As a starting point let us take time to identify and examine briefly the principal factors that have given rise to this situation. Perhaps this will give the leads we need to make some progress with the problem of excessive decay in poplar. I think we need to look first at the poplar timber resource, and next at the poplar-based industry to see if somehow these two factors might be contributing in major ways to the problem of utilizing defective poplar.

We have in Alberta a very large and heretofore unmanaged inventory of naturally grown poplar. The annual gross yield of new wood from this inventory exceeds by many times the annual cut of poplar, with the result that each year we fall further behind in the utilization of poplar growth. Year by year, because of far too small a cut, the overall condition of the poplar inventory becomes increasingly decadent for the very basic reason that poplar matures relatively early (about 70 years for trembling aspen and about 110 years for balsam poplar). At these ages, on our most productive poplar sites, trembling aspen is about 25% decayed and balsam poplar about 12% decayed.

Let us switch momentarily to look at the poplar-based industry. In relation to the size of our poplar inventory, we have in Alberta a very small, although efficient, poplar-based industry that up to now has depended very heavily upon large-dimension logs. The industry is far too small, in terms of its annual wood requirement, to utilize more than a token proportion of the annual growth of poplar. I think it is fair to say that the industry up to now has lacked diversity in terms of the variety of products it produces. Rather, it has based its operations on the increasingly difficult to get large sound log.

On the one hand we have a steadily depreciating poplar inventory, and on the other we have a highly selective poplar industry. If both situations persist indefinitely, we can only steadily progress towards a poplar resource so depreciated in quality as to defy utilization by today's standards. This is a most discouraging prospect, but nonetheless a very real one. There is no satisfactory alternative but to find a solution to this dilemma. Meanwhile, it is quite true, decay is a limiting factor to poplar utilization under present-day conditions in Alberta. It is limiting because of the increasingly decadent condition of the poplar resource, and it is limiting because of the smallness of our non-diversified poplar-based industry.

In a little more detail, what is the condition of the poplar inventory right now? Some facts are available from a survey of cull concluded about 6 years ago through the joint efforts of the Alberta Forest Service and the federal Department of Forestry, in which some 800 trembling aspen and 600 balsam poplars were cut and examined within the broad triangle Grande Prairie-Whitecourt-Swan River. Three clearly distinguishable site conditions allowed for a separation of the total sample into contrasting units. For lack of better terminology, we can refer to these in terms of soil moisture conditions as dry sites or pure trembling aspen sites, moist sites or mixed trembling aspen and balsam poplar sites, and wet sites or pure balsam poplar sites.

The standards of measurements used were: stump height = 1 foot log length = 8 feet 8 inches, minimum diameter inside bark at small end = 3.5 inches when referring to cubic measure; and 6 inches for foot board measure (fbm), 1-inch trim allowance added to rot diameters when using fbm, logs 67% defective culled when using fbm.

Employing these standards, the survey showed that the time required to grow a tree that will yield at least one log measuring 10 inches inside bark at the small end is as follows: dry site aspen = 100 years, moist site aspen = 80 years, moist site balsam poplar = 70 years, wet site balsam poplar = 60 years. The survey also showed that: 100-year old trembling aspen is likely to be 35% decayed (cubic foot basis) or 80% decayed (fbm basis); 80-year old trembling aspen would be 28% decayed (cubic foot basis) or 73% decayed (fbm basis); 70-year old balsam poplar would be 7% decayed (cubic foot basis) or 14% decayed (fbm basis); and 60-year old balsam poplar would be 4% decayed (cubic foot basis) or 8% decayed (fbm basis).

The possibilities for growing trembling aspen to supply an industry requiring 10-inch minimum-sized logs are clearly not good, even when decay is the only limiting factor to utilization. If additional limiting factors are introduced into utilization standards (e.g., prohibition of surface knots, shake, heartwood stain, etc.), the possibilities of producing acceptable 10-inch trembling aspen logs are even more remote. At best, I would think that subsidiary markets for the major amounts of small dimension and otherwise rejected material would be almost necessary to make the large-log trembling aspen industry an economic enterprise. Failing this, such an industry would have to resort to a high-grading system of utilization. On the other hand, the possibilities for growing balsam poplar to supply a large-log industry are much better than for trembling aspen.

If the standards of utilization were lowered to admit a log of minimum top diameter of 3.5 inches, the survey showed that the time required to grow a tree that will yield at least one such log of trembling aspen is 20 years in both moist and dry sites. At this age dry-site trembling aspen is likely to be 5% decayed and moist-site aspen to be 4% decayed. In fact, it is likely that we could stay below the 10% cull level, including heartwood stains, by growing trembling aspen to 40 years, and to 50 years if we can accept 15% cull. Forty-year old trembling aspen has an approximate average diameter at breast height of 5.5 inches in dry sites and 6.3 inches in moist sites. Fifty-year old trees are 6.5 inches in dry sites and 7.5 inches in moist sites. While trees of such dimensions do not satisfy the large-log industry, they do produce substantial amounts of fiber at these ages. The minimum yield of fiber from dry site trembling aspen is in the nature of 1500 ft^3/acre at 50 years.

It appears to me that a major shift of emphasis is needed in the kind of poplar utilization we practice in Alberta, if we are to overcome the limiting factor of decay. The shift will likely have to be in terms of a greatly increased use of small-dimension logs such as can be produced from trees 50 years old and younger. Concurrently, a major expansion of the poplar industry is obviously needed, to bring utilization more into line with the size and growth capacity of the poplar inventory.

It appears to me also, that some attention should be given to improving the quality of poplar through stand improvement practices. By way of illustrating how cultural practices might improve the quality of poplar, I want to refer to some research results that have followed the cull survey mentioned earlier. Briefly, it has been found that possibilities exist for preventing about 40% of the decay normally found in older aspen trees. This has come to light by learning that some of the major fungi that cause heartwood decay in aspen enter trees via branchwood infections, and that branchwood infections are about twice as frequent in moist sites as in dry sites. It is known now that about 8 years are required for branchwood infections to become established, i.e., infections do not occur much if any earlier than 8 years following the death of branches. This could mean that branch pruning by artificial means of selected trees at an early age, say 10-15 years, would substantially reduce the amount of decay that would otherwise be expected in trees at the time of cutting. An experimental pruning of this nature was made 2 years ago in Manitoba, and I am hopeful that it will yield good results. Cultural practices of this kind might yield long-term benefits to poplar utilization, and therefore they should be considered.

CHAPTER IX

ANATOMY AND FUNDAMENTAL WOOD PROPERTIES OF POPLAR

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INTRODUCTION

This paper is a review of the literature concerning the anatomy and wood properties of the genus *Populus*, with special attention given to the five North American species of commercial significance. These five species are spread throughout three sections of the genus: Leuce - trembling aspen, largetooth aspen; Tacamahaca - balsam poplar, black cottonwood; Aegeiros - eastern cottonwood.

Much of the total experience with poplar derives from continental Europe, where not only rapid growth rates can be achieved, but the light weight, toughness, abrasion resistance and lack of extractives makes poplar more attractive than low-density, imported tropical timbers in European markets (Mayer-Wegelin 1958). As a consequence, European as well as North American literature is reviewed, since the different species of poplar display similar behavior and characteristics.

ANATOMY

General

Poplars in general are low-density, diffuse-porous hardwoods. There is some tendency for fast-grown cottonwoods to exhibit a semi-ring porous structure. Species of poplar cannot be separated with accuracy, although the aspens have a somewhat finer texture. In aspens, the largest vessels have a maximum tangential diameter of 50 - 100 μ, while in the cottonwoods and balsam poplar the corresponding range is 75 - 150 μ (Panshin, de Zeeuw and Brown 1964). Meyer-Uhlenried (1958) has carried this concept further in order to separate the five sections of the genus on the basis of the tangential diameter of the first-formed earlywood vessels.

Vessels occupy approximately 20 to 33% of the cross section and fibers 56 to 79% (Anon. 1958; Mayer-Wegelin 1953). The average ray parenchyma volume for three North American species is 11.4% (Panshin, de Zeeuw and Brown 1964). The rays are uniseriate, although Gabriel (1956) has found certain clones of eastern and black cottonwood with multiseriate rays. Vertical parenchyma is rarely present as more than an interrupted zone of boundary tissue at the end of a growth ring. The low parenchyma count promotes felting of pulp made from poplar, and results in a paper of high tear strength (Mayer-Wegelin 1953).

The heartwood is generally cream-colored in the aspens, and shades of gray or brown in the other species. Sachsse (1965) found colored heartwood formation beginning 3 years behind the cambium in poplar hybrids, where its formation was encouraged by green pruning which decreased the vitality of living parenchyma cells.

Fiber length

Variation in fiber length has been studied intensively, since it is directly related to pulp strength, particularly tear and burst (Buijtenen, Einspahr and Peckham 1962; Einspahr, Buijtenen and Peckham 1963). The most elemental form of length variation occurs within a single growth increment, where latewood fibers are 10-20% longer than those of earlywood (Johnson 1942; Liese and Ammer 1958). Superimposed upon this pattern is the much more significant variation due to number of rings from pith. This pattern is demonstrated graphically in Fig. 1, which was constructed from data of Kennedy (1957) for black cottonwood. Fiber length is seen to increase rapidly with increasing age from the pith, but no pattern with height is evident. The values compare fairly closely with those of Liese and Ammer (1958) who noted an increase in fiber length from 0.71 mm to 1.13 mm in the first 10 rings, after which length remained essentially constant, and with those of Boyce and Kaeiser (1961) who found an increase from 0.70 mm in the 5th ring from pith to 1.38 mm in the 40th ring.

The influence of rate of growth on fiber length is also shown in Fig. 1. Analysis of variance indicated that fast rate of growth was significantly related to longer fibers. Similar results have been noted in 1- and 2-year-old cuttings, seedlings and sprouts of various poplar species (Kennedy 1957; Kennedy and Smith 1959; Cech, Kennedy and Smith 1960; Schulz 1962). Boyce and Kaeiser (1961) also concluded that rate of growth, as well as age, influenced fiber length of eastern cottonwood. Differences in tree diamater for rings of the same age accounted for about 3% of the variation in fiber length. Their results showed that the 10th ring from pith at breast height could be expected to have a fiber length of 1.01 mm in a tree 6-inches in diameter, and 1.07 in a tree 12-inches in diameter. Johnson (1942) also concluded that fast rate of growth was correlated with long fibers among poplar hybrids, but his failure to eliminate the confounding influence of age from pith invalidates his conclusion. On the other hand, Brown and Valentine (1963) found no influence of growth rate in controlling fiber length of trembling aspen.

A moderate to strong genetic influence on fiber length has been observed. Estimates of genetic variance range from a conservative 0.30 in

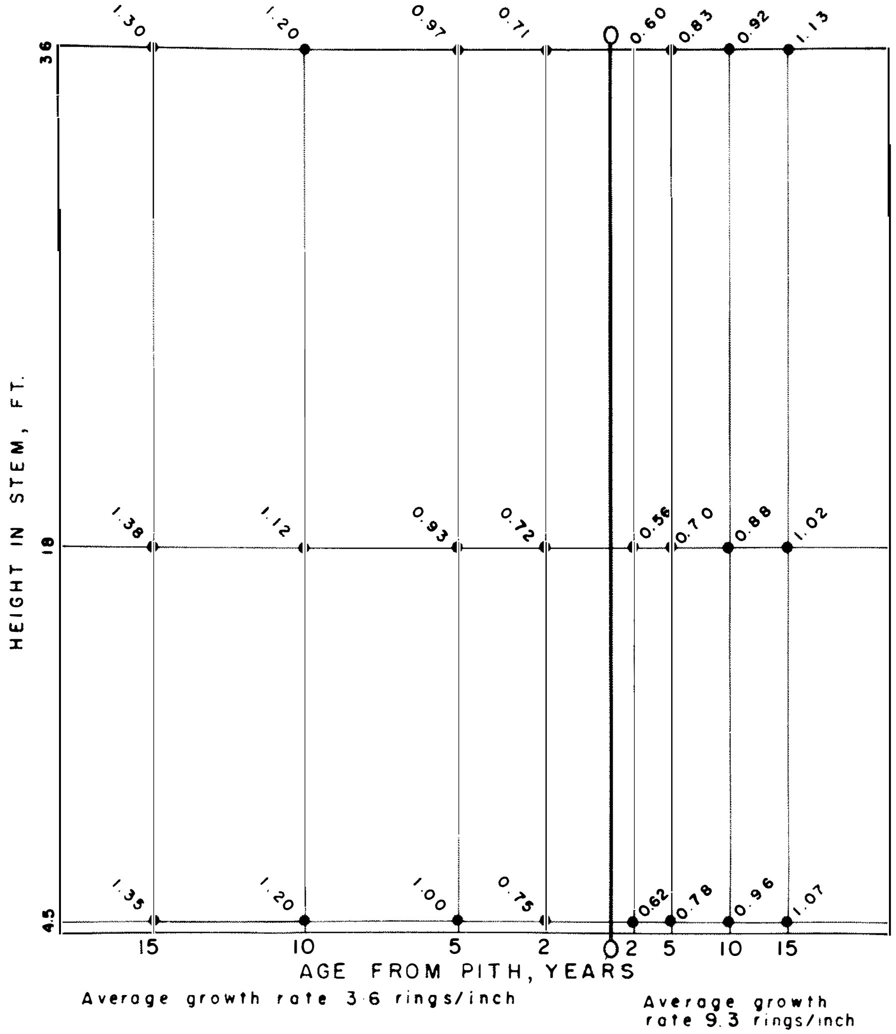

Figure 1. Fiber length variation (mm) for the first 15 years from pith in four fast- and four slow-grown trees of black cottonwood. Each value represents the mean of 40 fibers from four trees.

eastern cottonwood (Boyce and Kaeiser 1961) to a gross heritability of 0.86 in triploid trembling aspen (Einspahr, Buijtenen and Peckham 1963). Buijtenen, Joranson and Einspahr (1958) found that five triploid aspens had an average fiber length 26% greater than five similarly growing, normal diploids. Differences in fiber length among clones of the same species have been regularly noted (Gabriel 1956; Brown and Valentine 1963). Schulz (1962) found as much as a 40% difference between clones with similar growth rates when grown under the same environmental conditions.

Reaction wood

Tension wood, the reaction xylem of hardwoods, is found extensively in poplar. Its presence is associated with leaning stems, particularly if the angle of lean is greater than 4 degrees (Kaeiser and Pillow 1955). Contrary to general belief, there is ample evidence that tension wood in poplar is not necessarily associated with stem eccentricity (Wahlgren 1957; FAO 1958; Griffioen 1958; Lassen 1959). The gelatinous fibers which characterize tension wood are usually concentrated on the upper side of leaning stems, particularly at lower levels in the bole, but they may be arbitrarily scattered throughout the cross section, especially at greater heights.

Tension wood may be formed in poplars and other hardwoods in reaction to low levels of auxins and presence of growth inhibitors. There is some evidence that the more frequent occurrence of tension wood on the upper sides of leaning stems may be due to movement of auxin to the under side. Necesany (1958) was able to prevent the formation of tension wood on bent seedlings of *P. monilifera* by application of indole acetic acid (IAA) to the upper surface of the stem. Application of IAA to the upper surface of branches of European white poplar also succeeded in preventing tension wood formation. Furthermore, application of an anti-auxin to erect stems of red maple, and white elm caused tension wood to form near the site of application (Cronshaw and Morey 1965; Kennedy and Farrar 1965).

Tension wood may be reduced to a minimum by eliminating leaning stems from forest stands, or by genetic selection, since stem straightness appears to be an inherited trait in poplar (Boyce and Kaeiser 1964), and certain clones may be predisposed to formation of tension wood (Anon. 1958). Pruned poplar hybrids formed significantly more tension wood than unpruned controls (Sachsse 1965). Approximately three times as much tension wood was noted in three of the five hybrids pruned. Since living branches as well as dead ones were removed, the increased tension wood may have resulted from a decrease in auxin availability at the cambium.

Severe tension wood is characterized by a high proportion of gelatinous fibers and reduced vessel volume (Fig. 2). Sachsse (1964) investigated the ultra-structure of the gelatinous fibers in *P.* 'Regenerata', and found normal S_1 and S_2 layers in the secondary wall, and a thickened, gelatinous S_3 layer with a honeycombed, faintly lamellar structure. The lumen side of the S_3 layer was bordered by a very thin, electron-dense, terminal lamella. Kaeiser (1956) found that the length of gelatinous fibers was unrelated to lean of the stem.

Because of the common occurrence of tension wood in poplar, its special influence is discussed in the survey of physical properties which follows.

SPECIFIC GRAVITY

Variation between species

The average specific gravities for the five important North American poplars are summarized in Table 1. Black cottonwood appears to

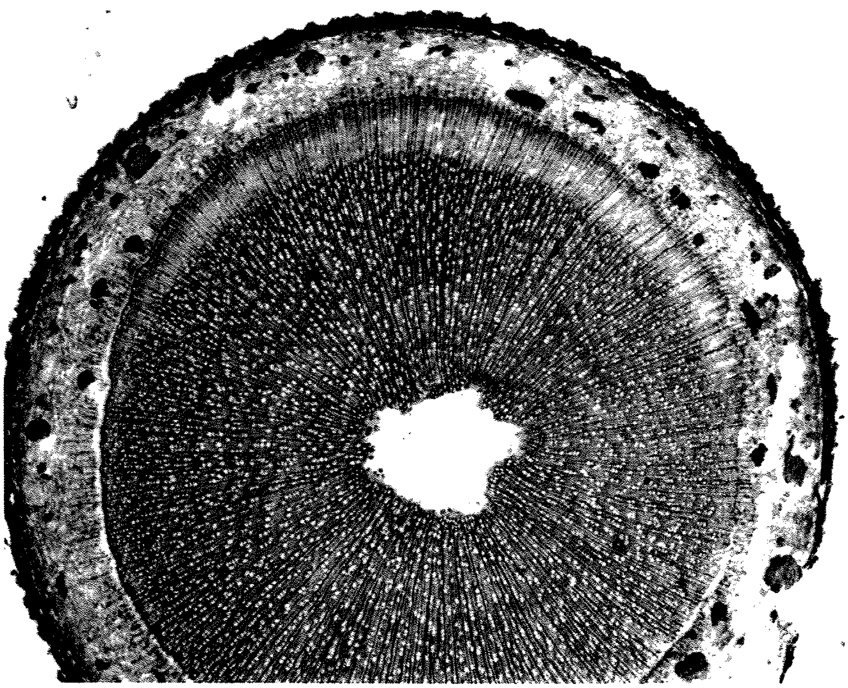

Figure 2. Arc of tension wood produced on the upper side of a trembling aspen seedling tilted 70 degrees from the vertical for a 14-day period. The arc is typified by masses of gelatinous fibers and reduced vessel volume.

be considerably less dense than eastern cottonwood or the aspens. The relative lack of data for balsam poplar and the discrepancy between the two values reported allow no conclusion to be drawn for this species.

Variation within species

The wide variation noted in Table 1 suggests that specific gravity is subject to environmental and/or genetic control. One of the most critical wood quality considerations in management of fast-growing poplar stands and plantations is the effect of rapid growth on density, upon which production of solid wood substance depends. For example, Paul (1956) has shown that with a specific gravity of 0.40, one cord of poplar will yield 1 ton of dry wood, whereas 1.33 cords are necessary to produce the equivalent weight of dry wood at a specific gravity of 0.30.

The influence of growth rate on specific gravity in poplars is controversial. Paul (1956, 1963) has summarized data from 360 specimens of poplar species and hybrids. He found a negative linear relationship between growth rate and specific gravity such that specific gravity decreased from 0.37 with a growth rate of 0.05 inch per year to 0.30 with annual growth rate of 0.95 inch. Age showed no relationship to specific gravity. The relationship between clonal source, growth rate and specific gravity

TABLE 1. AVERAGE SPECIFIC GRAVITY FOR NORTH AMERICAN POPLARS

Species	Specific gravity (green volume)	Variation	Source
Trembling aspen	0.374	±.024[1]	Kennedy (1965)
	0.35	---	Markwardt and Wilson (1935)
	0.375	0.325-0.421[2]	Wilde and Paul (1959)
	0.389	0.310-0.470[2]	Buijtenen, Einspahr and Joranson (1959)
Largetooth aspen	0.390	±.037[1]	Kennedy (1965)
	0.35	---	Markwardt and Wilson (1935)
Balsam poplar	0.372	±0.032[1]	Kennedy (1965)
	0.30	---	Markwardt and Wilson (1935)
Eastern cottonwood	0.352	±0.038[1]	Kennedy (1965)
	0.37	---	Markwardt and Wilson (1935)
	0.366	±.036[1] 0.287-0.518[2]	Walters and Bruckmann (1965)
	0.380	0.320-.461[2]	Farmer and Wilcox (1966)
Black cottonwood	0.295	±.027[1]	Kennedy (1965)
	0.32	---	Markwardt and Wilson (1935)
	0.31	.28-.40[2]	U.S. Dep. Agr., For. Serv. (1965)

[1]Standard deviation.

[2]Range.

as determined by Cech, Kennedy and Smith (1960) on 1-year old black cottonwood is shown in Fig. 3. The pronounced influence of growth rate is evident as well as a clonal effect. It is not known, however, whether this density-growth rate relationship would continue to be evident with increasing age.

Mayer-Wegelin (1953), speaking of poplar in general, stated that there was an inverse relationship between growth rate and density. Mayer-Wegelin later (1958) summarized some European and North American literature which indicated a general value of 0.33 for poplar of 10 mm annual growth rate, increasing to 0.37 for annual increments of only 3 mm. Jayme and Harders-Steinhauser (1954), Griffioen (1958), Kennedy and Smith (1959) and Sacre (1963) all conclude that more rapid growth rate is correlated with lower density. Sacre (1963) found a density differential of about 0.03 for ring widths between 5 and 13 mm in hybrid poplars. Hardness, compression and bending strengths also decreased with wider ring widths in this latter study.

On the other hand, Johnson (1942), Anon. (1958), Boyce and Kaeiser (1964), Walters and Bruckmann (1965) and Farmer and Wilcox (1966) could find no relationship between growth rate and density. However, the latter two studies dealt with a narrow range of rapid growth rates, in which number of rings per inch varied from 4.0 to 8.8 and 1.0 to 2.5, respectively. The effect of growth rate on specific gravity is not readily apparent unless a wide range of ring widths are available for study.

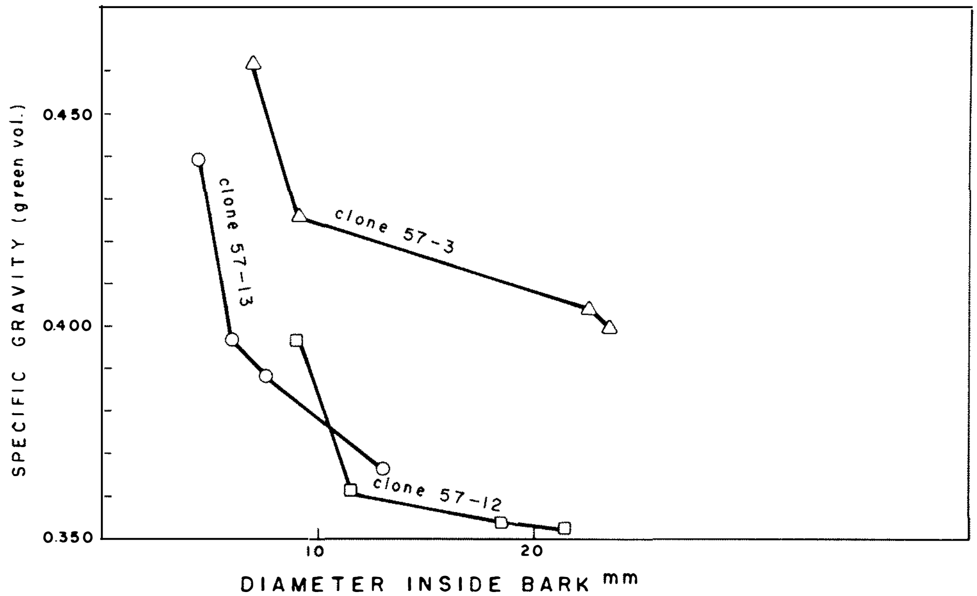

Figure 3. Specific gravity variation due to clonal source and rate of growth in 1-year old black cottonwood.

Brown and Valentine (1963) have reported both positive and negative correlations with growth rate in trembling aspen clones. It is perhaps significant that, with the exception of this investigation, significant relationships between growth rate and specific gravity have been negative. The weight of evidence thus suggests faster growth rates may lead to lower specific gravities, but this trend may not be strong, nor may the losses in density be of great practical importance except when comparing extreme rates of growth.

Conflicting results of growth rate-density studies may also be due to confounding with a genetic influence. Fig. 3 shows the strong independent influence of clone on specific gravity of 1-year-old black cottonwood. Clones 57-12 and 57-3 had similar average growth rates (15.1 and 15.5 mm), yet significantly different average specific gravities of 0.366 and 0.423, respectively. Growth rate alone may therefore not be reliable in predicting specific gravity of genetically variable material.

The specific gravity of trembling aspen was studied by Valentine (1962) and Brown and Valentine (1963). Specific gravity varied significantly among 23 areas sampled within the Adirondack mountains. Although the area means ranged from 0.343 to 0.432, a low intra-class correlation coefficient of 0.17 indicated a wide variation among individual trees within a given area. An intensive investigation of four clones showed a significant variation within trees in three of the clones. Such differences within clones point to a strong environmental effect on specific gravity. Buijtenen, Einspahr and Joranson (1959) reached a similar conclusion in an independent study of trembling aspen clones. The wide range of specific gravity within clones, coupled with small clonal differences, led to a gross heritability estimate of only 0.17. A further study (Buijtenen, Einspahr and Peckham 1962) produced estimates ranging from 0.17 to 0.43, while Einspahr, Buijtenen and Peckham (1963) found a value to 0.38.

In summary, although some studies show only low to moderate genetic influence on specific gravity, the possible deleterious influence of fast growth on density probably can be overcome by selection. Pechmann (1958) has cited two poplar clones growing in the Po valley under optimal conditions for 10 year rotations, where the mean specific gravity of one clone is 0.32, while that of the other is 0.40.

The anatomical element most closely associated with density variation in poplar is the fiber (Scaramuzzi and Ferrari 1964). The ratio of fiber wall thickness to fiber radius accounted for 86% of the total variation in 25 poplars whose specific gravities ranged from 0.264 to 0.509. It can be assumed that proportion of vessels is not an important variable, since the simple percentage of fibers was likewise not closely related to specific gravity.

Effect of reaction wood

It is to be anticipated that the thick gelatinous layer present in tension wood fibers should cause an increase in specific gravity. An increase in specific gravity from 0.02 to 0.06 units has been reported in the literature (Lassen 1959; Sacre and Evrard 1963; Perem 1964). Boyce and Kaeiser (1964) found an average specific gravity of 0.360 in 170 cores from straight and crooked logs of eastern cottonwood. The cores with specific gravity greater than 0.410 generally came from the upper side of crooked stems, where tension wood reaches its best development. Among three trees investigated intensively, the proportion of gelatinous fibers and the wall thickness of non-gelatinous fibers increased with higher specific gravity. Regardless of the increased specific gravity obtainable from tension wood, reaction tissue is undesirable because of its limiting physical properties described in the sections: Mechanical Properties, Machining and Processing, Moisture Relations and Shrinkage.

CHEMICAL CONTENT

The carbohydrate content of poplars is remarkably high, and the lignin content correspondingly low. Trembling aspen has the highest chlorite holocellulose (80.3%) and the next-to-lowest lignin content (18.1%) of 8 hardwoods and 8 softwoods commercially important in Canada (Clermont and Schwartz 1951, 1952). Browning (1963) also indicates this species as having the highest glucan (57.3%) and the lowest lignin (16.3%) content of 9 hardwoods and 10 softwoods listed. The lignin content is appreciably lower than the average (22.5%) for the remaining 8 hardwoods. Worster and Sugiyama (1962) have found a low lignin content in both trembling aspen (18.5%) and black cottonwood (19.0%).

Relatively few studies have been carried out on the influence of growth and heredity on chemical content. Wilde and Paul (1959) found no significant difference in chemical composition of trembling aspen grown on a variety of soil types. Cech, Kennedy and Smith (1960) found no influence of rate of growth or clonal source on holo- or alphacellulose content in 1 year old cuttings or seedlings of black cottonwood. Higher cellulose contents in suckers were attributed to tension wood associated with their leaning habit.

The higher cellulose content of tension wood is not necessarily advantageous, because lower hemicellulose content may result in weaker pulp. Clermont and Bender (1958) pulped trembling aspen tension wood and found that more beating time was required to get the same freeness as normal wood, and slightly lower breaking length and folding endurance was realized, although bursting strength was the same as normal wood, and tear strength higher. The tension wood contained 5.3% more alphacellulose and 1.1% less lignin (oven-dry wood basis).

Klauditz (1958) emphasises that normal poplar wood has an average alphacellulose content of 42.5%, and that values exceeding 44% (and rising to more than 60%) are due primarily to tension wood. It therefore appears that there may be little variation in cellulose content in stems free of tension wood, and that genetic and growth factors other than a leaning habit may not influence cellulose percentage.

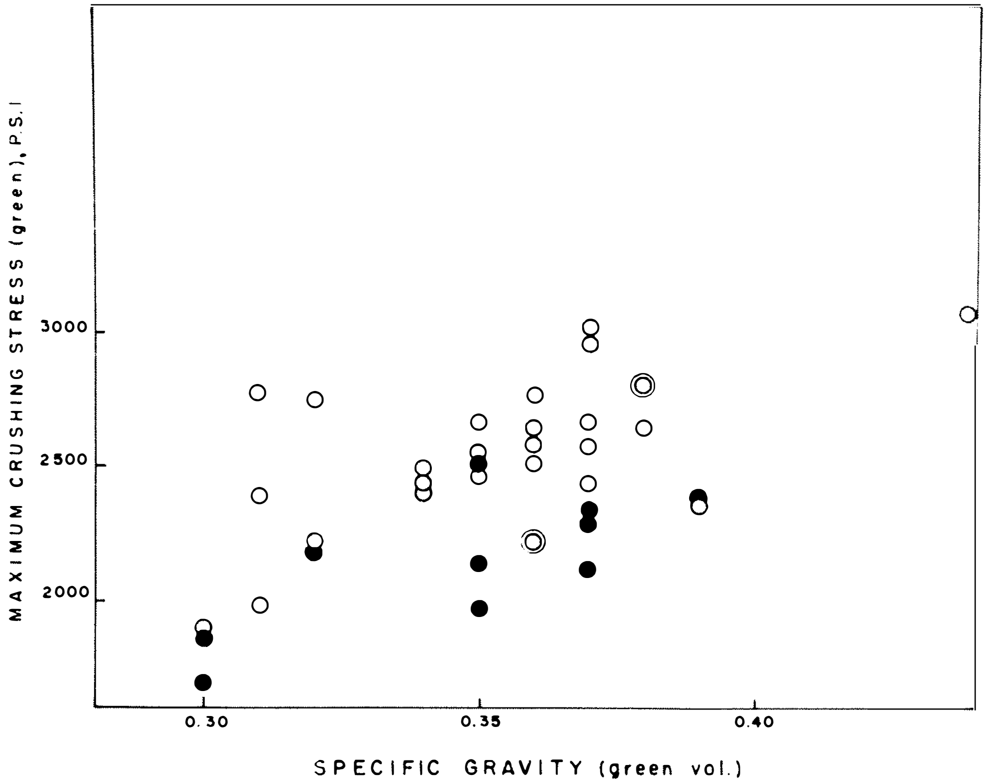

Figure 4. Scatter diagram of maximum crushing stress of North American poplars (solid circles) and other commercial species of similar specific gravity (open circles). (See footnotes of Table 2 for list of species).

MECHANICAL PROPERTIES

General

Because of its low specific gravity, poplar wood in general is weak. Its nail-holding capacity is also naturally poor, but its low tendency to split in nailing makes it a useful wood for boxes and crates.

In order to determine whether poplars are inherently weaker than other species due to factors other than low density, the effect of specific gravity must first be removed before making inter-species comparisons. Figure 4 shows green maximum crushing stress plotted against specific gravity for poplars and all other commercial Canadian species of comparable specific gravity (0.30 to 0.39) (Kennedy 1965). Similar data for these species from United States is also included (Markwardt and Wilson 1935). The poplars appear to have a lower strength-specific gravity ratio (specific strength) than other species. This was confirmed statistically through a "t" test that compared the specific strength of poplars to that of the remaining species using the combined Canadian and U.S. data. The results of several comparisons are summarized in Table 2, which shows the inferiority

TABLE 2. SIGNIFICANCE OF DIFFERENCES IN SPECIFIC STRENGTH AND VOLUMETRIC SHRINKAGE BETWEEN POPLARS AND OTHER SPECIES OF SIMILAR SPECIFIC GRAVITY[1]

Specific property		Mean of poplars[2]	Mean of others[3]	t
max crushing stress (green)	psi	6181	7238	4.44***
max crushing stress (air-dry)	psi	13218	14968	4.41***
modulus of rupture (green)	psi	14108	14982	2.09*
modulus of rupture (air-dry)	psi	24481	25807	1.74
modulus of elasticity (green) 10^3	psi	2936	3077	0.83
modulus of elasticity (air-dry) 10^3	psi	3841	3882	0.22
volumetric shrinkage (green to oven-dry)	%	34.4	29.8[4]	2.89**

[1]Calculated from combined data of Kennedy (1965), Markwardt and Wilson (1935)

[2]Species: Trembling aspen, largetooth aspen, balsam poplar, black cottonwood and eastern cottonwood.

[3]Includes red alder, basswood, butternut, eastern white cedar, western red cedar, amabilis fir, balsam fir, eastern white pine, western white pine, red pine, Engelmann spruce, red spruce, Sitka spruce and white spruce.

[4]Excluding basswood.

* Significant at the 5% level.

** Significant at the 1% level.

*** Significant at the 0.1% level.

of poplars in compression strength in both the green and air-dry (12% moisture content) condition. Specific bending strength (modulus of rupture) is likewise reduced in green poplar, but does not extend to the air-dry condition. Modulus of elasticity is not lower in poplar when compared with other species of equivalent specific gravity. The low crushing resistance of poplars may be related to their low lignin content, since it is commonly assumed that lignin enhances the compressive strength of wood.

Effect of reaction wood

Few data are available on the comparative mechanical properties of tension and normal wood. The only two significant studies on North American poplars (Lassen 1959; Perem 1964) are summarized in Table 3. Although specific gravity is higher in tension wood, most strength properties appear to be reduced. Thus this discrepancy in strength would be more marked if tension and normal wood were compared on a specific strength basis.

Toughness looms as a very important exception to the strength-tension wood relationship. Sacre and Evrard (1963) have also reached this

TABLE 3. DIFFERENCES IN MECHANICAL PROPERTIES BETWEEN TENSION WOOD AND NORMAL WOOD OF POPLAR

Species	Moisture condition	Difference between tension and normal wood (per cent of normal wood)					
		Sp gr	fiber stress at prop limit	mod of rupture	mod of elasticity	max crush stress	toughness
Trembling aspen[1]	green	+8.0	-24.6	-2.2	-1.6	-3.5	+ 62.3
	air-dry	+6.7	-15.6	-5.3	-0.7	-5.3	+ 43.4
Eastern cottonwood[2]	air-dry	+4.7			+6.6	-7.1	+124.6

[1]Perem (1964).

[2]Lassen (1959).

conclusion in an investigation of poplar hybrids. The increased toughness of tension wood has been correlated with the number of gelatinous fibers present (Lassen 1959).

MACHINING AND PROCESSING

Because of its low specific gravity and porous structure, poplar can be expected to cut roughly, and present a somewhat heavy surface. Cantin (1965) found that largetooth and trembling aspen were generally somewhat inferior to denser Canadian species in machining properties. The best performance of the aspens was in boring tests, while they were generally unsatisfactory in turning.

The characteristic low density of poplar is an advantage in the manufacture of particle board. Under a given pressure, low-density chips form a more compact board of greater strength due to better bonding between individual chips.

The tendency to roughness on machining can be accentuated greatly by the presence of reaction wood (Wahlgren 1957; Clark 1958; Haskell 1958; Lassen 1959; Perem 1964), particularly in green timber. The wooliness and projecting fibers characteristic of sawn poplar with a significant number of gelatinous fibers are shown in Fig. 5. Transverse surfaces of such wood feel silky to the touch, presumably due to the gelatinous fibers being pulled rather than cut cleanly from the wood. The presence of gelatinous fibers, along with the extreme growth stresses that may be present in areas of tension wood, can also pinch and clog saws, thereby contributing to overheating, dulling and loss of efficiency in sawing (Haskell 1958; Lassen 1959; Perem 1964).

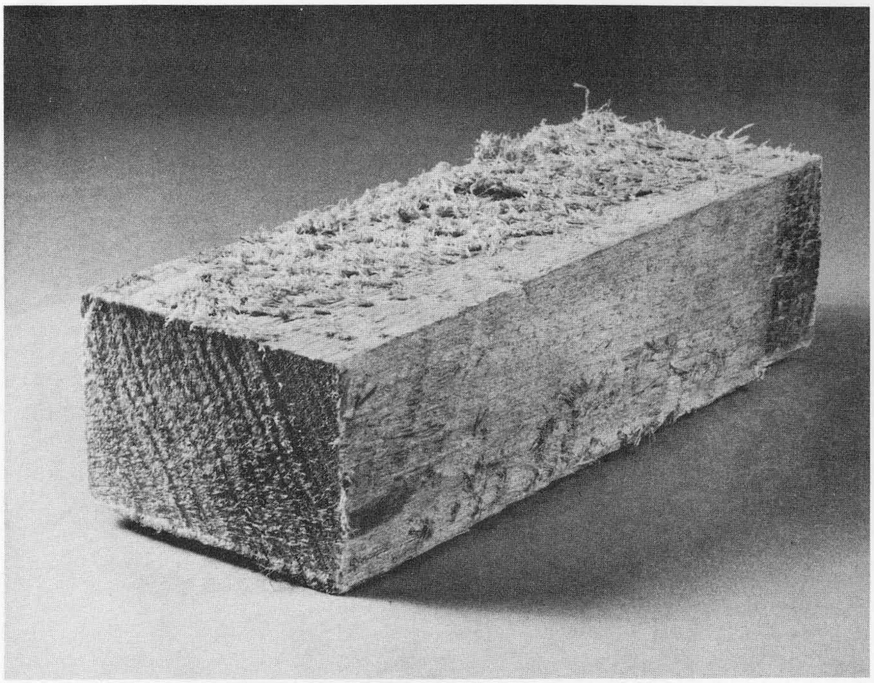

Figure 5. Woolly surface produced by sawing black cottonwood containing tension wood. Lack of gelatinous fibers in upper-right corner of block resulted in comparatively smooth surfaces in this area.

Tension wood is also responsible for extreme wooliness noted in poplar veneer (U.S. Forest Prod. Lab. 1950; Sacre and Evrard 1963). Such fuzzy veneer may require as much as 60% more glue on its surfaces (Schreiner 1959).

MOISTURE RELATIONS AND SHRINKAGE

Standing poplar trees have a high moisture content. Gibbs (1935) found an average moisture content of 130% in trembling aspen in winter, which decreased to 65% in the summer months. Bendtsen and Rees (1962) found a similar set of values of 113 decreasing to 80%. In both of these studies, the sapwood generally had a higher moisture content than the heartwood.

The fiber saturation point of poplar wood has been estimated to be 32 (Anon. 1958) or 33% (Mayer-Wegelin 1953). On the basis of this unusually high figure, a greater than average shrinkage can be expected. The average volumetric shrinkage (green to oven-dry) for the five commercially important species in Canada is quite constant, ranging only from 11.6 to 11.8% (Kennedy 1965). Estimates for the same species in the United States vary from 10.5 to 14.1%. The final line in Table 2 compares specific volumetric shrinkage (volumetric shrinkage ÷ specific gravity) for poplars vs. other commercial species of similar density. It is necessary to calculate specific volumetric shrinkage for this comparison, since shrinkage is a function of specific gravity. Basswood was not included among the other species, because its extremely high specific shrinkage (50.2%) places it in a very special position. With basswood eliminated from consideration, the poplars have a significantly higher specific shrinkage (34.4%) than the other species (29.8%) against which they have been compared.

The reduced volumetric shrinkage of poplars compared to basswood is offset by the fact that poplars have a high ratio of tangential to radial shrinkage. The estimate for this ratio obtained from combined Canadian-U.S. figures is 2.2 for poplars and 1.4 for basswood. Thus the poplars will be more subject to cupping and diamonding, seasoning defects that result from a discrepancy between tangential and radial shrinkage.

Longitudinal shrinkage is generally negligible for normal wood of all species, averaging about 0.2%. Tension wood, however, has a significantly higher longitudinal shrinkage, which leads to bowing, crooking, and more severe checking of lumber and buckling of veneer. Longitudinal shrinkage in aspen tension wood has been reported as 0.34% (Perem 1964). Terrell (1952) found a variation in longitudinal shrinkage in aspen from 0.16 to 0.72%. Both Terrell and Wahlgren (1957) obtained a significant correlation between longitudinal shrinkage and the proportion of thick-walled gelatinous fibers.

PERMEABILITY

Very little information is available on the permeability of poplar. MacLean (1935) placed cottonwood and largetooth aspen in the second of four groups of woods ranked in order of decreasing ability to accept preservatives under pressure. Species in this group are considered to have heartwood moderately difficult to penetrate. Since coastal Douglas-fir is also in this group, it may be argued that no serious limitations exist in treating poplars with preservatives under pressure.

If tyloses are present in the heartwood, the permeability may be markedly reduced. Stone (1956) found that trembling aspen heartwood had the next-to-lowest permeability to air among eight softwoods and 19 hardwoods tested. However, the heartwood of both eastern cottonwood and balsam poplar was very easily penetrated, as was the sapwood of trembling aspen. Since tylosis formation is limited in poplars, permeability will probably be satisfactory in most cases.

DECAY RELATIONS

Decay is commonly encountered in living trees of all poplar species and results in significant losses in pulpwood and veneer logs. Black cottonwood stands may have between 32 and 77% of the trees measurably decayed at ages 80 and 180 years, respectively (Thomas and Podmore 1953).

Over 90% of the loss in this species is caused by *Polyporus delectans* and *Pholiota destruens*. Initial decay by the latter fungus reduced lengthwise compressive stress by 7.5%.

Approximately 70% of the trees in typical trembling aspen stands may be decayed (Basham 1958; Thomas, Etheridge and Paul 1960). The white-rot organism, *Fomes igniarius*, is responsible for the bulk of the decay in this species. Fritz (1954) found that this and most other fungi attacking living trees were unable to continue to cause deterioration in stored mixture of trembling aspen and balsam poplar pulpwood. The exception was *Poria cocos*, which may continue to produce a brown rot in pulpwood bolts.

Stored pulpwood deteriorates rapidly. Fritz (1954) found four species of white-rot fungi which were able to attack wood, and cause advanced decay after only two seasons of storage as pulpwood. After storage of eastern cottonwood bolts for 48 weeks, Eslyn (1966) found specific gravity losses up to 15.4% for white rots and 9.4% for brown rots.

All poplars are also subject to a variety of heartwood discolorations and stains, some of which are associated with bacteria (Wallin 1954; Anon. 1958; Schreiner 1959), and termed "wetwood". Wallin found this type of infection in an irregular zone between the sapwood and heartwood. Wetwood is characterized by a darkened appearance, and unusually high moisture content. In utilization of wood from young stands, discolorations associated with wetwood may assume more importance than heartwood decay.

SUMMARY

The various species of poplar have similar microscopic characteristics, thereby making species separation impractical. About two-thirds of the volume of poplar wood is composed of fibers which have a mature length in the range of 1.2 to 1.4 mm. Fiber length can be improved through genetic selection, resulting in a superior pulp product. In tension wood, the fiber is modified to include a gelatinous layer next to the lumen. Gelatinous fibers result in somewhat increased specific gravity, higher cellulose content, lower specific strength properties with the important exception of toughness, higher longitudinal shrinkage, and the production of fuzzy or woolly surfaces when machined.

The average specific gravities of North American poplars show no important differences among species, with the exception of black cottonwood in which it may be lower. Rapid growth rate appears to depress average specific gravity. Failure to find such a relationship in some studies may be due to interaction with heredity, since specific gravity is under moderate genetic control. Through clonal selection, it may be possible to achieve both high volume increment and high specific gravity, thereby significantly increasing dry-weight yield.

Poplars have an extremely low lignin and high alphacellulose content compared to other trees. They are weaker than other low-density species in lengthwise compression, possibly due to their low lignin content.

Considering its low density, normal poplar wood machines as well as could be expected, but the frequent presence of tension wood often gives the impression that it is a rough-surfaced wood. Normal poplar wood shrinks somewhat more than that of other low-density species with the exception of basswood, and has a moderately high ratio of tangential to radial shrinkage. The high longitudinal shrinkage of tension wood may lead to increased checking and warping of lumber and veneer.

Poplars are fairly permeable except when tyloses are encountered in the heartwood.

Poplar stands are heavily infected with heartrot, and the timber is very perishable after cutting. Stains, some of which are associated with bacterial infection, are also common. Decay and discoloration reduce the usefulness of poplar as a pulp and veneer source.

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CHAPTER X

USE OF POPLAR FOR THE MANUFACTURE OF PULP AND PAPER

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INTRODUCTION

Of the eight species of the genus *Populus* native to Canada, five occur in commercial size and quantity (Irwin and Doyle 1961). These are: trembling aspen, largetooth aspen, balsam poplar, eastern cottonwood, and black cottonwood. The cost of transporting pulpwood is high; consequently, although all five of these species of poplar are used in the manufacture of pulp, paper and board in Canada, the species or mixture of species used in a particular case depends upon the location of the mill. With few exceptions, poplar and other hardwoods are not shipped over long distances, and many mills, especially in eastern Canada, purchase their supplies of these pulpwoods from local farmers. The distribution of poplar species in Canada has been discussed by Maini (Chap. II); as might be expected from his data, trembling aspen is the predominant poplar species used by pulp mills east of the Rocky Mountains. In British Columbia poplar usage is confined exclusively to black cottonwood.

Volumes of poplar used in pulping in Canada

The amounts of all poplar[1] species used for pulping in Canada and in separate provinces are shown in Fig. 1 for the years 1953 to 1965, the latest year for which official statistics were available when this review was being prepared (Anon. 1953-1965). The quantity used was relatively stable over this 12 year period, averaging about 480,000 cords per annum for the country as a whole. In Ontario in 1965 (Fig. 2), poplar accounted for about 7% of the roundwood pulpwood used in that province, with the other provinces using 1.5-2.0% in their roundwood supply. Figure 3 shows the quantities of poplar used in various pulping processes throughout Canada. Increasing amounts have been utilized in mechanical and semichemical methods, reaching a peak of 220,000 to 235,000 cords in the period 1960-1964: although the volume dropped to 180,000 cords in 1965 this was

[1]Volumes of poplar in Figs. 1, 3, 4 and 5, and percentage relationships in Figs. 2, 10 and 11 refer to roundwood only. See p. 175.

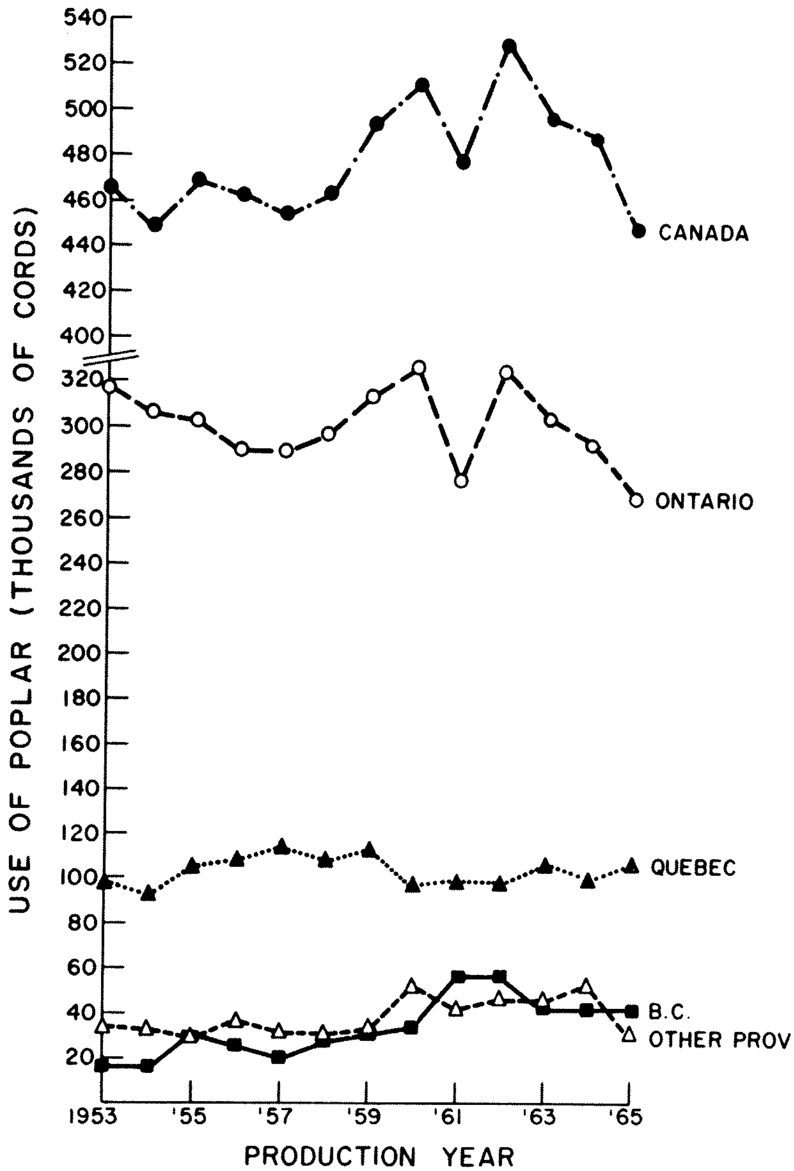

Figure 1. Volumes of poplar used as pulpwood in Canada and provinces, 1953-1965.

Notes: (1) *Anon. (1953-1965). The figures for Ontario and Canada for 1963 and 1964 have been corrected - see p. 189 and footnote to Table 2.*

(2) *Volumes are in terms of rough or unpeeled cords, on the basis of one rough cord as equivalent to 85 ft*^{3} *of solid wood.*

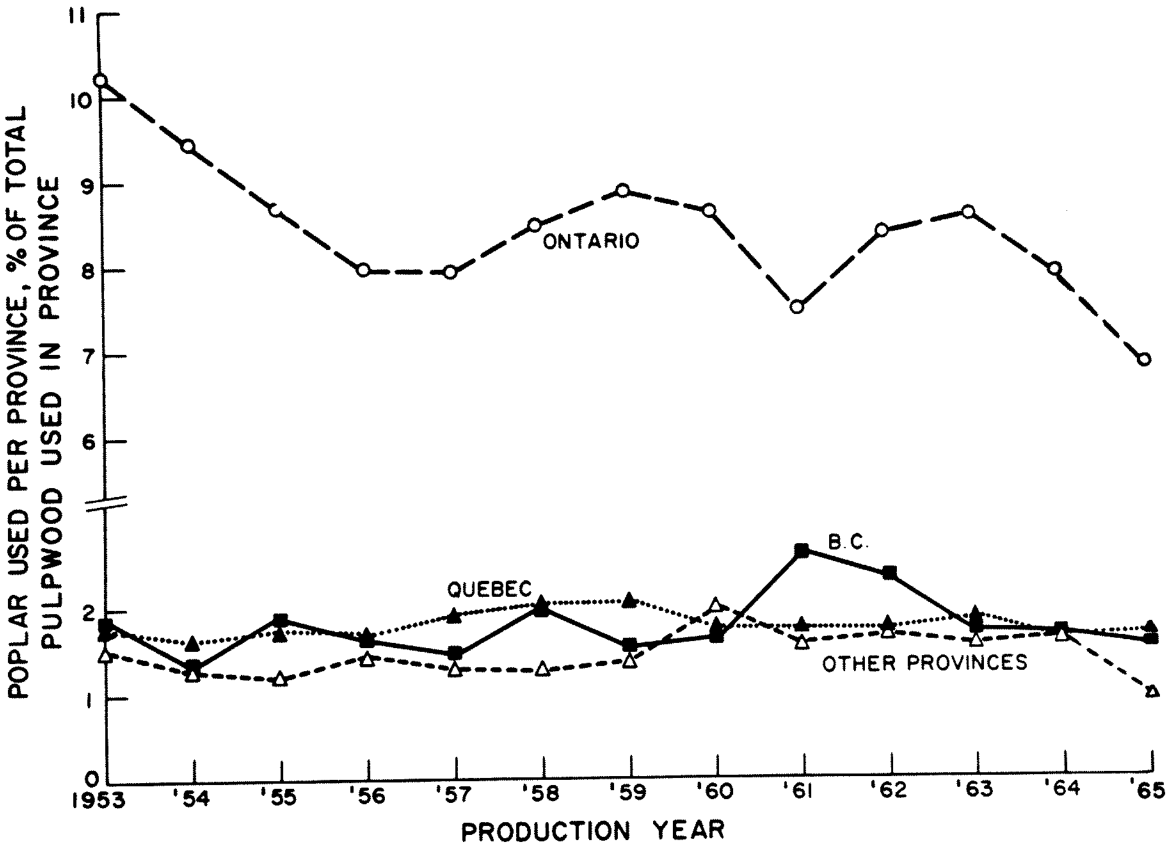

Figure 2. Poplar used per province as a percentage of the roundwood pulpwood used in that province, 1953-1965. Anon. (1953-1965). Note: Wood residues not included. See p. 175.

still a substantial increase over the 136,000 cords used in 1953. In contrast, there was a striking reduction (Fig. 3) in the volume of poplar used in "sulfate and soda" pulping because of the inclusion of increasing quantities of dense hardwoods in the kraft pulping of mixed hardwoods, particularly in Ontario. Trends in the use of poplar for various processes in Quebec and Ontario are plotted in Figs. 4 and 5.

The average value per cord of various pulpwoods in a given year was recorded by the Dominion Bureau of Statistics up to 1961. In Figs. 6, 7, 8 and 9 these data are plotted for Quebec, Ontario, British Columbia and as an average for Canada as a whole. Although poplar has been much cheaper on a cord basis than spruce and jack pine in Quebec and Ontario, it became more expensive than all softwoods in British Columbia from 1958 to 1961 (Fig. 8). The demand for black cottonwood is increasing there and the price has continued to show a generally rising trend since 1961. Special efforts are therefore being made to assure the supply by planting and tree-breeding projects. The statistics indicate that in Ontario from 1953 to 1961 (Fig. 7), poplar was more expensive than other hardwoods on a cord basis. In Quebec in 1960-61 the price per cord was slightly lower than other hardwoods but this tiny differential (Fig. 6) is more than cancelled out if the prices

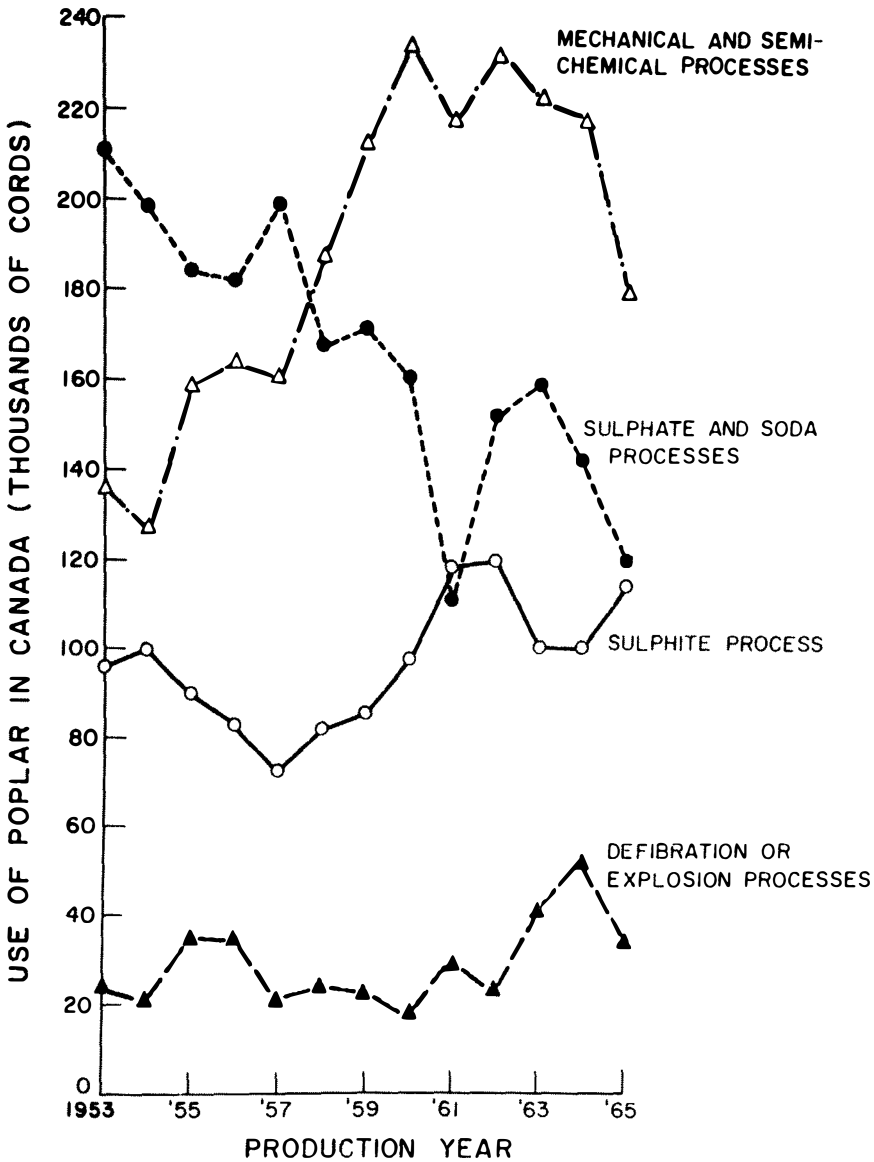

Figure 3. Volumes of poplar used in each type of pulping process in Canada, (1953-1965).

Notes: (1) Anon. (1953-1965).

(2) Volumes are in terms of rough or unpeeled cords, on the basis of one rough cord as equivalent to 85 ft^3 of solid wood.

(3) Soda pulp is not now produced in Canada. In recent years the output of this type of pulp has been small and in 1965, pulpwood described by the Dominion Bureau of Statistics as used in "Sulfate and Soda" pulping was entirely used in sulfate (kraft) pulping.

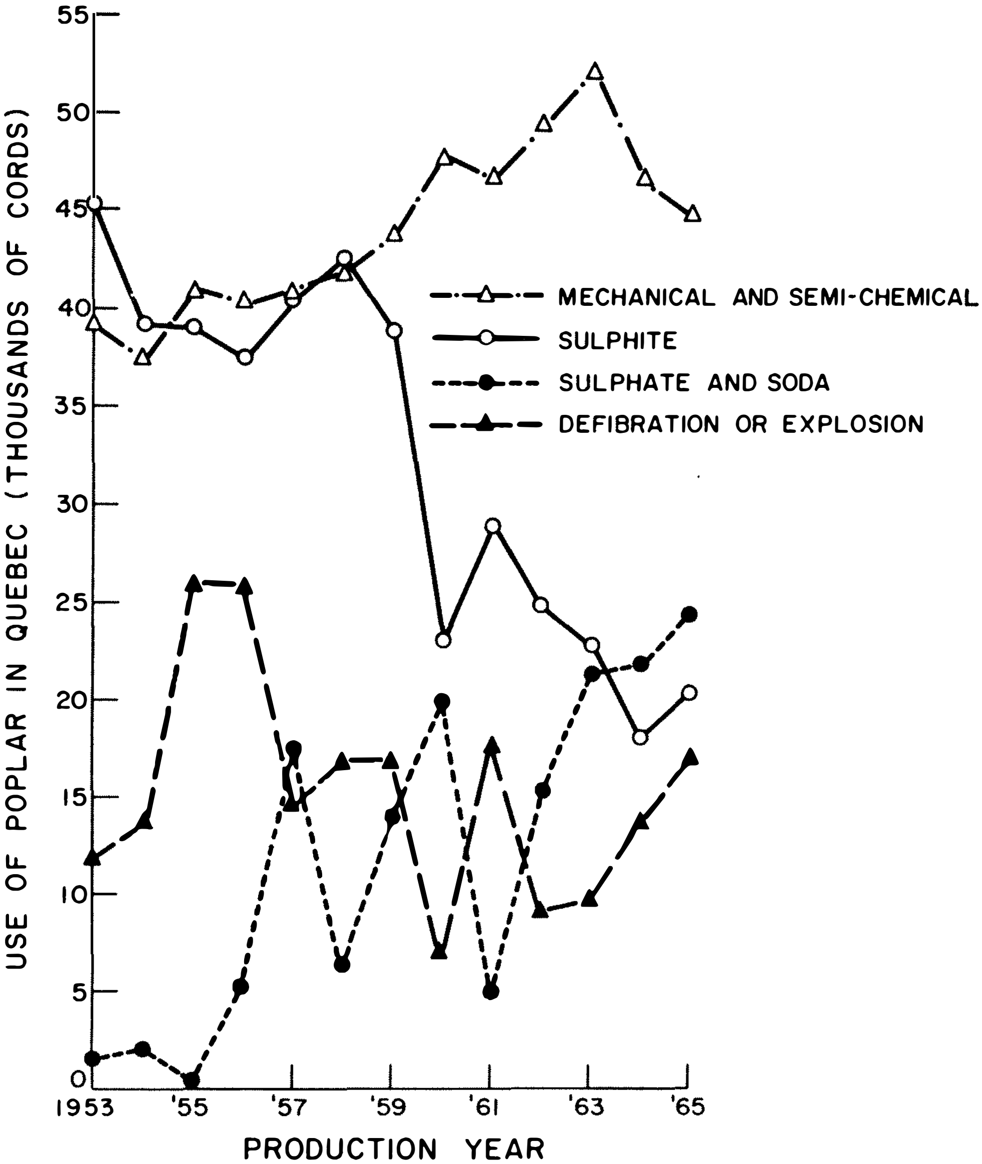

Figure 4. Volumes of poplar used in each type of pulping process in Quebec, (1953-1965). Notes as in Fig. 3.

are converted to a weight basis. The basic densities of the poplar species used for pulping in Canada range from about 19 to about 24 lb. of moisture-free wood per cubic foot of green volume (Besley 1960), whereas the average for Canadian hardwoods excluding poplar species is about 31 lb./ft^3. Since pulp yield per cord increases with basic density, these considerations have contributed to the decline in the use of poplar for alkaline pulping.

Figure 10 reveals that hardwoods as a whole (including poplar) accounted for nearly 7% of the roundwood pulpwood used in Canada in 1965, compared with about 4% in 1952. The use of poplar had not increased proportionately: in 1953 it accounted for 4% of the roundwood pulpwood and for over 80% of the hardwoods used. During the next 12 years, the amounts

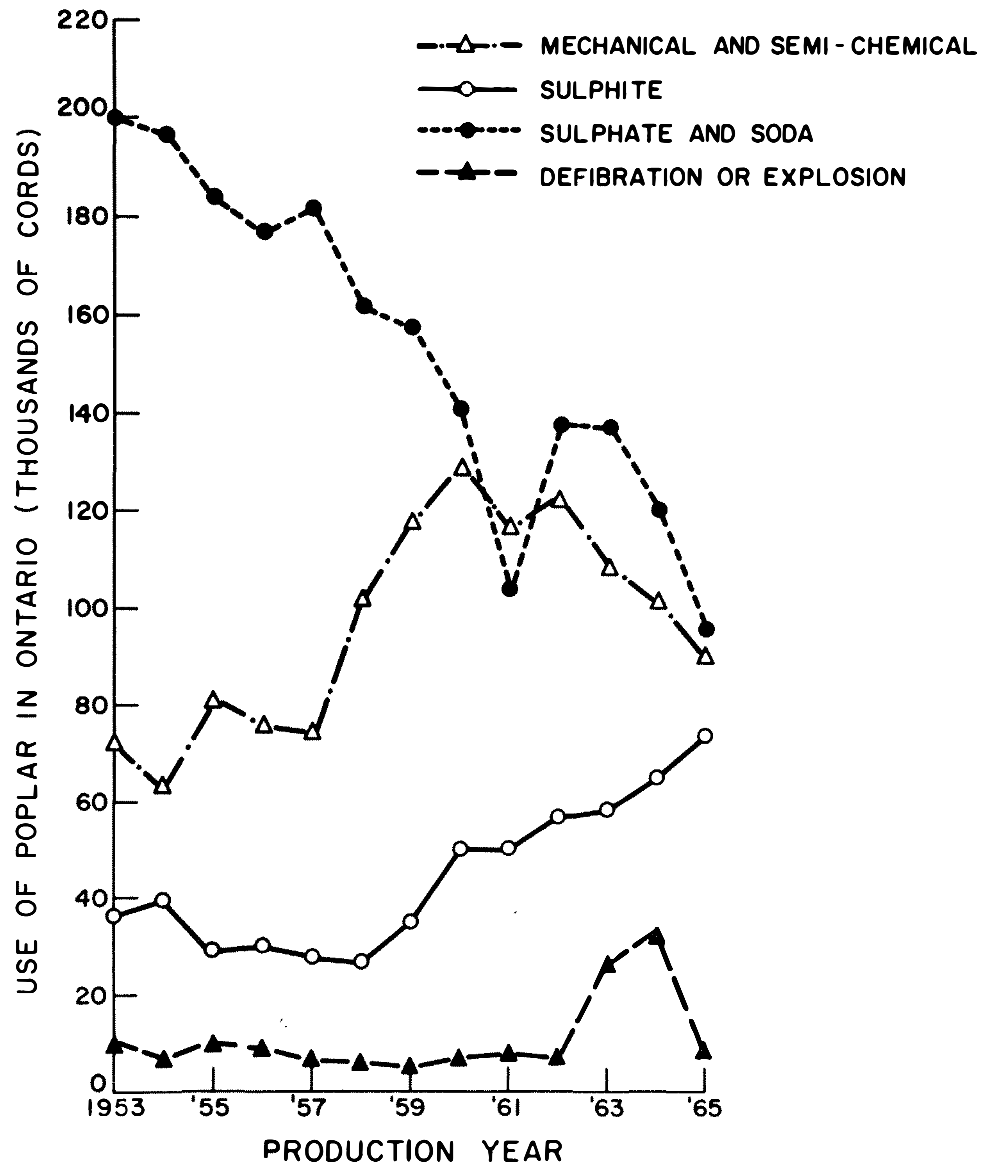

Figure 5. Volumes of poplar used in each type of pulping process in Ontario, (1953-1965). Notes as in Fig. 3.

used per annum never exceeded 4% of the roundwood pulpwood and in 1965 were less than 3.0%. This decline in the use of poplar relative to other hardwoods is shown in Fig. 11. Although, in 1965, it still comprised about 40% of the total hardwoods used in pulping there had been a striking downward trend since 1952, barely checked in the period 1956-58. As Fig. 1 shows, this genus has been holding its own, with relatively minor fluctuations, on a volume basis, but no sustained increase was recorded during the 12 years ending in 1965.

The latest figures available (for 1965) on the use of poplar as pulpwood are collected in Table 1. Comparison of these figures with those for 1964 (Table 2) shows, *inter alia*, that although the consumption of

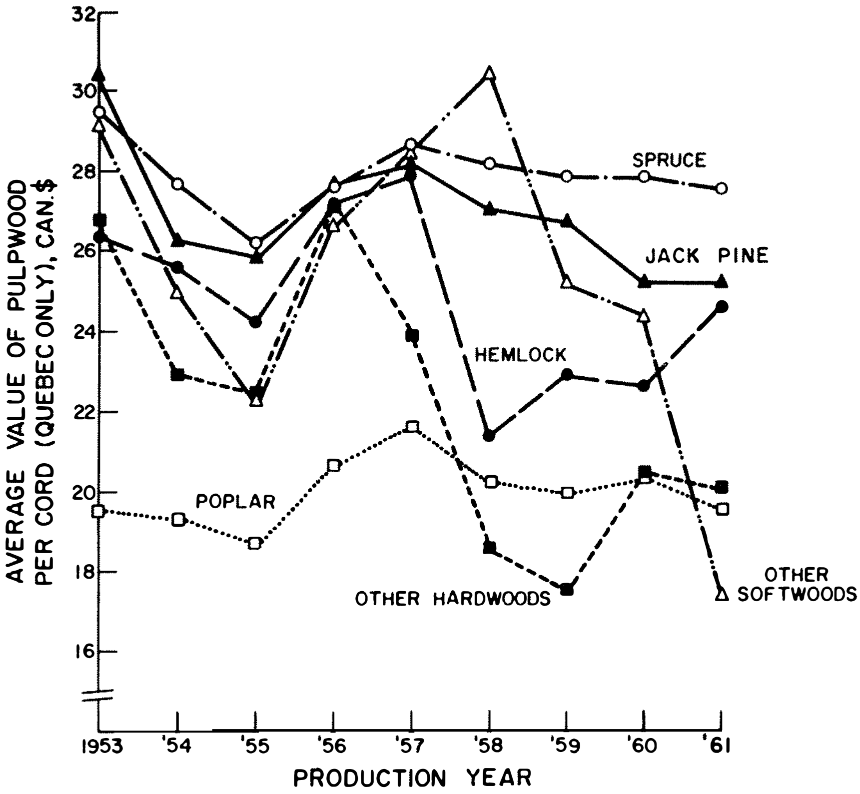

Figure 6. Average value of pulpwood per cord in Quebec, 1953-1961. Anon. 1953-1965.

roundwood pulpwood in Canada increased from about 16.1 million cords in 1964 to nearly 16.5 million cords in 1965, the consumption of poplar dropped from about 490,000 to less than 450,000 cords. Thus the roundwood poplar used, calculated as a percentage of the roundwood pulpwood consumed, dropped from 3.0 to 2.7%.

All the above figures, including the calculations on which Figs. 2, 10 and 11 are based, refer to roundwood only. In 1965, wood residues including sawmill and veneer mill chips, slabs and edgings, shavings, sawdust, and butts and cores equivalent to an additional 4.3 million cords accounted for 20.7% of the total consumption (20.8 million cords) of pulpwood. Preliminary figures for 1966 (Anon. 1967) indicate an increase in the consumption of residues to the equivalent of 5.1 million cords, representing 22.4% of the total pulpwood consumption in 1966. Data are not available on the individual species comprising these residues, but in 1965 it was recorded (Anon. 1965) that only 3% of them were hardwoods. Even if it were to be assumed that nearly all of the hardwood residues were poplar species, this still would not raise the amount of poplar used, calculated as a percentage of the total pulpwood (including residues) consumed in 1965, significantly above the 2.7% calculated on the basis of roundwood only.

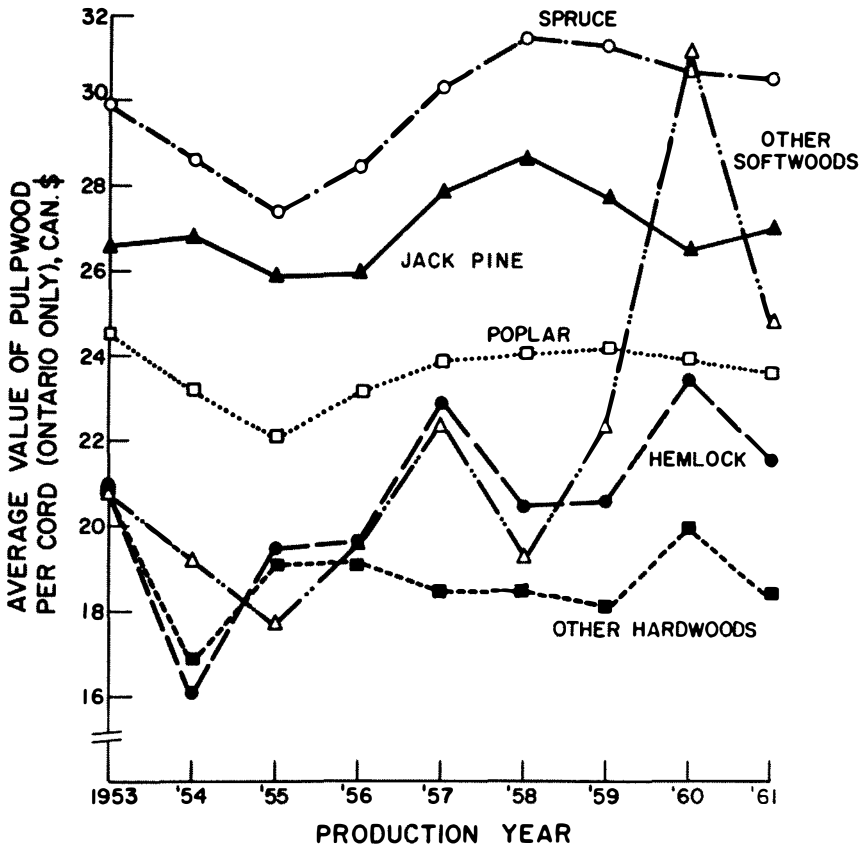

Figure 7. Average value of pulpwood per cord in Ontario, 1953-1961. Anon. 1953-1965.

A preliminary estimate (Anon. 1967) indicates that about 482,000 cords of poplar roundwood were used in 1966. This still represents only about 2.7% of the roundwood pulpwood consumed in that year. The demand is likely to increase in only a few special cases, e.g. for the manufacture of groundwood for toilet tissues, and of neutral sulfite semi-chemical (NSSC) pulp for corrugating medium and as a filler for newsprint.

The anatomical and physical characteristics of poplars have been described by Isenberg (1951), Irwin and Doyle (1961), Besley (1960) and more recently by Kennedy (Chap. IX), and data on their chemical constitution have been obtained in a number of laboratories (Isenberg 1951; Browning 1963, p. 70; Rydholm 1965, p. 95). The pulping characteristics of poplar have been investigated exhaustively, and good bibliographies are available (Brown, Saeger and Weiner 1957; Roth and Weiner 1964).

KRAFT PULPING

Although all species of poplar are probably used in chemical pulping, both kraft and sulfite, trembling aspen is the most widely used

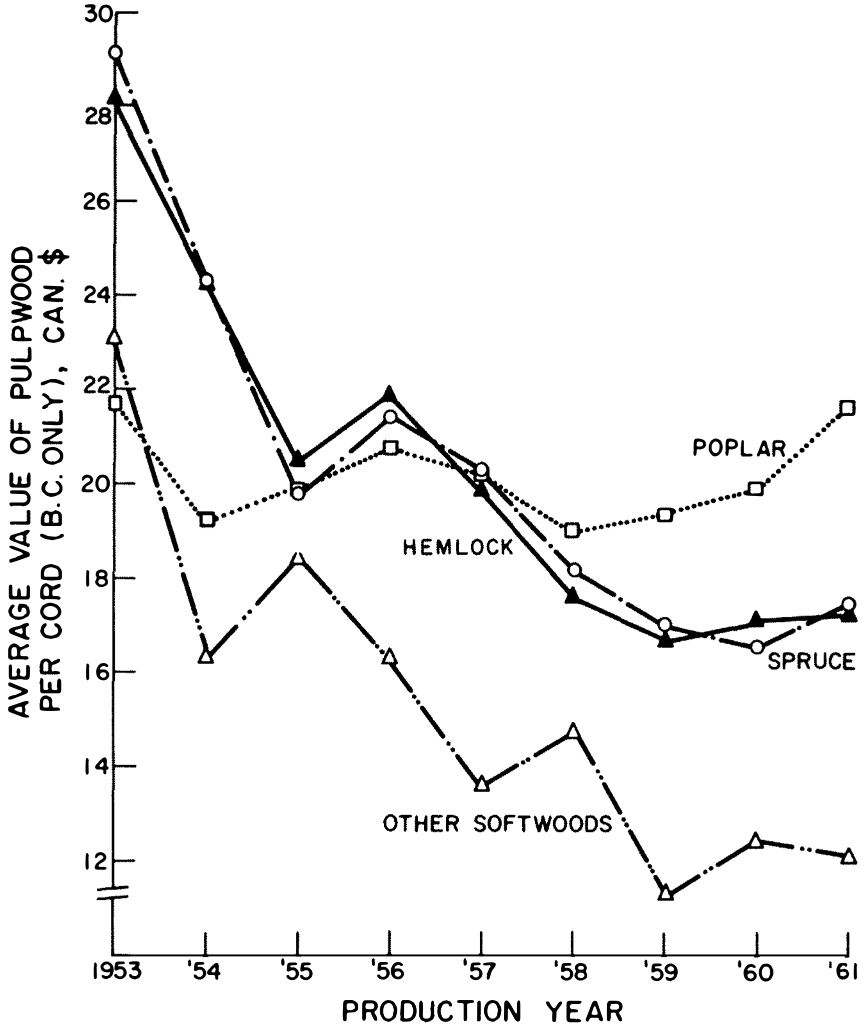

Figure 8. Average value of pulpwood per cord in British Columbia, 1953-1961. Anon. 1953-1965.

for this purpose, sometimes alone but more frequently in admixture with other species. In the kraft pulping of mixed western softwoods about 5% of black cottonwood is sometimes included in the mixture but the total amount used in this way is relatively small.

Table 3 summarises the fiber dimensions, wood density and chemical constitution of trembling aspen and the properties of bleachable-grade kraft pulps in comparison with white birch, Douglas-fir, and black spruce. Hardwoods in general have a lower lignin content than softwoods. Consequently they pulp faster than softwoods and give a higher yield at a given pulp lignin content. Most specimens of trembling aspen have an even lower lignin content than other hardwoods and thus give somewhat higher pulp yields on a dry weight basis. However, the basic density of poplar species is low -- lower than that of all other Canadian hardwoods except basswood. Consequently, since pulpwood is bought on a volume basis, the yield of pulp per cord of poplar is frequently lower than with the denser hardwoods.

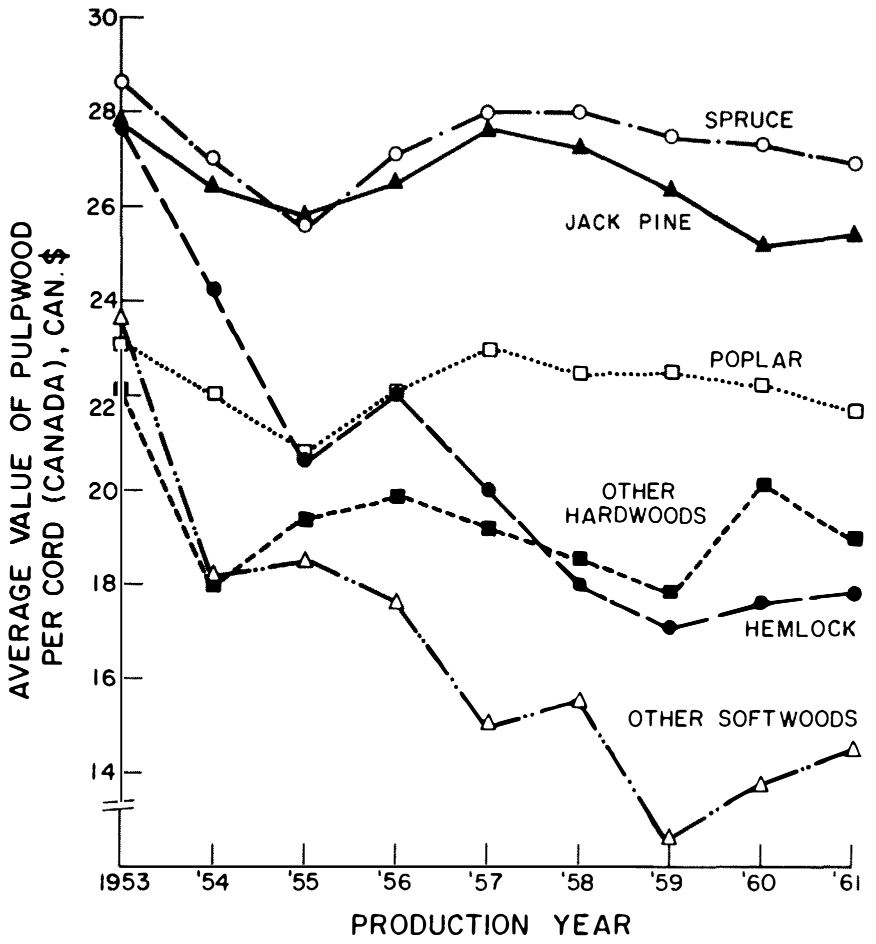

Figure 9. Average value of pulpwood per cord in Canada, 1953-1961. Anon. 1953-1965.

The kraft process is not as sensitive to extractives as the sulfite process, but one mill has reported difficulties due to deposition of poplar resins during the bleaching and screening of a kraft pulp blend containing a 50:50 mixture of trembling aspen and jack pine, although similar problems do not occur in papermaking.

As with other hardwoods, the fiber length of poplar is lower than that of softwoods, and poplar pulps are weaker than softwood pulps. Fiber length has a particularly marked effect on tear factor which decreases with decreasing fiber length (Table 3). Poplar pulp has an even lower tear factor than birch, a relatively long-fibered hardwood. Poplar kraft pulps are not made directly into paper or converted into market pulp because of the difficulty of running pure poplar pulp on the machines; the wet web strength is too low to allow the pulp to be run at reasonable production speeds. Consequently the poplar pulp is blended with a longer-fibered softwood pulp, frequently jack pine or a mixture of spruce and jack pine. Even then, difficulties are experienced if the content of poplar pulp reaches or exceeds 75%. In one mill a blend of jack pine kraft (about 45% yield) and poplar kraft (about 55% yield) is made by cooking the two species

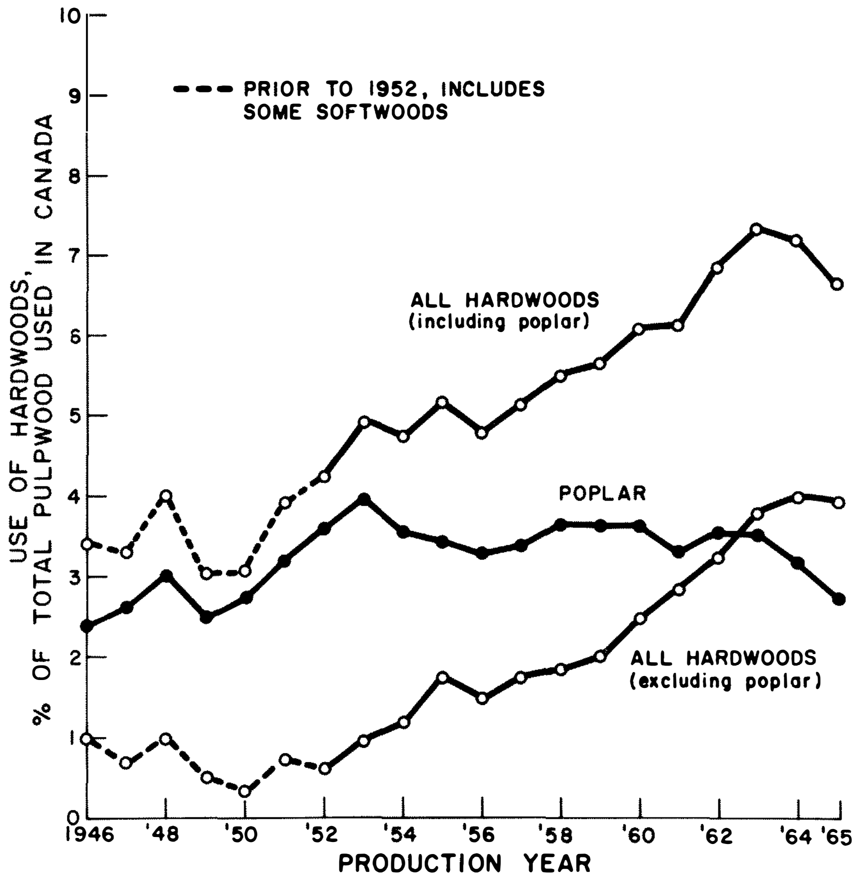

Figure 10. Hardwoods used in pulping, as a percentage of the roundwood pulpwood used in Canada, 1946-1965. Note: Wood residues not included. See p. 175.

in separate digesters and blowing simultaneously. The pulps are then bleached in the form of the blend.

Poplar kraft pulp has high opacity and good bulk and printability. Blends with softwood kraft containing 10-50% poplar are used in book papers, offset printing paper and many other fine papers. Mixed hardwood pulps are similar to a pure poplar pulp and are also used for such papers: the advantage of cooking poplar alone is that longer cooking times are required for the denser hardwoods, partly because the impregnation time must be geared to the requirements of the least easily impregnated wood. Poplar itself is very easily impregnated unless it contains tyloses (Stone and Green 1958). In deciding whether to cook poplar alone or in admixture and if the latter, in what proportion, an individual mill must consider in some detail the economics of the cooking cycle required for denser hardwoods, and weigh these against the availability and relative cost per unit of dry weight (rather than per cord) of different woods, as well as against the demand of customers for pulps of a particular specification. In general, as discussed above and shown in Fig. 3, the use of poplar for kraft pulping is decreasing. One mill ceased kraft cooking pure poplar in 1955, and in 1966 was pulping mixed hardwoods, predominantly maple and elm, with only 3.6% poplar in the mixture.

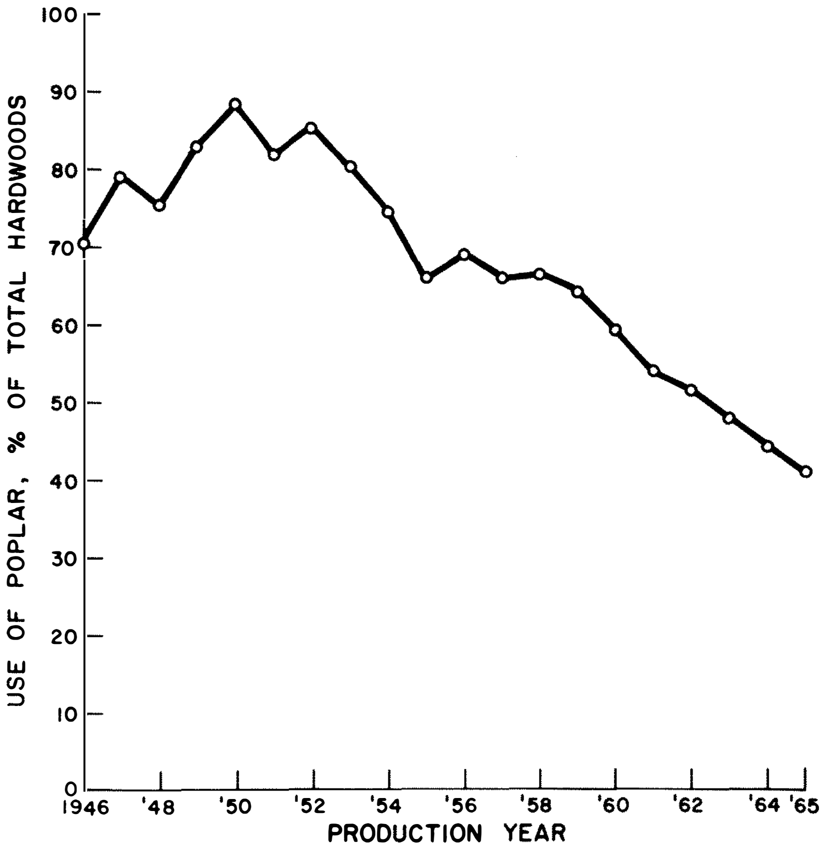

Figure 11. Poplar used in pulping, as a percentage of the roundwood hardwoods (including poplar) used in Canada, 1946-1965. Note: Wood residues not included. *See p. 175.*

SULFITE PULPING

In Ontario and Quebec the local species of poplar are pulped alone or in admixtures by the sulfite process. Calcium base sulfite liquor has traditionally been used, but at least one mill has converted to sodium base. The sodium base sulfite pulping of poplar involves an impregnation stage of 3.5 hours at 160C, giving a pulp yield of about 51%. As in the case of kraft pulps, the opacity of poplar sulfite pulps is higher than that of softwood pulps at a similar yield, but the pulps are weaker than softwood sulfite pulps (Table 4) because of the shorter fiber length of poplar. Poplar has a somewhat higher pitch content than the spruce-balsam mixture commonly pulped by the sulfite process, but gives no particular trouble in processing provided it has been seasoned.

Like poplar kraft, poplar sulfite pulp confers good formation on pulp blends and is used in admixture with other pulps, e.g., spruce kraft or sulfite, and mixed hardwood kraft, in all grades of fine papers, in amounts ranging up to 40%.

TABLE 1. THE USE OF POPLAR AS PULPWOOD IN CANADA IN 1965[a]

Process	Mechanical and Semi-Chemical			Sulfite			Kraft			Defibration and Explosion			All Processes		
	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %
Quebec	45,324	2,945,815	1.5	20,549	2,287,280	0.9	24,577	1,032,474	2.4	17,294	90,839	19.0	107,744	6,356,408	1.7
Ontario	90,769	1,525,356	6.0	73,600	1,252,109	5.9	95,927	1,174,074	8.6	9,211	20,980	43.9	269,507	3,972,519	6.8
B.C.	22,142	925,957	2.4	19,676	915,837	2.2	-	938,217	-	-	-	-	41,818	2,780,011	1.5
Other Prov.	22,121	1,214,210	1.8	643	1,400,704	<0.1	-	743,932	-	7,915	19,299	41.0	30,679	3,378,145	0.9
Canada	180,356	6,611,338	2.7	114,468	5,855,930	2.0	120,504	3,888,697	3.1	34,420	131,118	26.3	449,748	16,487,083	2.7

[a]Anon. 1965. Note: Wood residues not included. See text.

TABLE 2. THE USE OF POPLAR AS PULPWOOD IN CANADA IN 1964[a]

Process	Mechanical and Semi-Chemical			Sulfite			Kraft			Defibration and Explosion			All Procces		
	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %	Poplar cords	Pulpwood cords	Poplar %
Quebec	47,009	2,859,353	1.6	18,015	2,253,337	0.8	22,036	1,020,493	2.2	13,805	95,483	14.5	100,865	6,228,666	1.6
Ontario	101,843	1,476,604	6.9	64,596	1,335,362	4.8	120,701	1,209,244	10.0	9,000[b]	44,706	20.1	296,140	4,065,916	7.3
B.C.	25,027	863,543	2.9	17,166	944,240	1.8	-	822,325	-	-	-	-	42,193	2,630,108	1.6
Other Prov.	45,871	1,129,967	4.1	1,053	1,350,789	0.1	-	723,460	-	6,041	17,896	33.8	52,965	3,222,112	1.6
Canada	219,750	6,329,467	3.5	100,830	5,883,728	1.7	142,737	3,775,522	3.8	28,846	158,085	18.2	492,274	16,146,802	3.0

[a]Anon. (1964). Note: Wood residues not included. See text.

[b]This figure is an estimate, based on the graph in Figure 5, of the quantity of poplar used in defibration and explosion processes in 1964: from Figure 5 it may be inferred that the totals reported for 1963 and 1964 for Ontario were too high. They probably included some poplar used for particleboard. The totals for 'all processes' have been corrected to agree with this estimate.

TABLE 3. PROPERTIES OF KRAFT PULPS FROM POPLAR AND OTHER WOODS

	Douglas-Fir	Black Spruce	Trembling Aspen	White Birch	Average, Canadian Softwoods	Average, Canadian Hardwoods	Average, Canadian Hardwoods exc. Poplar
Basic Density, lb./cu ft	28[a]	25[a]	22[a]	30[a]	24[b]	28[c]	31[d]
Average Fiber Length, mm	3.9[a]	3.3[a]	1.0[a]	1.9[a]	3.5[b]	1.2[c]	1.3[d]
Average Fiber Diameter[f], mm	0.040[a]	0.028[a]	0.019[a]	0.025[a]	0.035[e]	0.024[c]	0.023[d]
Gross Composition of Extractive-free Wood:							
Lignin, %	25-30[g]	28[h]	16[k]	19[k]	29[k]	21[k]	22[k]
Cellulose, %	38-47	46	53	41	43	45	43
Hemicelluloses, %	28-32	26	31	40	28	34	35
Anhydrosugars, % in Extractive-free Wood:							
Glucan, %	43.5[m]	49.0	57.3[m]	44.7[k]			
Mannan, %	10.8	10.8	2.3	1.5			
Xylan, %	2.8	5.6	16.0	24.6			
Galactan, %	4.7	3.2	0.8	0.6			
Arabinan, %	2.7	1.3	0.4	0.5			
Kraft Pulp[p]:							
Total Yield, %, at Roe No. ~ 5 (sw); ~ 2.5 (hw)	47.7[h]	46.7	59.1[n]	54.8[n]			
Paper Properties[p] at 300 cc CSF:							
Beating Time, min	68	75	40	37			
Breaking Length, km	13.6	14.6	10.7	12.5			
Tear Factor	130	113	74	96			
Burst Factor	106	110	61	84			
Bulk, cc/g	1.33	1.40	1.30	1.34			

a Average figures calculated or cited by Besley (1960) from data given by Isenberg (1951).
b-e Averages of values listed in (a) for: b = 19; c = 15; d = 10 and e = 17 spp. respectively.
f Isenberg (1951) used the term "fiber diameter", rather than "fiber width".
g Data on extractive-free Douglas-fir from Isenberg (1951).
h Analytical data for black spruce wood, and pulp yield and paper properties of black spruce and Douglas-fir kraft pulps are from previously unpublished results obtained at the Pulp and Paper Research Institute of Canada.
k Data on extractive-free wood from Rydholm (1965) p. 95.
m Data on anhydrosugars from Browning (1963) p. 70.
n Pulp yield and paper properties from Legg and Hart (1959).
p Laboratory-made pulps.

sw = softwood; hw = hardwood; CSF = Canadian Standard Freeness.

TABLE 4. PROPERTIES OF COMMERCIAL BLEACHED SULFITE PULPS FROM POPLAR AND SPRUCE-BALSAM[a]

Pulp	Beating Time min[b]	Freeness, ml, CSF[b]	Density, g/cc[b]	Burst Factor[b]	Tear Factor[b]	Printing Opacity[c]
Poplar (Eastern species)	0	635	0.71	25	79	-
	2	615	0.72	30	66	-
	4	587	0.74	34	63	71.1
	8	495	0.76	40	58	-
Spruce-Balsam	0	689	0.69	34	109	-
	2	673	0.71	44	90	-
	4	658	0.73	49	81	66.8
	8	610	0.75	56	72	-

[a]Data from Anon. (1967a).

[b]Average values for standard beater tests on weekly composite samples.

[c]Opacity values: poplar, average of three tests; spruce-balsam, average of 53 tests.

DISSOLVING PULP

Mixed hardwoods, including poplar, are used in the manufacture of certain grades of dissolving pulp. The high percentage of xylan in hardwoods is a disadvantage in the production of acetate grade pulps but poses no problem when the pulp is destined for cellophane or textile (rayon) manufacture. One mill uses a mixture containing about 7% poplar. The short fibers of poplar and other hardwoods can be a disadvantage because in the slurry steeping step for preparing alkali cellulose for the viscose process the drainage is poorer than with the long-fibered woods. Drainage rate at this stage often determines the rate of production of a viscose plant and therefore fiber length may be a matter of concern.

MECHANICAL AND SEMI-CHEMICAL PROCESSES

Mechanical pulping

The preferred species for newsprint groundwood are spruce and balsam, but a number of mills in Ontario and Quebec include small amounts -- 1% or less -- of poplar in the mixture. Their supply of this poplar, bought from local farmers, is variable. Larger amounts of poplar are included in groundwood for the manufacture of insulating board: one insulating board mill reports the following species mixture (percentages in parentheses): trembling aspen (59); largetooth aspen (11); balsam poplar (5); basswood (1); mixed softwoods (24). The inclusion of as much as 75% of poplar in this mixture is related largely to a plentiful local supply.

Attempts have been made to include substantial quantities of poplar in newsprint groundwood, and in one case special arrangements were made to ship the poplar from some distance away. This mill reported no particular difficulties in harvesting or shipping poplar, but the decay rate of barked poplar in storage was about 25% faster than spruce-balsam, and was accelerated when the poplar was stored with bark on. No poplar was used for the production of rotogravure pulp, but 10-15% was included in newsprint groundwood. The yield was 97-98%, including bull screen tailings. For a given production rate the power consumption was about 16% higher than for spruce-balsam. It was found difficult to combine jack pine and poplar groundwood. Pitch and/or slime appeared which caused web breaks.

As with chemical pulps, the shorter fiber length of poplar tends to produce a weaker groundwood than do softwoods. In one case, the bursting strength of a poplar groundwood was about 70-74% of that of spruce groundwood. Using a groundwood containing 10% poplar in admixture with softwood sulfite pulp for newsprint, it was necessary to add 1.5% more sulfite pulp to the mixture to achieve a bursting strength comparable to that obtained when a pure softwood groundwood was used. The effect upon bursting strength of the addition of various quantities of poplar to a softwood groundwood is shown in Table 5.

The influence of rotted wood on the properties of poplar groundwood is striking. One mill compared the properties of pulp made from selected poplar in good condition with pulp made from "normal" poplar, which included rotted logs. The selected poplar gave a superior pulp with a brightness averaging 12% higher than pulp from normal poplar of the same age. The bursting strength of the pulp from selected poplar averaged about 15% higher and the chop was 78% lower than with pulp from "normal" logs, albeit at a freeness averaging 25% lower.

The bleaching of poplar groundwood can be done in the grinder pit with hypochlorite but the temperature is too high and consistency too low

TABLE 5. EFFECT OF POPLAR ON NEWSPRINT GROUNDWOOD[a]

Amount of Poplar, %	Decrease in Bursting strength, %
10	4
20	9
30	15

[a]Data from Anon. (1967a).

for optimum results. To match spruce groundwood, an indicated usage of 4% available chlorine has been suggested with yield loss equivalent to 3% of pulp. The properties of laboratory-made groundwood pulps from trembling aspen and from white spruce were compared with those from a young hybrid poplar, *P.* 'IH-78B', by Montmorency and Stone (1959). The results (Table 6) must be regarded with caution since they refer only to single trees, but they confirmed the higher power requirements reported for the mill production of poplar groundwood and showed that the hybrid required much higher power than the natural poplar, and that even then it produced a pulp of lower strength. Table 6 includes a comparison of the properties of commercial pulps from trembling aspen and spruce; as might be expected these are lower than those of the laboratory pulps.

High percentages of poplar groundwood are blended with softwood groundwood in the manufacture of toilet tissues. One mill in eastern Canada, at present using a mixture of one-third poplar and two-thirds softwood, plans to increase the proportion of poplar to two-thirds. This is mainly because the cost of bleaching the poplar to the required brightness is lower than for the softwoods, but supply is also a factor: peeled poplar is readily available, whereas softwoods have to be barked.

Black cottonwood is also used for toilet tissue on the west Coast. The pulp is soft and bulky, odorless, and easily bleached to high brightness.

Groundwood pulps obtained by the disk refining of chips have strength properties superior to those of pulps prepared from the same wood species by conventional stone grinding, when compared at a given freeness (Neill and Beath 1963). Refiner groundwood for newsprint is produced commercially from softwoods in Canada, but although a considerable amount of development work has been done on the disk refining of poplar and also birch, refiner groundwood from mixed hardwoods or from pure poplar is not made commercially in Canada, and only to a small extent (from trembling aspen) in the United States.

The term "supergroundwood" was first applied (Neill and Beath 1963) to the superior pulps obtained by the direct disk refining of wood chips. More recently, the term has also been applied to chemi-mechanical pulps prepared from poplar by the disk refining of chips which have previously been submitted to a mild chemical treatment with a solution containing sodium hydroxide and sodium sulfite at a concentration such that about 2% of each is taken up by the wood (Richardson and Le Mahieu 1965). In the United States there are at present two commercial systems producing this type of chemi-mechanical pulp from aspen (R.A. Leask, personal communication). The processes differ only in the conditions used for the chemical treatment. In one, a temperature of 170F (about 77C) and a pressure of 60 psi are applied for 15 min (Richardson and Le Mahieu 1965), while in the other system the impregnation is carried out at atmospheric pressure and the retention time is 30 min instead of 15 min. Chemical treatment prior to refining leads to pulps which have higher bursting and tearing strengths at a given freeness but lower bulk, opacity and brightness than those prepared by direct disk refining (Table 7). Bleachability also decreases as the consumption of sodium hydroxide increases.

TABLE 6. PROPERTIES OF GROUNDWOOD PULPS[a]

	MINIATURE GRINDER						MILL		
	Hybrid Poplar		Trembling Aspen		Spruce		Trembling Aspen	Spruce[b]	
								Average	Range
Wood Density, lb./cu ft	20	20	25	25	26	26	-	-	-
Wood Moisture, %	56	56	55	55	54	54	-	-	-
Grinding Pressure, psi	24.7	30.0	24.7	27.3	32.6	37.9	-	-	-
Production, od Tons/sq ft/24 hrs	0.46	0.86	0.98	1.54	2.12	2.63			
Hp Days/ad Ton of Wood	240	176	116	90	83	76	-	75	-
Screened Pulp Characteristics:									
Freeness, ml Can Std	55	90	73	143	116	164	82	87	66-108
Burst Factor	11.2	10.4	12.7	11.9	17.4	14.5	9.3	16.3	13.5-18.7
Tear Factor	38	38	42	57	64	52	25	41	38-47
Breaking Length, metres	2850	2510	3100	2730	3980	3400	2190	3210	2865-3620
Bulk, cc/g	2.45	2.60	2.41	2.55	2.49	2.81	2.45	2.44	2.15-2.68
Brightness, G.E., %	61.4	65.9	70.9	68.4	63.1	61.2	57.6	-	-

[a]Data from de Montmorency and Stone (1959).

[b]The properties of commercial spruce groundwood pulps are quoted from test data obtained recently in the laboratories of the Pulp and Paper Research Institute of Canada by W.H. de Montmorency. The values differ slightly from the older data given by de Montmorency and Stone (1959).

TABLE 7. POPLAR - CHIP GROUNDWOOD AND CHEMI-MECHANICAL PULP[a]

Sample No.	Treatment	Refiner Brake Hp Days/ad Ton of Wood	TAPPI Standard									
			Freeness, ml Can Std	Burst Factor	Tear Factor	Breaking Length, m	T.E.A.[b] ft lb./sq ft	Stretch, %	Bulk, cc/g	Brightness, % As Delivered	Brightness, % pH 4.5	Opacity
1	Direct disk refining of poplar chips	87.0	143	7.8	34.9	2440	-	-	2.49	58.9	60.1	96.9
2	2.4% NaOH + 2.3% Na_2SO_3, 30 min, 175F, atmospheric pressure, then disk-refined	52.6	129	19.7	63.0	3750	1.02	1.4	2.02	64.0	63.8	91.0
3	Sample 2, bleached with 0.6% H_2O_2	52.6	112	22.8	57.8	5400	2.03	1.6	1.94	73.0	73.0	84.5
4	2.7% NaOH + 4.1% Na_2SO_3, 10 min, 173F, 60 psig, then disk-refined	55.5	190	15.9	56.0	3780	1.36	1.6	2.16	66.0	66.0	89.0
5	Commercially produced poplar chemi-mechanical pulp	65	140	21.2	62.7	4200	26.2	2.7	2.00	55.5	56.5	88.5
6	Spruce stone groundwood (Typical book grade)	-	76	13.1	45.0	3850	-	-	2.47	60.0	-	96

[a]Data supplied by Leask (1967).

[b]The tensile energy absorption is not TAPPI Standard.

Although such processes are not yet (in 1967) applied commercially to hardwoods in Canada, they offer interesting possibilities which may well lead to increases in the use of poplar by the pulp and paper industry.

Neutral sulfite semi-chemical pulping (NSSC)

There is a steady demand for poplar, especially in eastern Canada, for use in neutral sulfite semi-chemical pulping. This process involves treatment of the chips with a solution of sodium sulfite buffered with sodium carbonate to a pH close to neutrality. Conventional NSSC cooking involves a maximum cooking temperature of 170-180C, a total cooking time of 3-5 hours, and a sulfite to carbonate ratio of 3:1 (pH 8.5). Continuous vapor phase NSSC pulping may use a temperature as high as 200C, and cooking times may be reduced to 10-20 min (Rydholm 1965, p. 422). These treatments weaken the interfiber bonds, and the softened chips are then defibrated in disk refiners. Such pulps, typically produced in yields ranging from 70-85%, contain a high percentage of lignin and hemicelluloses. Consequently they have comparatively low conventional strength but possess high stiffness -- a quality which fits them for use as corrugating medium.

The NSSC process is more suited to hardwoods than to softwoods because of the lower lignin content of the hardwoods. Poplar, with a lower lignin content even than other hardwoods, is thus a desirable wood for this purpose. It produces a brighter NSSC pulp than do softwoods under the same conditions and its cost per cunit is lower. Vis-à-vis the dense hardwoods, it gives a lower yield per cord but this must be weighed against the ease with which it is pulped by the NSSC process, coupled with its ready availability in certain areas. Few NSSC mills possess barking facilities and poplar is obtained on a sap-peeled basis. One mill reports that the supply of sap-peeled wood is diminishing and that barking facilities will eventually have to be provided.

Some wood mixtures used for NSSC pulping have been reported as follows (percentages in parentheses):

1) Poplar (23); white birch (19); yellow birch (34); maple (15); other hardwoods (5); softwoods (4). In this case the poplar consisted of trembling aspen (80); largetooth aspen (15) and balsam poplar (5).

2) Poplar (50); elm (15); maple (15); birch (10); others (10).

The pulps made from such mixtures are destined almost entirely for use in corrugating medium. The operation of a mill producing 54,000 tons per year of 9 pt corrugating medium by the NSSC pulping of a wood mixture containing 38% poplar has recently been described (Anon. 1966). Other NSSC pulps, made from mixtures of poplar with softwoods, are used as a filler for newsprint. One mill is currently (1966) using about 18,000 cords of poplar per annum (60% trembling aspen, 40% largetooth aspen) pulped as a mixture of 75% poplar with 25% spruce-balsam. The pulp is used in standard newsprint, the furnish containing 12% poplar as NSSC pulp.

DEFIBRATION AND EXPLOSION PROCESSES

As shown in Figs. 3, 4 and 5, a small amount of poplar is used in these processes. The quantities reported for Ontario for 1963 and 1964 are erroneously high, probably because they included some poplar used for the manufacture of particle board. This is not a true pulping process because it does not involve the weakening or breakage of interfiber bonds. Most of the poplar reported as used in defibration and explosion processes is probably destined for such products as Masonite. In the Masonite process, the wood chips are rapidly heated to about 200C with high-pressure steam and then to 280-285C for a few seconds. Rapid release of the pressure defibrates the wood with explosive violence. The use of poplar rather than other hardwoods for such processes is probably based entirely on considerations of wood costs and availability. In 1965 poplar accounted for about 26% of the roundwood used in Canada under this heading (Table 1) but since the total volume of production was small, the quantity of poplar thus consumed was only about 34,000 cords.

CONCLUSIONS

The use of poplar species as pulpwood in Canada did not increase proportionately with the use of other hardwoods during the period from 1953 to 1965. Although these species are the only hardwoods which have been ground with any degree of success, poplar groundwood is used mainly in toilet tissues and has not been used extensively in newsprint, the major product of our pulp and paper industry. Poplar does find application as a newsprint filler when pulped by the NSSC process, but the main use of poplar NSSC pulp is as corrugating medium. It is possible that the disk refining of poplar chips, which produces a stronger groundwood pulp than that obtained by conventional stone grinding, may ultimately lead to increased use of poplar groundwood, but this process has not yet been commercially applied to poplars in Canada.

Poplar has also failed to keep pace with the rapidly-growing production of kraft pulp in Canada, mainly because it offers insufficient advantages over mixed hardwoods for this purpose. On the west Coast, poplar is in high demand, but in eastern Canada, increased use of poplar will depend largely on successful competition with other hardwoods.

ACKNOWLEDGMENTS

I wish to thank the staff of fifteen Maintaining Member Companies of the Pulp and Paper Research Institute of Canada for completing and returning questionnaires on the use of poplar, and for answering more detailed enquiries. This report was prepared after discussions with several members of the Institute staff. I acknowledge their help, and in particular wish to thank R. Poole, who prepared the graphs and assisted in the processing of data, and W.H. de Montmorency, who collaborated in the preparation of the section on groundwood.

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Anon. 1965. Canadian forestry statistics. 1962, Ind. Div. Cat. No. 25-202. Dom. Bur. Statist. Ottawa.

CHAPTER XI

UTILIZATION OF POPLAR IN FIBERBOARD AND PARTICLEBOARD

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INTRODUCTION

In surveying the utilization of poplar in the Canadian manufacture of fiberboard and particleboard, it is relatively straightforward - though not necessarily easy - to establish what is being done and what is planned. All one needs is a good deal of correspondence, wires and phone calls, good cooperation from a fairly large number of busy mill managers who normally dislike being bothered with questionnaires, several sharp pencils and an uncanny knack of 'guesstimating' missing figures. Some earlier surveys of this general topic (Burns 1966; King 1956) do not focus sufficiently on poplar. We have now tried our hand at such a survey and will present the results, but with no claim to being statisticians. When it comes to completing the picture, however, and surveying its potential, it is necessary to look more deeply into the nature and requirements of the particular processes and products involved and the properties of poplar itself when used in these processes.

As a general reference, Fig. 1 shows very briefly the main steps in the several major panel-type fiberboard and particleboard processes currently being used. The key paths show the routings to follow for each of the listed processes. For example, the S-1-S (smooth-one-side) wet hardboard process consists of chipping, fiber preparation (usually steam cooking and mechanical refining), washing and chemically treating the furnish (resins, sizes, pH adjusting chemicals), forming the mat, cold pressing, hot pressing the cold pressed mat (on a screen), post-baking or tempering the pressed board and fabricating and finishing. Wet process S-2-S (smooth-two-sides) follows the same initial paths to the cold pressed mat but then the mat goes into dryers where the moisture content is reduced to a low value. The mat is then hot pressed at high temperature and pressure at short cycles without a backing screen. It then rejoins the S-1-S process flow for post-treatment, fabrication and finishing. Insulation board follows the S-2-S wet process but does not go through the hot pressing stage. Particleboard is a dry process and follows a different process of particle preparation, furnish treatment and mat formation. However, it then goes through the hot pressing and post-hot press treatments, though, of course, employing different techniques.

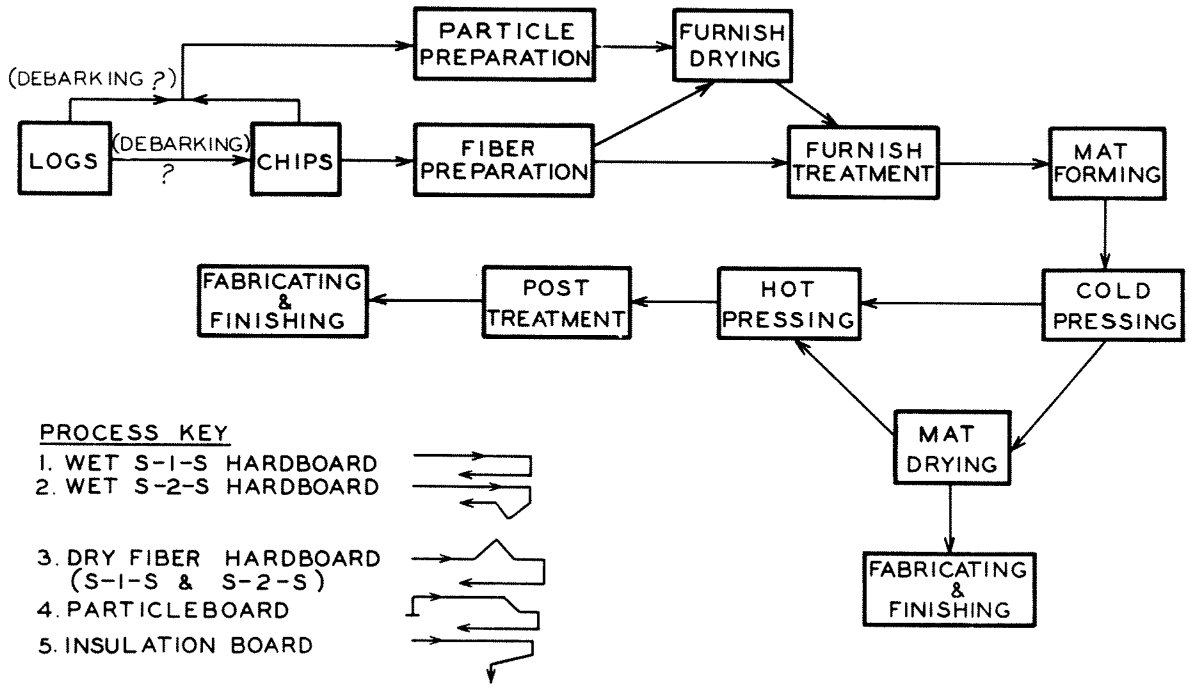

Figure 1. Schematic flows of major panelboard processes.

For the purposes of this paper, we will deal mainly with the potential of poplar in wet process hardboard, since this is where the main chance for increased poplar utilization and also the main uncertainty in poplar suitability seems to lie.

CURRENT AND PLANNED UTILIZATION

By written questionnaire and telephone, a survey was conducted in January 1967 of all the major Canadian hardboard, particleboard and insulation board mills known to us. In all, five hardboard, nine particleboard and ten fiber insulation board mills were contacted. Our questions covered not only amounts of poplar used but forms used, future plans and operating advantages and disadvantages being experienced with poplar.

Replies showed that the vast majority of Canadian particleboard is made of 100% poplar; Canadian fiber insulation board is generally better than 50% poplar but seldom 100%; and Canadian hardboard, surprisingly, contains from 0 to only 22% poplar at most. The latter finding is all the more surprising when we consider that poplar constitutes the main species for several large hardboard operations immediately south of the Canadian border in the Wisconsin, Minnesota, Michigan area. Single mills alone there use several times the total Canadian consumption of poplar for hardboard. Is this rejection of poplar by Canadian hardboard manufacturers based on adverse operating experience in Canadian mills, or is it due to other local circumstances of availability or economics? The survey suggests some evidence of technical difficulties with poplar in hardboard (which will be dealt with later) but also suggests that the low consumption is as much or more due to local reasons of availability and use priority.

Figures 2 and 3 show 1966 total annual Canadian production and poplar consumption (from our survey) respectively in each of the three industries, with projections compiled for the immediate future (1967). Our production projection figures are derived from trends and annual increases in these industries over the past several years. Poplar consumption projections for 1967 are based on mill intentions as reported to us through our questionnaire.

Figure 2 shows annual production reported in square feet of the various equivalent thicknesses selected by the industries and because of this, the overall comparative magnitudes of the bar graphs must not be taken as a measure of the comparative wood usage of the particular industries. Such an interpretation (on a weight basis) is approximately correct for the hardboard and insulation board bars since 1/8-inch hardboard and

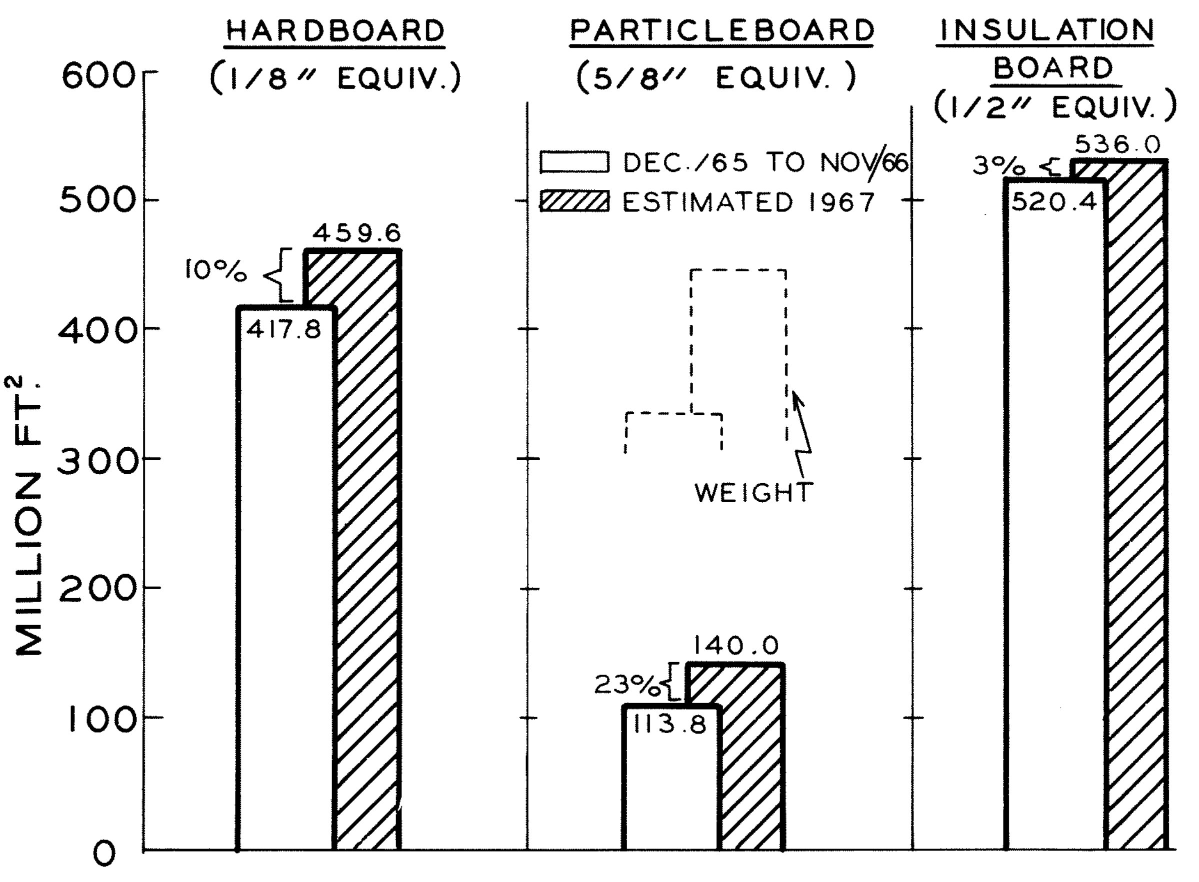

Figure 2. Annual Canadian production in square feet of various equivalent thicknesses. Based on Dominion Bureau of Statistics Production Reports, Dec. 1965 - Nov. 1966.

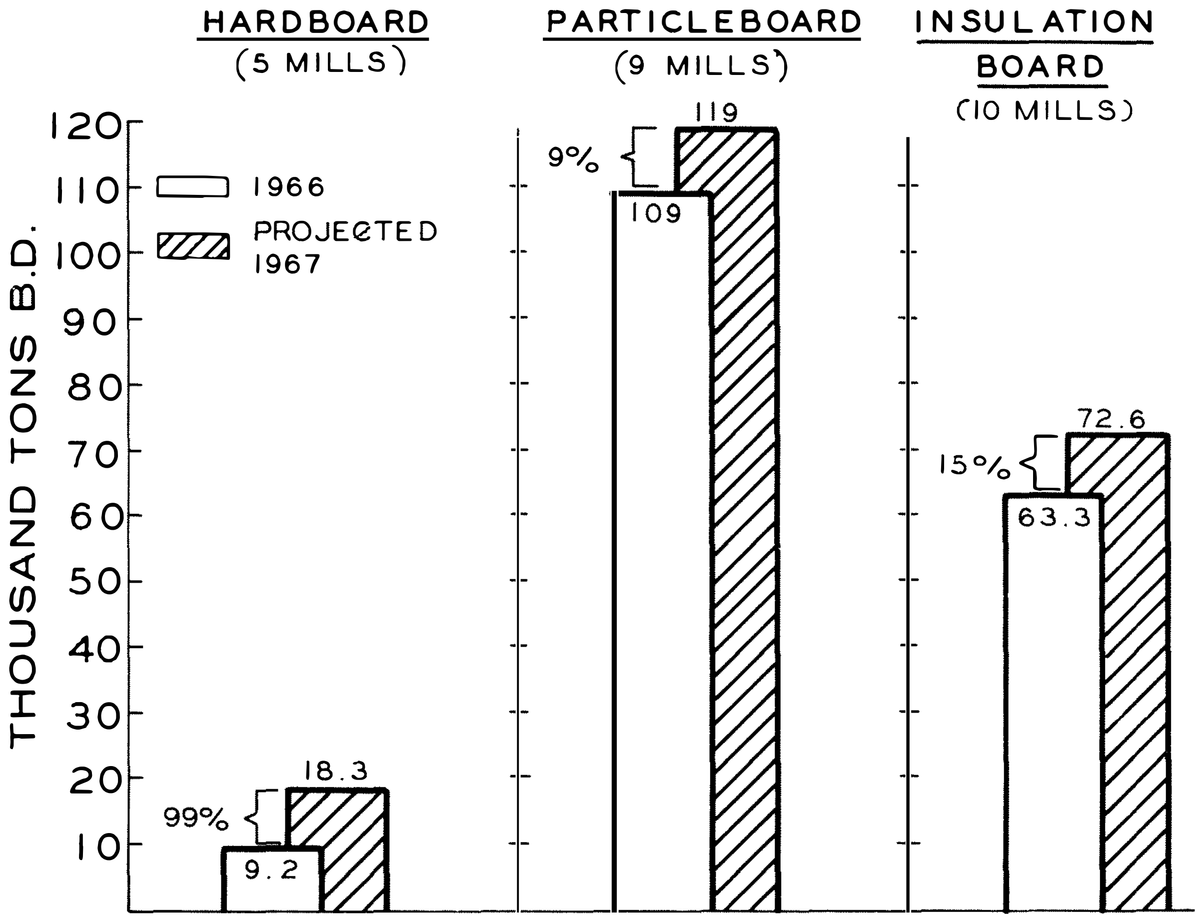

Figure 3. Canadian poplar consumption in dry tons with bark. Based on Dominion Bureau of Statistics Production Reports, Dec. 1965 - Nov. 1966.

1/2-inch insulation board on the average have roughly the same basis weight, i.e., 700-725 dry pounds per thousand square feet. However, the basis weight of 5/8-inch particleboard at approximately 2000 pounds per thousand square feet is three times that of 1/8-inch hardboard and 1/2-inch insulation board. If we magnify the particleboard production bar by a factor of three (dotted bars in Fig. 2) then the relative wood consumption of the three industries on a weight basis becomes apparent and we see that they run fairly close to each other.

Poplar consumption (Fig. 3) - perhaps the more interesting for this symposium - is shown on a directly comparable moisture-free weight basis. In compiling these data from questionnaire replies, we used the following volume-weight conversion units for poplar:

1 cord (with bark) = 0.80 cunits (no bark)
1 cord (with bark) = 1740 lb. dry (with bark)
1 cunit (no bark) = 1.09 tons dry (with bark).

It will be seen from this graph that although we foresee a doubling of poplar consumption in 1967 for Canadian hardboard, the total amount used in that industry will still be only one-seventh of that consumed for particleboard and a little more than one-quarter that used in insulation board. The big poplar increase in the hardboard industry is mainly due to a new mill start-up in 1967, though there were also indications in our survey that some increase in percentage poplar usage was being contemplated by others. There were major variations from mill to mill in their reported plans for poplar usage in insulation board in 1967.

Other interesting facts brought out by our questionnaire were:

- In all three industries poplar is mainly procured in the unbarked log form. Two particleboard mills purchase peeled logs and one a small amount of veneer cores.
- Poplar bark is generally used in the furnish by hardboard mills and by all but one of the poplar-using insulation board mills. However, only about half of the particleboard mills use the bark in their board.
- The poplar species used in all three industries is predominantly trembling aspen with some largetooth aspen.
- Major advantages of poplar for particleboard manufacture cited included low density and hence good compactability, light color, and availability. Problems mentioned were higher glue consumption and longer press cycles.
- Insulation board mills reported good results with poplar up to 75% of furnish but beyond this problems are encountered with low product strength and with formation.
- For hardboard, some difficulty was reported in sizing poplar furnish and with slow draining fiber stock.
- Several mills reported trouble with barking frozen poplar.

WET PROCESS HARDBOARD

Though poplar is a broad-leaved, deciduous tree we do not regard it as a "hardwood" since it behaves and exhibits properties in the wet hardboard process more like a hybrid of the softwoods and the usual heavy hardwoods. This is one of its desirable features since it is less sensitive in defibration than the sometimes tricky heavy hardwoods and yet more easily defibrated than the more stubborn softwoods. It is thus easier to maintain consistent pulp quality and hence product uniformity with poplar. Such uniformity is most important in many of today's industrial hardboard markets. In specific gravity, 0.37 to 0.42, it is also not extreme, thus making it versatile and usable for both low and higher density products (fundamentally it is difficult to make a low density composite board out of a high density wood). Similarly, bulk of the formed poplar mat is a reasonably happy medium between the bulky softwood extreme which can cause consolidation and handling problems and the dense hardwood extreme which often creates caliper control and pressing difficulties. Formation clotting, a basic phenomenon with all wood fiber webs which causes the "mottle" in paper and the "hammer" in hardboard, is much less severe with poplar furnish than with most softwoods though still a little worse than with the shorter fibered heavy hardwoods, such as oak.

Though hardboard furnishes are usually bolstered with added binder and size to provide the final desired end use physical properties, nevertheless the wood species acts as the starting point. In basic strength and water resistance property potential, poplar again occupies an average position. This can be seen in Figs. 4 and 5 which show the results of some fundamental species studies performed in our research laboratory. In each case the species was steam-cooked, defibrated and processed into S-1-S wet process hardboard by conventional means but with no chemical additive or post-press treatment of any kind. The water resistance test comprises 24-hour immersion under 1 inch of water at 70F. These figures also show the effect of the inclusion of bark on the strength and water resistance properties of the resultant boards. Again, poplar shows up favorably compared with other species.

In other more recent basic studies (Goring and Baldwin, In Press) a pronounced beneficial effect on wet pressed fiber to fiber bond strength development with steam cooking was found with poplar which was not as evident with, for instance, spruce -- again indicating the favorable nature of poplar as a species for wet process fiberboard manufacture.

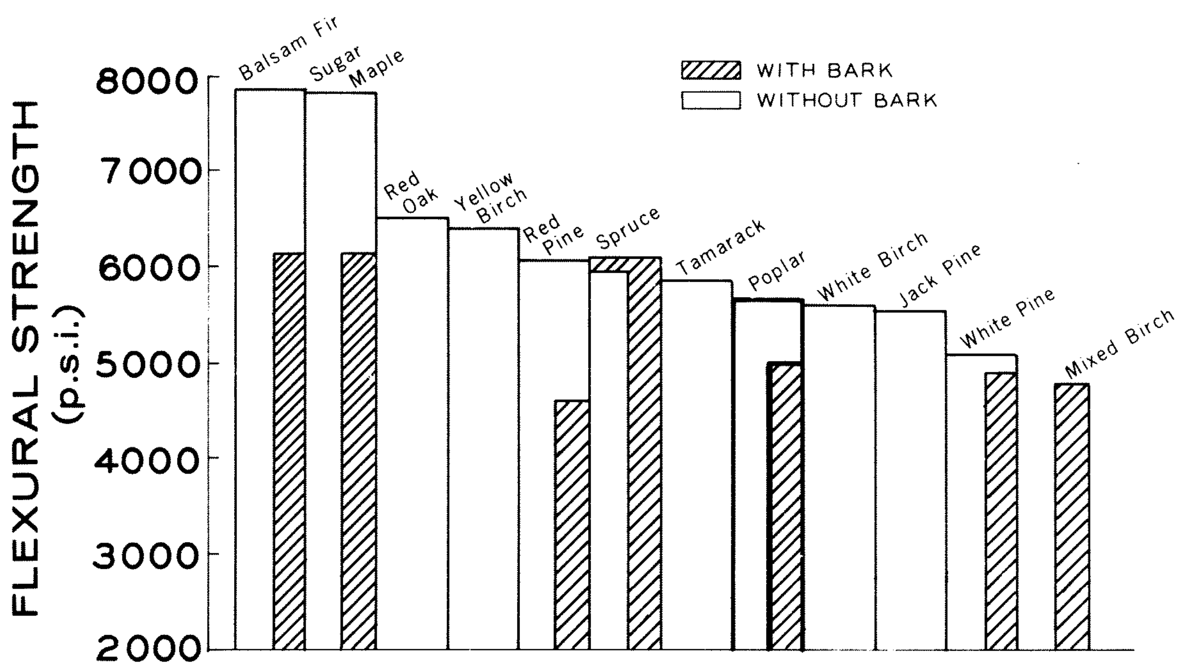

Figure 4. Comparison of strengths of basic species.

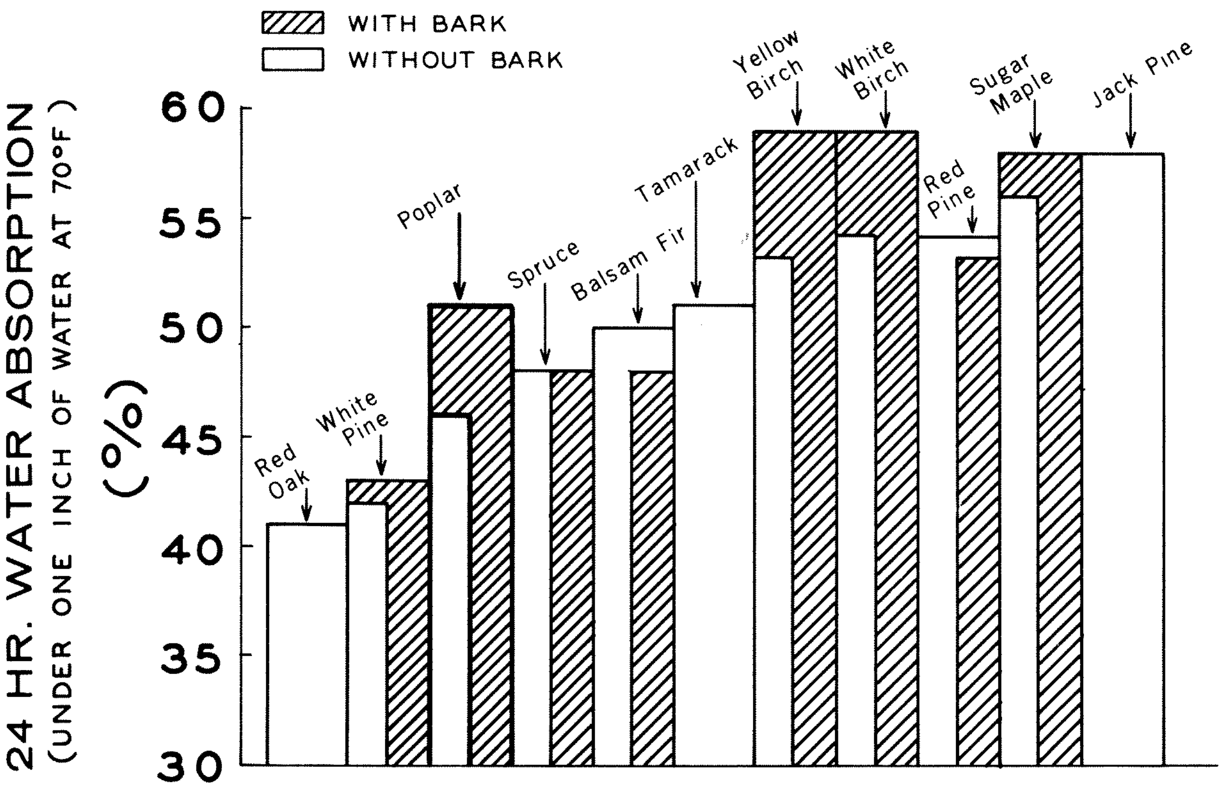

Figure 5. Comparison of water resistance of basic species.

One negative point against poplar's general wet process performance is that while uniformity can be maintained, the stock tends to drain slowly, due to fines generated in defibration. This reduces forming machine speed, increases the tendency to blister during hot S-1-S pressing of the wet mat and necessitates lengthening of the press cycle somewhat to avoid such blistering - thus adversely affecting production rate. In the S-2-S process, the slower forming speed remains a disadvantage but the blistering tendency and the effect on press cycle are not problems since the mat is essentially dry when hot pressed and hence the critical in-press drainage factor is removed.

Generally speaking, the inclusion of bark in hardboard furnish is detrimental to product quality. It is economically desirable, of course, to use it and it can generally be tolerated in S-1-S board grades destined for general purpose markets where the resultant lowered strength and paintability and the increased grittiness of the screen side are not serious. However, in the manufacture of S-2-S hardboard, surface finishing properties are of prime concern since this board goes into the demanding tileboard and furniture markets where it is enamelled, grained, printed, etc., with fine decorative finishes. Here it is imperative that surface defects such as raised spots, pits, unpaintable material, be eliminated and most of these defects are caused by bark particles. If 100% bark removal could be economically achieved, almost any wood species - at least hardwood - could probably be successfully used for S-2-S hardboard. However, since such complete bark removal is extremely difficult and costly, we naturally favor wood species where bark is both more easily removable and least objectionable in the process. Poplar is one of these - though in our case, even with poplar we had to install a Centricleaner operation in our Alpena, Mich., S-2-S mill to remove the resinous sclereid particles which occur in the poplar bark. These caused prohibitive pin-holing in our board surface when they stuck to the hot press platen surfaces, were pulled out of the board and then were impressed into subsequent boards. Figures 6 and 7 show the defect and the bark particles in question. The remedial cleaning approach solved our problem because the objectionable poplar particles were amenable to such centrifugal cleaning action. The same approach would not have worked satisfactorily with the barks of such species as birch or oak - both of which are equally objectionable in the board. Such a properly cleaned poplar S-2-S board is a premium product on today's market for finishing purposes.

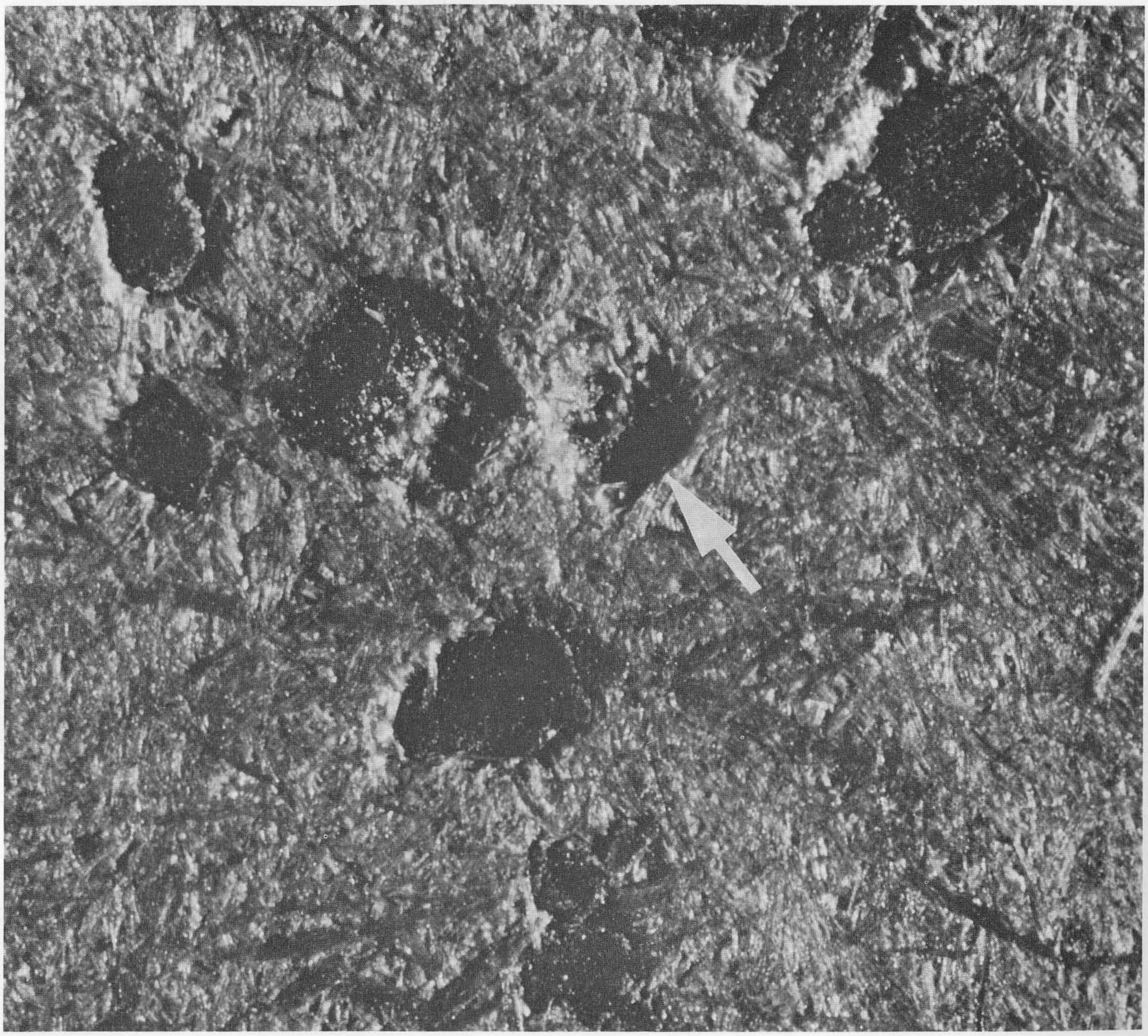

Figure 6. Pit-holes left in surface of hardboard sheet when speck pulls out in press (arrow) and "moats" left around periphery of imbedded specks. X 35.

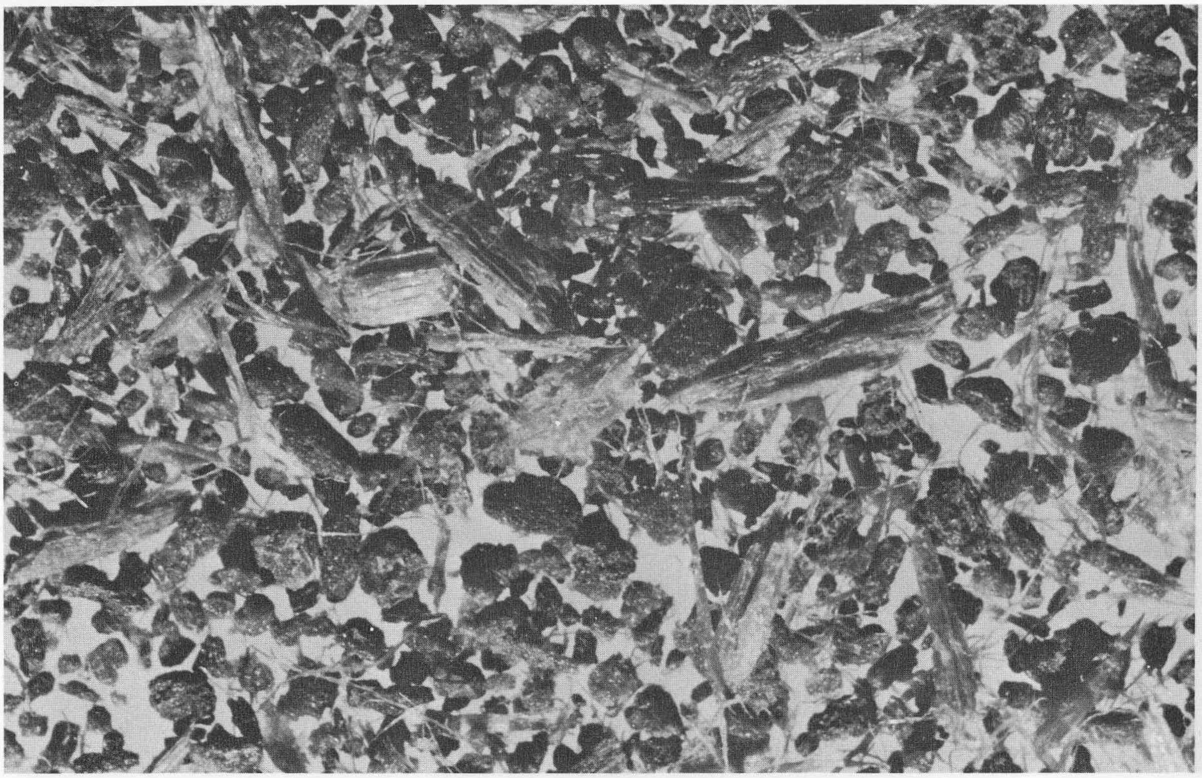

Figure 7. Concentrated centricleaner rejects showing resinous sclereid particles from poplar bark. X 15.

FORESTRY AND WOOD HANDLING

We have been discussing the behavior of poplar in the board manufacturing process itself. From the forestry and wood handling viewpoint, poplar exhibits interesting characteristics and some important advantages.

It is well recognized that reconstituted wood products such as fiberboard and particleboard are ideal for poplar utilization since these industries do not demand large premium logs. By the time poplar gets to large log size rot usually sets in. Foresters in our Alpena, Mich., operation report that if properly cut, poplar will reproduce strongly and quickly at relatively low cost. Wherever possible they prefer clear cutting, which will result in regeneration by root suckers in 40 years to 8 inches dbh. Our average use diameter currently runs about 6 1/2 inches and we accept any 100-inch stick having a minimum diameter of 4 inches at the smaller end. They estimate that if thinning of regenerated clear-cut stands were economically feasible, i.e., if a suitable market were found for the thinnings, the cutting cycle might be as short as 20 years.

Poplar is fairly straight, limbs easily, and barks easily (except when frozen). It is believed that the high moisture content (100-120% on oven-dry weight basis) is an aggravating factor in the latter as well as a detriment in the particleboard furnish drying stage. Poplar will rot rather rapidly if left to lie in moist conditions, and once this degrading process begins excessive wood loss is suffered at the barkers and eventually the wood will break up. Hence poplar should not be run on a long stock-pile storage system.

A further forestry factor exists in our Alpena, Mich., operation which may be novel to the Canadian scene. The woodlands in the lower Michigan peninsula are privately owned by hunt clubs and we purchase our wood from these lands. Thus forestry practices must also be geared to the recreational use of the land, which means the management and support of the large deer herd in the area. Here again poplar has proven to be a preferred species since it is a good deer food as well as a good raw material for fiberboard. The problem is to grow it in a way which will keep both the game managers and the mill managers happy. Shorter cutting cycles would be one way to please both.

CONCLUSION

In summary, we believe the following can be said about poplar utilization.

1. Far from its original "weed species" role, poplar is now a species of major importance for fiberboard and particleboard manufacture.

2. Poplar is an excellent wood for particleboard and Canadian manufacturers have fully recognized this fact in their operations - four major mills are using 100% poplar furnish.

3. Poplar is a major species in the manufacture of Canadian insulation board, usually comprising at least 50% of the furnish, but is almost always used in conjunction with other species, usually softwood, mainly for strength improvement reasons.

4. Poplar is not a major factor in the present Canadian hardboard wood supply picture, the highest content at any mill being only 22%. We feel that its potential here has not yet been realized. It is a particularly good wood for high quality wet process S-2-S hardboard but this process is not presently being used in Canada.

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CHAPTER XII

UTILIZATION OF POPLAR FOR PLYWOOD AND LUMBER

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INTRODUCTION

The lumber and plywood industry of Canada has an entrepreneurial base. Most of the firms operating in Canada in 1967 owe their beginnings to the hard work and enterprise of an individual or group of individuals as most lumber and plywood companies began as small private companies. Because the embryonic pioneering approach to developing natural resources is different than the approach traditionally taken in Canada's pulp and paper and mining industries the patterns of development and growth have also been quite different.

Today, many of our larger plywood and lumber companies are publicly owned and a few of them are world corporations. The species innovation in the industry continues to come from the private firm, partly because the smaller firms do not have substantial timber resources of presently favored species, and also because the individual sawmill operator has been first to locate on the furthest fringe of existing transportation networks. For these reasons, poplar utilization has progressed furthest in Canada in the lumber and plywood industry. In both these industries most of the manufacturing for many years was carried on by smaller firms and in some cases it was this start which allowed the firms to grow and diversify eventually into other species as their source of supply. For the same reasons the development of the poplar lumber and poplar plywood industries has been uneven, and the future is somewhat uncertain. Although there are several medium-sized firms (annual sales of over 2 million dollars) that utilize poplar as their main timber supply, no large firm today in the lumber and plywood industry is heavily committed to poplar and the industry's largest firm has recently begun reducing its production of this species.

The challenge and appeal which the tremendous quantities of poplar in Canada have for the entrepreneur is undeniable, yet the uneven results that have been obtained, the relatively low utilization still being realized and the inclination of those companies already in poplar production to diversify out of the species are all indicators that the lumber and plywood companies of Canada have not found poplar to be a satisfactory, long term investment.

HISTORICAL

Lumber

In both eastern and western Canada, some poplar lumber has always been manufactured from large trees while logging primarily for other species. No exact record has been kept of the development of poplar lumber, but packing cases made from poplar lumber were certainly produced on a small scale in the 1920's, and for many years poplar timbers or half sawn logs were a favored material for stable floors because it was believed to be a very tough wood. However, no sawmill in Canada has ever cut more than 10,000 cunits of poplar in a year. One or two companies in Ontario tried to set up small units with drying facilities specializing exclusively in poplar, but these plans were short-lived and soon the mills were converted to a mixture of species, with the poplar content being less than 3,000 cunits per year.

The technical problems involved in producing poplar lumber were never very difficult to solve if someone wished to apply himself to the problem. Poplar lumber had a reputation for twisting, which was probably well deserved because of the large quantities of tension wood in almost every tree. Cottonwood trees in western Canada had a substantial amount of ring shake which made sawing difficult, but wide boards could be produced by a good sawyer from most of these large logs. In the 1950's several mills decided that drying facilities were essential if the large United States market for inexpensive lumber was to be tapped. In many cases this poplar had to compete against undried southern hardwood species such as gum and the extra cost of drying could seldom be made up in freight savings.

Occasionally a lumber producer would be excited by the possibility of producing clear lumber for industrial use, particularly in the furniture market, and a few thousand cunits would be brought into the plant in an attempt to high-grade out the best material. A lot of excellent clear lumber was produced but most mills found that their recovery from both aspen and cottonwood logs was too low to justify their continued effort.

Plywood

The history of the poplar plywood industry is quite different. In 1932, a Russian immigrant named Dvorjetz produced commercial quantities of poplar plywood at New Westminster, B.C., but a few years later moved his plant to Nelson, B.C. This first operation was short lived, but the example wasn't lost on Mr. John Bene, a Czechoslovakian, who arrived in Canada with a background in European poplars. When Mr. Bene started his own firm, Western Plywoods Limited, in Vancouver, B.C., in 1945, he concentrated on producing high grade plywood having poplar faces and a softwood core. The panel was aimed at the furniture and cabinet producers who were dissatisfied with the heavy grain of fir plywood. The product's unique qualities soon won many buyers. Utilizing black cottonwood from the lower Fraser Valley area, Western Plywoods continued to grow, and, incidentally, to expand into other species, culminating their poplar efforts in 1956 with a mill in Edmonton designed to use poplar exclusively. Since that time, this company has expanded production into the province of Ontario but has cut back the level of its poplar plywood production in Alberta and British Columbia.

About the same time as Mr. Bene was outflanking the existing fir plywood producers in Vancouver by using poplar, Mr. M.A. Rogers from Edmonton, Alta., who had been peeling small quantities of veneer in a millwork shop in Edmonton, together with others, started the Hamjea Plywood Company at Hudson Bay, Sask., to utilize extensive aspen stands in the area. They produced their first plywood in 1948.

These first ventures were amazingly successful; but the whole construction plywood industry in those years was quite profitable and it is difficult to say that the poplar plywood manufacturers were any more successful than the traditional fir plywood manufacturers. In any case, poplar plywood became better known in the major markets of eastern Canada and imitators quickly followed. The mill at Hudson Bay, Sask., had been producing 4 by 4 foot plywood panels with a single 4-foot lathe and very basic plywood equipment. A better 4-foot mill was established in 1952 at Prince Albert, Sask., and, at about the same time, an 8-foot mill was started in Grande Prairie, Alta. Shortly after this the Forest Products Laboratories published their definitive work on the peeling of poplar for plywood production (Irwin and Doyle 1961), and soon other mills were being established in Ontario, Quebec and the Prairie Provinces. In the last 10 years, as many as 18 poplar plywood plants have been in operation in Canada, but only 10 of these plants were operating in 1967, and only half of these list poplar as their primary species. This is mainly attributed to erroneous estimates of the poplar resources suitable for economic plywood manufacture.

PROBLEMS IN UTILIZATION

Resource estimation

The National Forestry Conference meeting at Montebello, P.Q., February 1966, compiled some figures suppied by the Forest Resources Inventory (F.R.I.) of the various provinces, and concluded that the allowable cut of poplar in Canada was 15 million cunits per year, the second highest allowable cut for any species. The kind of optimism and promise indicated by these figures permeates down through all levels of government until at the local level, available figures for almost any community in the Boreal Region of Canada indicate that substantial quantities of poplar are there for anyone who can invent a commercial application. The local representatives of forestry departments will be enthusiastic about the quantities of poplar shown on inventory maps and will give figures which the novice considers accurate, or even understated for veneer bolts because cull figures of 50% have been applied in arriving at the total poplar resource of the area. However, subsequent experience by plywood manufacturers indicated that the poplar stands were grossly over estimated for veneer bolts.

This over estimation is not limited to poplar veneer bolts, as there are also examples of lumber companies operating in areas for poplar lumber where the actual sawlog production was much less than estimated. Many pulp companies have found, at least in northern Ontario, that the available poplar pulpwood was substantially less than they had been led to believe by the F.R.I.

The entrepreneur and the local Chamber of Commerce planning a plywood mill are of course, not only too impressed by the figures of the F.R.I., but also by what they had seen with their own eyes. "Everyone" knows of large stands of poplar where the 20-inch stems rise straight and clean 50 to 80 feet before breaking into a small crown. In British Columbia the fertility of the soil makes the trees even bigger. In hardwoods straight clean logs are rare, and only the slightest encouragement by the Industrial Development Bank or some finance company will get the local group of investors into the plywood business.

Wood decay

It was not until later that some of the structural problems of Canada's poplar inventory became evident to the individual plywood plants. It was soon realized that not more than one-half of even a good tree could be utilized as a veneer bolt. The rest of the tree wasn't too small, it was usually too rotten. Secondly, some of the trees were so rotten that they might not contain even one veneer bolt, and cutters are cautious about cutting trees that do not have at least two 8-foot veneer bolts in them. Therefore, large stands of poplar that had appeared to be sufficient for many years' cutting were soon depleted, and the companies had to go further afield. This low volume of veneer bolts per acre was the cause of rapidly increasing log costs for producers in the prairies and eastern Canada, and poplar's one major advantage -- its logs cost less than coniferous species - soon disappeared. When this happened, the poplar sheathing mills, particularly in the Edmonton area, were pressured into other species when it was found that other coniferous species besides fir made excellent plywood, particularly spruce. The customer would also pay more for spruce than poplar because, although the species was knottier than poplar, the knots were much smaller and therefore more attractive in sheathing.

Resource ownership and availability to manufacturers

In eastern Canada a second problem existed because of the dominant ownership position of the large pulp and paper companies. The use of poplar by the pulp and paper companies in eastern Canada and on the prairies is very small -- only one company cuts more than 20,000 cunits per year. Some of the best poplar occurs in mixed stands with other pulpwood species or on ridges, which are attractive for building roads. Because poplar has very little economic value for these owners, large quantities of the poplar allowable cut suitable for veneer bolts will be bulldozed to make roads or damaged when the coniferous species are taken out. Because Ontario and Quebec have no strong logging integration legislation, these practices will continue; in my estimation at least half of the poplar in Ontario and Quebec is not available to the plywood companies because it is mixed with other species in areas over which plywood companies have no rights.

We see, therefore, that not only do the mature poplar stands in Canada contain less than 25% veneer bolt material, which is the major economic use for mature poplar, but over half the mature poplar occurs in mixed stands or in small patches on areas owned by people who have little or no interest in poplar utilization. Assuming these figures to be approximately correct, the amount of poplar available for lumber and plywood production would therefore be not more than 12% of the gross poplar volume of all mature poplar on favorable sites.

Deterioration of present resources

A third problem is only now beginning to be felt by the plants in existence for 10 years or more. Traditionally, pulpwood or sawlog producers are used to working with coniferous stands that have relatively long lives, a slow rate of decay and a relatively even distribution of age class throughout the stand. Poplar is just the opposite. On an excellent aspen site in Ontario, Quebec or the Prairie Provinces, the poplar begins to deteriorate when about 100 years old and the stand is almost useless by the time it is 125 years old. Because of its growth rate, the stand couldn't be cut before it is 75 years old, and this leaves less than 50 years during which the poplar stand is merchantable. A further problem is that most of the large poplar stands were established at the end of the last century. Settlement fires and railway fires were major causes of the largest and some of the best poplar stands over the Boreal Region of Canada today; such fires are not reoccurring to the same extent as previously. Even if the fires did occur, in many cases the governments rush in with their coniferous seeding programs to ensure that the traditionally economic species are reproduced. Logging cutovers from both pulpwood and saw timber harvests were another source of poplar stands of today, but the increased planting programs of the provinces mean that most of these are turned over to coniferous plantations even though the site may be marginal for coniferous species. Many members at the annual meeting of the Canadian Institute of Forestry at Fort William in 1965 were surprised to see the Ontario Department of Lands and Forests clearing a relatively good poplar stand to plant coniferous species in an area which many foresters considered a poor coniferous site, and this when the local plywood mill was short of veneer bolts. These factors, combined with the short utilization period for poplar, mean that there are large age gaps in the management plans of the poplar plywood mills. It means that large scale investment cannot be continued and that companies cannot continue to grow because they do not know where their timber will be coming from in 25 years' time.

STATE OF THE INDUSTRY AND A LOOK AT THE FUTURE

The present utilization of poplar in eastern and western Canada has been increasing at a slow rate over the last 10 years, and presently poplar is being utilized for lumber and plywood at the rate of 200,000 cunits per year (Tables 1 and 2). During the recent decline in lumber markets, the price of poplar lumber in the United States industrial market was severely affected and many mills in Canada curtailed poplar production in 1965. The poplar plywood industry has been heavily hit by a recent increase in productive capacity and a general decline in plywood prices due to a lack of growth in plywood markets, but the situation is expected to correct itself by the end of 1967.

Estimates made at the National Forestry Conference would indicate that the consumption of poplar for lumber and plywood could increase to as much as 700,000 cunits by 1975 provided sufficient timber can be made available. In all provinces, much of the allowable cut of poplar exists beyond the present transportation systems, and will not likely be used for many years.

TABLE 1. POPLAR PLYWOOD PRODUCTION ESTIMATED FOR 1965

	Plywood produced sq. ft. 1/4" equiv.	Poplar used cunits
Quebec	20,000,000	10,000
Ontario	72,000,000	36,000
Alberta	62,000,000	28,000
British Columbia	50,000,000	13,000
Total	204,000,000	85,000

TABLE 2. LUMBER PRODUCTION ESTIMATED FOR 1964

	Lumber produced fbm	Poplar used cunits
Ontario	25,000,000	36,000
Other Provinces	15,000,000	22,000
Total	40,000,000	58,000

However, a tremendous waste presently occurs in the practices of companies logging for other species, because poplar has not yet received widespread commercial success. If the trend towards bulldozing merchantable stands and wasting poplar in mixedwood Boreal types can be arrested, and if integrated logging becomes a fact, I would estimate that it should be possible to utilize as much as 1.5 million cunits of poplar per year in the sawlog and plywood industries of Canada by the year 2000. Because these industries have a very high employment factor per cunit used, and because plants are located close to the forests, the establishment of a poplar industry of this size would result in substantially increased local employment opportunities in the forested areas themselves. Furthermore, high quality skills are required in the plywood industry and the high salaries paid for such skills would help to keep highly skilled people in small communities.

If, on the other hand, significant steps are not taken by Ontario, Quebec and the Prairie Provinces some of the existing plants will close, some within a year, and the long term future of poplar, both as a sawlog species and as a plywood species will decline.

At the present time there is a great demand for the large areas of even textured white wood which exists between the dark brown knots of a poplar tree. It will be unfortunate if government cannot combine with industry to ensure that a satisfactory supply is made available to the market.

Looking at the long-term future, it would seem possible to me that reasonably good acreage will earn a high return both in the Clay Belt of northern Ontario and on marginal farm land in the prairies if fast growing poplars were established on a 12- to 20-year rotation. Land available in the Fraser Valley commands a price of $500 to $1000 per acre; at present establishing plantations on these sites would appear to be uneconomic. Good, low cost sites adjacent to existing plywood mills do exist on the prairies and in Ontario, some of it already purchased under the A.R.D.A. program of the federal and provincial governments, and these should be planted now.

If government, as the land owner, will accept responsibility to supply these plywood plants in the future years, the growth of the present industrial units could exceed the growth due to new plant installations, and the more inaccessible stands of poplar might never be required. In the meantime, the poplar plywood industry is rapidly trying to put itself into the position of the poplar lumber industry, i.e., trying to become less dependent on poplar. Unless major programs can be initiated soon by the forest owners, the diversification efforts of the manufacturers of lumber and plywood may become so successful that poplar will once again revert to being a weed species.

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CHAPTER XIII

VENEER AND PLYWOOD FROM TREMBLING ASPEN

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INTRODUCTION

Trembling aspen is one of the most widely distributed species in Canada; it is found from the Atlantic Coast to the Mackenzie River. This timber species is of increasing importance as a commercial wood and the manufacture of veneer and plywood is one of the most recent fields of utilization. To assist in the efficient use of trembling aspen for this purpose, the Forest Products Laboratory at Ottawa has carried out research on the cutting of veneer and the manufacture of plywood from this species. The main part of this study was conducted during the years 1952 and 1953. However, further cutting experiments have been made on this species since that time and a long term study of exterior glue bond in poplar plywood is still in progress.

The veneer logs

The logs used for the primary studies were obtained from Saskatchewan and Ontario. The Forestry Branch of the Saskatchewan Department of Natural Resources provided eight 10-foot logs, chosen as representative of the average quality of veneer logs available to commercial plywood plants. Their diameters ranged from 11 to 15 inches and their general appearance was good. The only external defects were a few knots and slight crooks.

Twelve logs from Ontario were provided by an interested firm. They were chosen not as peeler logs but as being representative of the average quality of logs generally available. Some were high grade logs while others contained numerous knots, ring shakes, crooks, limb scars, and some decay. They were 14 feet long and from 12 to 18 inches in diameter. All logs were sawn to 3- or 4-foot lengths and stored in water prior to peeling.

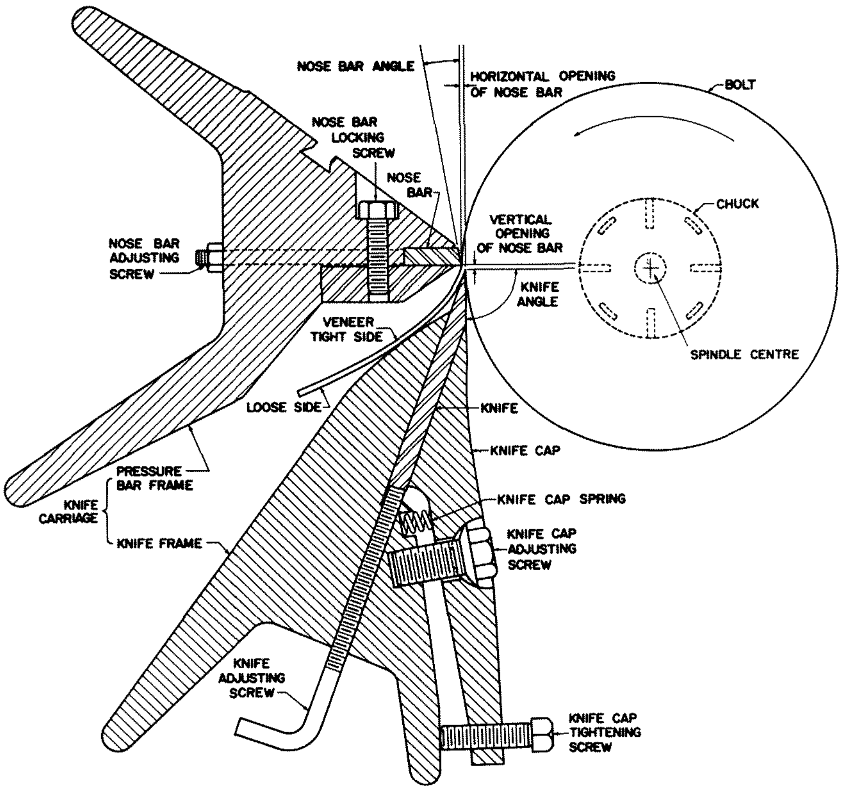

Figure 1. Section of a veneer lathe showing knife and nose-bar positions and adjustments.

ROTARY CUTTING STUDIES

The research method involved separating a number of interrelated variables and assessing the effect of each on the quality of the veneer produced. These variables were:

(a) veneer thickness,
(b) angle of veneer knife at various diameters,
(c) horizontal opening between knife tip and nose bar,
(d) vertical opening between knife tip and nose bar,
(e) knife bevel,
(f) shape of nose bar edge,
(g) bolt diameter, and
(h) bolt temperature.

Lathe knife and nose-bar positions and adjustments are shown in Figure 1.

In these studies the quality of veneer was assessed on the basis of the smoothness, the wooliness, the tightness, and the uniformity of thickness. Two thicknesses of veneer were peeled, 1/16 inch and 1/8 inch. For both thicknesses a medium degree of compression from the nose bar gave the best results. To obtain a uniform quality of veneer all through the bolt it was necessary to decrease the knife angle during the peeling process. Experiments on the effect of the cutting speed showed no difference in quality between veneer cut at 60 fpm or 200 fpm. One of the characteristics of trembling aspen veneer is the frequent formation on its surface of a wood composed of an agglomeration of loose fibers. It was found that practically no wool of this nature was formed when the wood was cut at a temperature near the freezing point but that the amount of wool increased generally as the temperature increased above 32F. However, this wool is only loosely attached to the veneer and, if necessary or desirable, it could be removed easily from the dried veneer by means of a light brushing. If the wool is allowed to remain on the veneer when the plywood panels are assembled, it will be pressed into the surface and, when it falls away, will leave tiny depressions in the faces.

The optimum cutting temperature was found to be slightly above the freezing point, although good veneer can be cut at room temperature (70F). If a bolt is cut while frozen, the veneer contains deep lathe checks extending through its entire thickness and is too delicate to be handled without tearing. For winter operations it would, therefore, be necessary to provide a log storage where the temperature could be maintained slightly above freezing to thaw the logs prior to peeling. From the results of this investigation, and subsequent experience in cutting various veneer thicknesses, the lathe adjustments given in Table 1 appear to be optimum. Nevertheless, before applying the information provided in this table it is important to realize that a lathe, which has been properly adjusted when a new knife or nose bar is installed, may get out of adjustment as soon as the cutting operation is started. This can occur as a result of play in the knife and nose-bar assemblies or, for species which require heating, as a result of heat distortion when cutting hot logs (Feihl 1960).

TABLE 1. OPTIMUM LATHE SETTINGS AND LOG TEMPERATURE FOR ROTARY CUTTING TREMBLING ASPEN VENEER

Veneer thickness (inches)	1/16	1/10	1/8	1/6
Thickness set (inches)	0.062	0.100	0.124	0.166
Knife angle at 24 inches diam.	90°30'	90°30'	90°30'	90°30'
Knife angle at 9 inches diam.	89°00'	89°00'	89°00'	89°00'
Horizontal opening of pressure bar (inches)	0.054	0.090	0.110	0.148
Vertical opening of pressure bar (inches)	0.010	0.020	0.020	0.030
Recommended temperature (F)	32	32	32	32
Maximum acceptable temperature (F)	70	70	70	70

NOTES:
1. Knife bevel = 20°. Concavity of knife face = 0.001 inch.
2. Angle between nose bar face and vertical when bar is in position in the lathe = 14°.
3. The knife angle should decrease steadily during the peeling process.

VENEER YIELD

After the optimum lathe settings had been determined, eight 4-foot bolts from Saskatchewan and twelve 4-foot bolts from Ontario were peeled for the yield study. The volume of veneer and waste obtained is indicated in Table 2.

TABLE 2. RESULTS OF YIELD AND WASTE STUDY ON TREMBLING ASPEN BOLTS FROM SASKATCHEWAN AND ONTARIO

Province	Avg Diam (inches)		Total Veneer Produced	Rounding Waste	Clipping and Trim	Core Waste
	Bolts	Cores	Per Cent of Bolt Volume			
Saskatchewan	12	4.0	69.7	15.6	6.0	8.7
Ontario	14.8	4.5	71.9	13.6	6.9	7.6

The yield of veneer from logs of both sources was approximately the same, i.e., about 70% of the log volume. It is pointed out that these yield figures were obtained under laboratory conditions and are not directly applicable to industrial conditions. If 8-foot logs were peeled instead of the 4-foot bolts cut at the laboratory, the rounding waste would be higher because of a larger difference between the large and small diameters and greater crook and sweep. The clipping waste would be appreciably higher than at the laboratory where a minimum of defects were clipped out. The core diameter would also be larger when peeling 8-foot logs, hence a higher percentage of core waste in industrial operations. Finally, the sanding and trimming wastes of the finished plywood which have not been considered in this study should be added to the other items.

VENEER GRADES

All the veneer produced in the yield study was graded after drying. As the present Canadian Standards Association (CSA) Standard 0-153-1963 for Poplar Plywood did not exist at the time this study was made, the grading standard used was essentially the same as that in the CSA Specification 0-115-1952 for Hardwood Plywood. The following is an abridged description of the grades:

Grade A - Tight, smoothly cut veneer, free of knots, mineral streaks, stain, and discoloration.

Grade 1 - Tight, smoothly cut veneer, free of knot-holes and doze, sound tight knots up to 3/8-inch diam permitted. Suitable for painting.

Grade 2 - Tightly cut veneer with open knot-holes not exceeding 3/8-inch diam. Suitable for painting after minor patching and filling.

Grade 3 - Reject grade containing open knot-holes up to 1-1/2-inches diam.

Of the total veneer cut in the yield studies the percentage of each grade is indicated in Table 3.

TABLE 3. RESULTS OF GRADE STUDY ON TREMBLING ASPEN VENEER FROM SASKATCHEWAN AND ONTARIO

Province	Grade A %	Grade 1 %	Grade 2 %	Grade 3 %
Saskatchewan	0	49.1	20.6	30.3
Ontario	2.4	25.9	24.6	47.1

When considering these grades it must be remembered that the logs from Saskatchewan were all peeler logs, whereas those from Ontario were chosen to represent a wide range of log grades. However, a yield of at least 30% of both Grade A and Grade 1 combined should be considered a satisfactory distribution of quality from the production of 1/4 inch 3-ply panels. Two typical panels of trembling aspen plywood are shown in Figure 2.

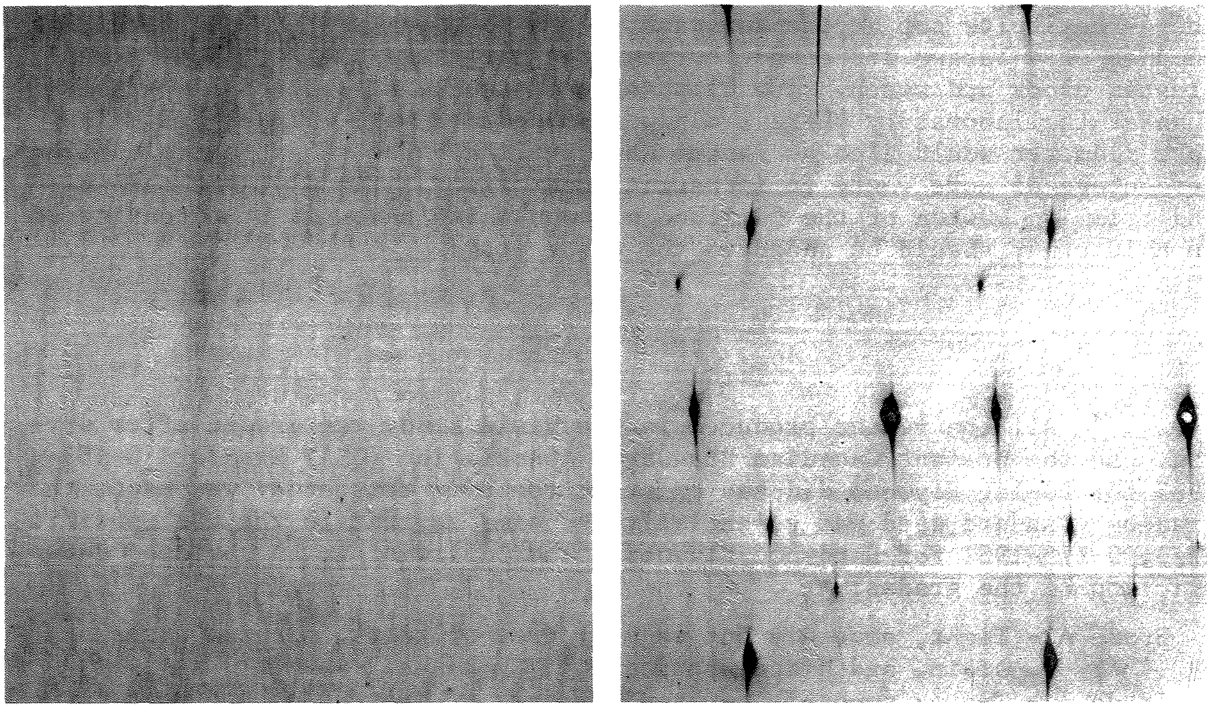

Figure 2. Typical trembling aspen plywood panels 40 by 30 inches showing various qualities of face veneers. Left panel shows no defects, and right panel shows full knots, open knots, pin knots, and stain streak.

GLUING TESTS

The object of these tests was to determine the quality of bonds produced in aspen plywood by a representative hot-press urea resin adhesive and a representative hot-press phenol resin adhesive. Plywood panels consisting of three plies of 1/16-inch veneer were prepared with each type of adhesive which was mixed, applied, and cured according to the manufacturer's recommendations. Panels glued with urea resin adhesive were subjected to the five-cycle delamination test for interior type plywood as specified in CSA Specification 0-115-1952 for Hardwood Plywood. In addition standard plywood tension shear specimens were prepared and tested dry.

Panels glued with phenol resin adhesive were cut to yield standard plywood tension shear specimens. Half of these were tested dry, and the remaining half were subjected to a cyclic boil treatment prior to test. No difficulties were encountered in bonding the plywood, and the test results indicated high quality bonds in all cases.

PROPERTIES OF TREMBLING ASPEN PLYWOOD

Aspen is a low density wood; its average weight per cubic foot air dry is 28 lb. as compared to yellow birch (43 lb.) or Douglas-fir (34 lb.). Its low density, combined with excellent gluing characteristics, makes trembling aspen veneer an ideal core and cross-band material for panels faced with more valuable hardwood or exotic veneers. On the other hand, its toughness, light weight, resistance to splitting in nailing, smoothness in wearing without splinters, and its lack of odor are very desirable qualities for shipping containers. Trembling aspen is superior to many species in paint and enamel holding properties, and its light color and lack of grain are an additional advantage in painting. Thus a large market is open for trembling aspen plywood in painted and unpainted furniture, built-in fixtures, wall panelling, signs, display fixtures, and furniture back panels. Lower grades with the appropriate type of bond are suitable for sheathing, floor underlay, and other construction purposes.

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CHAPTER XIV

THE POPLAR RESOURCE AND ITS CHALLENGE TO CANADIAN FORESTRY

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INTRODUCTION

Current interest in the poplar resource of Canada is a reflection of technological progress in hardwood-using industries throughout the world and a growing concern about the future role of hardwoods in Canada. Hardwood species make up almost one-fifth of all merchantable timber[1] in Canada. The poplars account for 54% of all net merchantable hardwood or 9% of our entire net merchantable forest resources. Although the poplars with their soft texture and short fiber have been used for lumber and pulp for many years, only since World War II have the prospects for poplar been greatly strengthened by major technological developments in the use of hardwoods for paper products as well as for veneer and plywood, fiberboard and particleboard and for many other newer uses.

The poplar resource in Canada has only been used to a very limited extent due, in part, to the fact that Canada is in the favored position of controlling nearly one-quarter of the coniferous area of the world. Historically, because of: (a) the ease of working most conifers; (b) their longer fibers; (c) their strength with respect to weight and (d) the large size of some species, conifers have earned a place of preference over hardwoods in the building trades and in the manufacture of pulp and paper. Many wood-using industries are organized to use mainly conifers and it can be expected that Canada will continue to place major emphasis on conifer usage.

When looking to the future, however, the challenge of the poplar resource should also be viewed in relation to the major competitive threats

[1]Volume data for poplar trees in the 4-inch dbh class and over, as supplied by the various provincial forestry departments, were placed on a common basis of net merchantable timber, i.e., gross volume less the volumes for tops, stumps and cull. Provincial cull factors were used where available. This initial step was not required for all provinces since some provinces reported volume data on the net merchantable basis. Poplar volumes reserved from commercial use, such as in National Parks, were excluded from the calculations.

to Canada's prominent world position for industrial wood production. These are outlined by the Royal Commission on Canada's Economic Prospects (Davis, *et al.* 1957) and are as follows: (a) the increased use of United States hardwoods for pulping; (b) the possibility of technological advances permitting greatly amplified use of tropical hardwoods and (c) a possible increase in Soviet wood exports. The competitive threats to Canada from the extended use of hardwoods may seem in the far distant future due to our high degree of specialization in the use of conifers and the vast amounts of coniferous species at our disposal. It does, however, point up how rapidly the technology in forestry has and is expected to advance, particularly with respect to hardwoods.

Poplar is considered by some as a "weed tree", or a tree having little or no economic value; by a few as a "cinderella tree", or a tree whose economic value is increasing rapidly; and by many as a hardwood of considerable interest but for which more information is required. The purpose of this paper is to provide information on the poplar resource, its utilization and some insight into the use of poplar by major poplar users across Canada.

POPLAR RESOURCE

General

Poplar is found throughout the forest zone of Canada. Eight species are native, five of which are suitable for commercial use, namely trembling aspen, largetooth aspen, balsam poplar, eastern cottonwood, black cottonwood (Chap. II; Anon. 1961). All are intolerant of shade, fast growing, and short-lived pioneer species.

The physical characteristics of the wood of all species of poplar are very similar, and so are the uses of the wood (Chap. IX; Irwin and Doyle 1961). Because of this, the term "poplar", used when speaking about the poplar resource, includes all species. Any exceptions to this are noted as they occur.

Current ownership or leasing of timber limits in which poplar occurs can, in the long run, change as the utilization of poplar changes. It is assumed, that when demand increases to the extent that poplar is in short supply, forest authorities through negotiations or through some other means can and will render available any poplar not being used by limit holders.

Location

The range of the various species of poplar (Anon. 1961), while of interest, is of secondary importance from the viewpoint of the user. What is of prime importance is the location of the major stands of poplar that are of the size, quality, and volume suitable for commercial use. These are the stands that will eventually support a poplar based industry. Poplar outside the poplar belt will likely be harvested coincident with other species for industries more dependent on species other than on poplar.

Figure 1 shows the major poplar area in Canada. It stretches in a relatively narrow band from western Quebec, through northern Ontario, across the prairies, and into northeastern British Columbia. There is also a major concentration of poplar in the central interior of British Columbia. Some poplar is reported in the Maritime Provinces but the volume there is relatively small, scattered, and occurs in association with other boreal species. There is no major poplar area in Newfoundland. In the Yukon and Northwest Territories there is a substantial volume of poplar but because of its remoteness from markets it is not commercially important at the present time.

Volume

Table 1 shows the relationship between net merchantable volume of poplar and other tree species by region and province. The total net merchantable volume of poplar in Canada is estimated at 65.6 billion ft^3 and comprises 54% of the total volume of all hardwoods and 9% of the combined volume of hardwoods and softwoods. The estimated allowable annual cut for poplar is 1.5 billion ft^3 (Fig. 2). The Prairie Region and the Yukon and Northwest Territories has almost 31 billion ft^3 of net merchantable poplar which is 47% of the total volume of poplar in Canada. The Central Region (Ontario and Quebec) and British Columbia follow in importance with a combined volume amounting to 52% of the poplar volume in Canada. The remaining volume occurs in the Atlantic region.

Prairie Provinces: In the three Prairie Provinces, poplar accounts for about 47% of the total Canadian poplar resource. Its main occurrence is in the Mixedwood Section of the Boreal Forest Region, which extends from southeastern Manitoba to the foothills of the Rocky Mountains in Alberta. The characteristic forest association of the well drained uplands in this area is a mixture in varying proportions of trembling aspen, balsam poplar, white birch, white spruce and balsam fir (Rowe 1959). Poplar is the cover-type of greatest aerial extent, primarily because of its ability to regenerate readily following disturbance. To the west of the Mixedwood Section, in the Lower Foothills section, lodgepole pine and poplar are the distinctive tree species. To the north, poplar is scattered and grows best on alluvial flats bordering rivers and lakes, on sandy soils in association with jack pine, and on low ridges; south in the Aspen Grove section, there is a clear height gradation in mature stands from the forest to the Prairie (Chap. II).

Of the three Prairie Provinces, Alberta with 16.7 billion ft^3 of net merchantable poplar, has the largest volume. It is located chiefly in the southern part of the Peace and Lac La Biche inventory sub-divisions and the Slave Lake sub-division (Fig. 3). Poplar is the only hardwood recorded in the Alberta provincial forest inventory. Poplar comprises 36% of the combined volume of hardwood and softwoods and has an estimated allowable

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Figure 1 (Page 217). Range of commercial poplar species and major area of poplar volume in Canada.

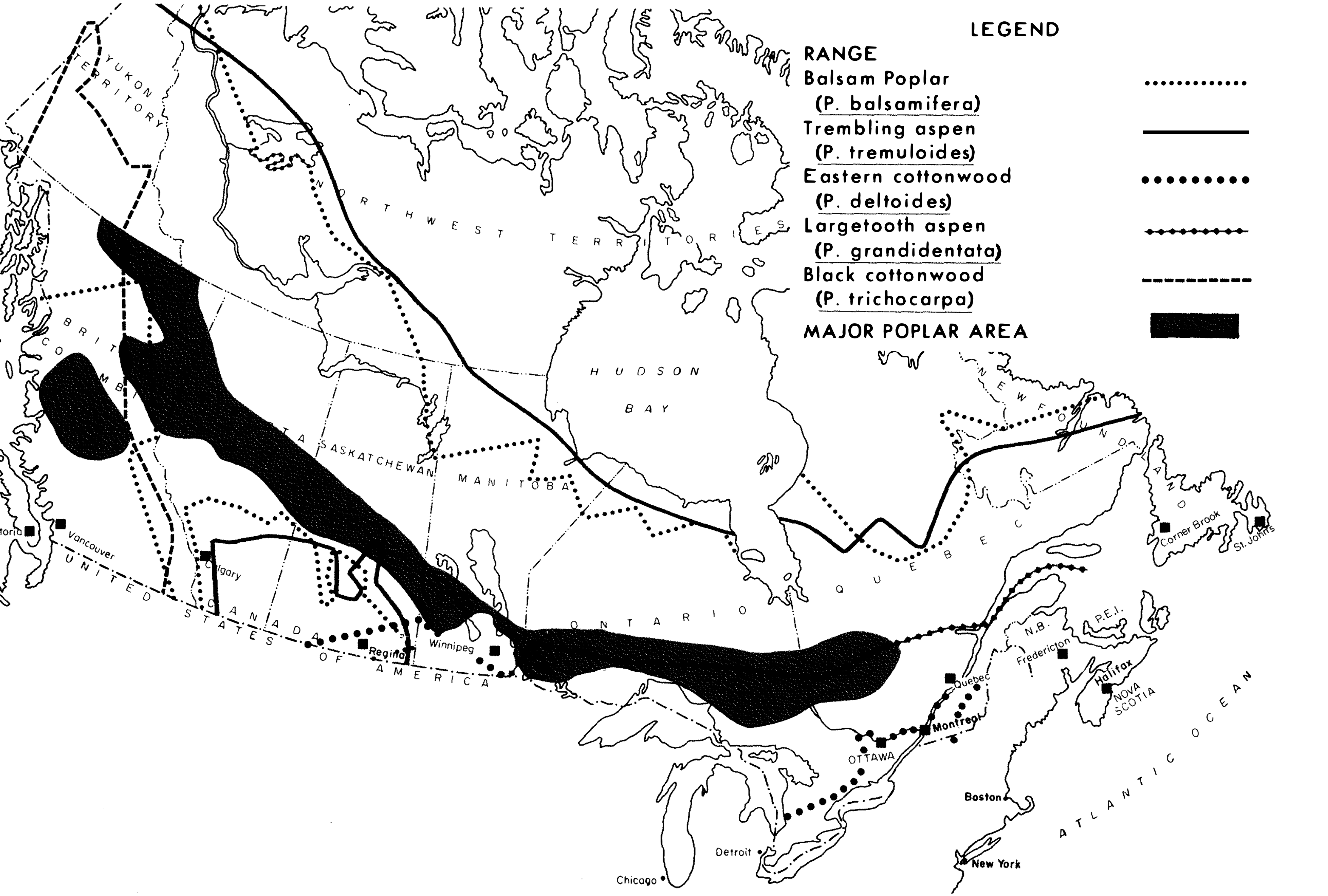

LEGEND
RANGE
Balsam Poplar (P. balsamifera)
Trembling aspen (P. tremuloides)
Eastern cottonwood (P. deltoides)
Largetooth aspen (P. grandidentata)
Black cottonwood (P. trichocarpa)
MAJOR POPLAR AREA
YUKON TERRITORY
NORTHWEST TERRITORIES
HUDSON BAY
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
CANADA
UNITED STATES OF AMERICA
Vancouver
Calgary
Regina
Winnipeg
OTTAWA
Montreal
Quebec
N.B.
P.E.I.
Fredericton
Halifax
NOVA SCOTIA
Corner Brook
St. John's
Boston
New York
Detroit
Chicago
ATLANTIC OCEAN

TABLE 1. THE POPLAR RESOURCE OF CANADA

Regions	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hardwoods	All Species	Total Poplar Volume in Canada
Prairie, Yukon and N.W.T.						
Alberta	16.7	16.7	46.3	100	36	26
Saskatchewan	8.7	10.1	22.5	86	39	13
Manitoba	2.2	3.2	12.2	85	18	3
Yukon and N.W.T.	3.3	4.6	21.0	72	16	5
Total	30.9	34.6	102.0	91	30	47
Central						
Ontario	17.6	36.1	97.3	49	18	27
Quebec	2.5	23.4	106.8	11	2	4
Total	20.1	59.5	204.1	34	10	31
British Columbia	14.0	19.6	365.7	71	4	21
Atlantic						
New Brunswick	.5	3.9	14.4	13	4	.8
Nova Scotia	.1	2.6	8.4	4	1	.1
Prince Edward Island	-	.7	.9	-	-	-
Newfoundland	Nil	.5	13.5	Nil	Nil	Nil
Total	.6	7.7	37.2	8	2	1
All Regions	65.6	121.4	709.6	54%	9%	100%

Note: Volume of all trees in the 4-inch dbh class and over.

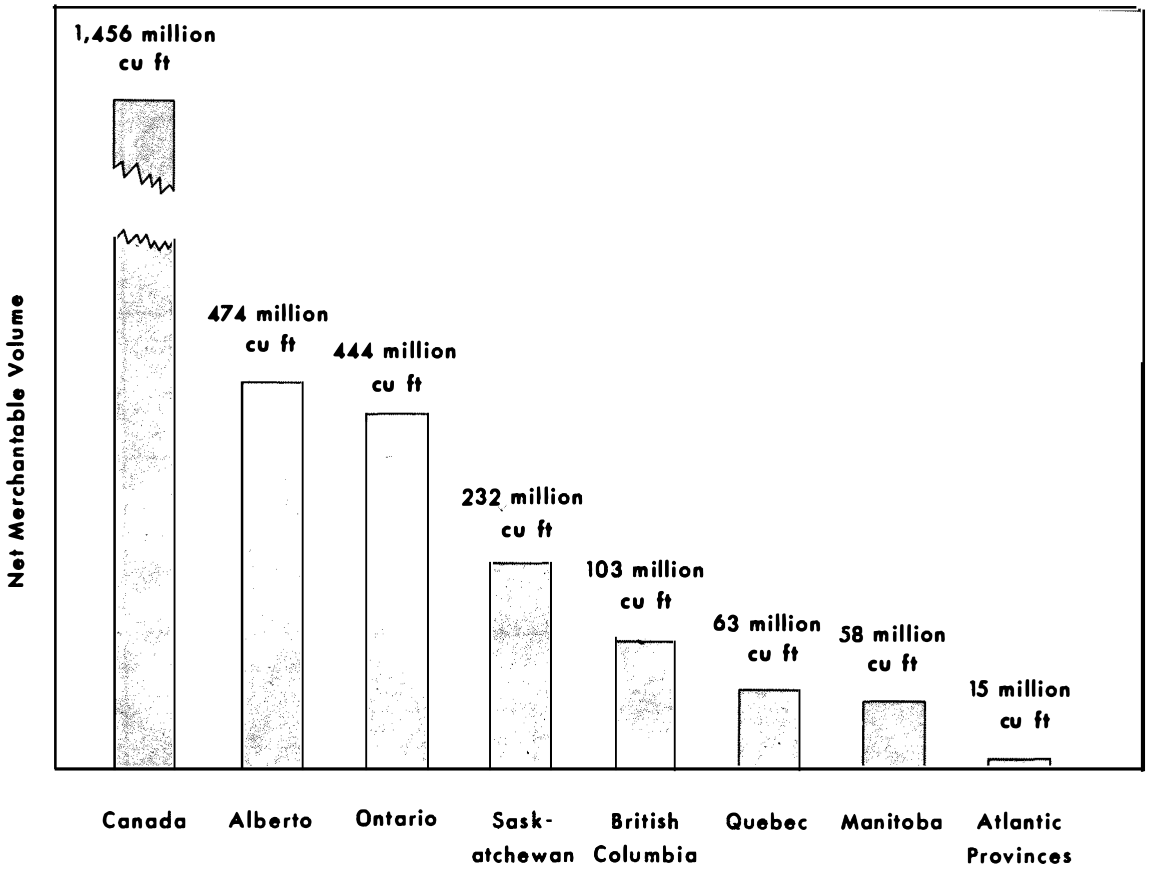


Figure 2. Allowable annual cut of poplar.

annual cut of 474 million ft^3. The major areas of Alberta account for 91% of the total poplar volume in the province (Table 2).

The Saskatchewan forests contain 8.7 billion ft^3 of net merchantable poplar. Poplar is located chiefly in the Hudson Bay, Prince Albert and Meadow Lake administrative sub-divisions (Table 3). These areas account for 68% of the total poplar volume in the province. Poplar comprises 86% of the hardwood volume and 39% of the combined hardwood and softwood volume in Saskatchewan. The allowable cut for poplar is estimated at 232 million ft^3.

The forests of Manitoba contain 2.2 billion ft^3 of net merchantable poplar almost 60% of which is in the Southeastern, Lowlands South, Winnipeg River, and Mountain inventory sub-divisions (Table 4). Poplar comprises 85% of the total hardwood volume in Manitoba but only 18% of the combined volume of hardwood and softwoods. The allowable annual cut for Manitoba poplar is estimated at 58 million ft^3.

Central Region: The forests of Ontario and Quebec contain 20.1 billion ft^3 of net merchantable poplar of which 17.6 billion ft^3 are located

Figure 3 (Page 221). Major poplar area, net merchantable volume, and allowable annual cut of poplar for the prairie region.

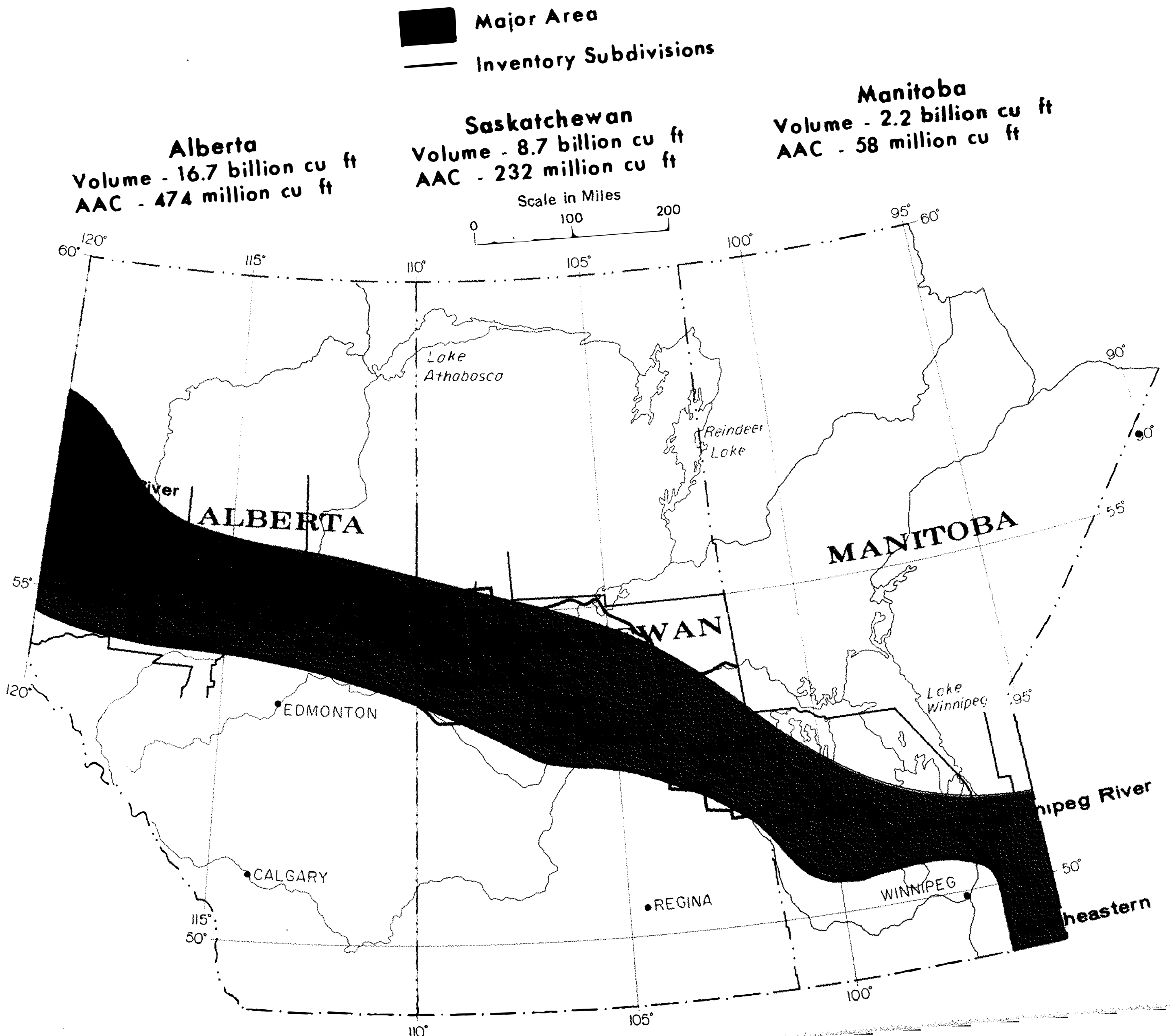

Major Area
Inventory Subdivisions
Alberta
Volume - 16.7 billion cu ft
AAC - 474 million cu ft
Saskatchewan
Volume - 8.7 billion cu ft
AAC - 232 million cu ft
Manitoba
Volume - 2.2 billion cu ft
AAC - 58 million cu ft
Scale in Miles
0
100
200
ALBERTA
MANITOBA
WAN
Lake Athabasca
Reindeer Lake
Lake Winnipeg
EDMONTON
CALGARY
REGINA
WINNIPEG
nipeg River
heastern

TABLE 2. THE POPLAR RESOURCE IN ALBERTA

Areas	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hardwoods	All Species	Total Poplar Volume in Alberta
<u>Major Areas</u>						
Peace River, South	4.8	4.8	10.5	100	46	29
Lac La Biche, South	2.8	2.8	7.5	100	37	17
Slave Lake	4.1	4.1	8.8	100	47	24
White Court	1.7	1.7	5.6	100	30	10
Grand Prairie	1.8	1.8	5.4	100	33	11
Total	15.2	15.2	37.8	100	40	91
<u>Other Areas</u>	1.5	1.5	8.3	100	18	9
Total	16.7	16.7	46.1	100	36	100

Note: Volume of all trees in the 4-inch dbh class and over.

TABLE 3. THE POPLAR RESOURCE IN SASKATCHEWAN

Areas	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hardwoods	All Species	Total Poplar Volume in Saskatchewan
Major Areas						
Prince Albert	1.6	1.8	4.9	89	33	18
Meadow Lake	1.6	1.8	2.7	89	59	18
Hudson Bay	2.7	2.9	4.1	93	66	32
Total	5.9	6.5	11.7	91	50	68
Other Areas	2.8	3.6	10.8	78	26	32
Total	8.7	10.1	22.5	86	39	100

Note: Volume of all trees in the 4-inch dbh class and over.

TABLE 4. THE POPLAR RESOURCE IN MANITOBA

Areas	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hardwoods	All Species	Total Poplar Volume in Manitoba
Major Areas						
Southeastern	.1	.1	.4	100	25	4
Winnipeg River	.2	.2	.9	100	22	8
Mountain	.8	1.0	1.7	80	47	38
Total	1.1	1.3	3.0	85	37	50
Other Areas	1.1	1.3	9.2	85	12	50
Total	2.2	2.6	12.2	85	18	100

Note: Volume of all trees in the 4-inch dbh class and over.

in Ontario (Table 5), and 2.5 billion ft^3 in Quebec (Table 6). The major poplar area in Central Canada is in a tapering band stretching from northwestern Quebec to the Ontario-Manitoba border (Fig. 4). Poplar is found chiefly in pure stands or as the dominant species in association with other Boreal hardwoods and softwoods. North of this band, black spruce predominates and poplar stands are relegated to river valley bottoms, around some lakes, and on south-facing slopes where favorable climate and soil conditions exist. South of this band the general characteristics of the soil and climate favor the pine communities.

The poplar volume in Ontario is evenly distributed across the North. This area has 78% of the total poplar volume in the province with almost 50% centering in the Kapuskasing-Cochrane, Port Arthur-Sioux Lookout forest districts. Poplar accounts for 49% of the total hardwood volume and 18% of the volume of all species - an indication of its relative importance in the predominantly softwood North. The allowable annual cut for poplar in Ontario is estimated at 444 million ft^3.

Quebec has only 2.5 billion ft^3 of net merchantable poplar, chiefly in the northwest part of the province, south of James Bay. Poplar accounts for 11% of the total hardwood volume and 2% of the combined volume of hardwood and softwoods (Table 6). The allowable annual cut for poplar in Quebec is estimated at 63 million ft^3.

British Columbia: In British Columbia there are two main poplar species, black cottonwood and trembling aspen. Black cottonwood occurs chiefly on the coast and southern interior. On the coast it grows well on moist lowland in association with Sitka spruce and with other hardwoods; in the interior it is associated with Western red cedar and Engelmann spruce. Trembling aspen is found in the northern part of the central interior and in the extreme northeastern part of the province (Fig. 5).

Poplar volume in British Columbia is estimated at 14.0 billion ft^3 of net merchantable timber and comprises 21% of the total poplar volume in Canada. Ninety-one per cent of the poplar volume is located in the central and northeastern part of the province (Table 7). In total, poplar accounts for 71% of the volume of all hardwoods in British Columbia but only 4% of the volume of all species. The allowable annual cut is estimated at 103 million ft^3.

Atlantic Region: The total volume of net merchantable poplar in the Atlantic Region is estimated at about 600 million ft^3 (Table 8), with an allowable annual cut of 15 million ft^3. Eighty-three per cent of the poplar volume is scattered throughout New Brunswick (Anon. 1966a). Little poplar is found in Prince Edward Island and no commercial poplar is reported in Newfoundland. The entire poplar volume of the Atlantic Region is only 1% of the total for Canada.

Figure 4 (Page 227). Major poplar area, net merchantable volume, and allowable annual cut of poplar for Ontario and Quebec.

TABLE 5. THE POPLAR RESOURCE IN ONTARIO

Areas	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hardwoods	All Species	Total Poplar Volume in Ontario
Major Areas						
Sioux Lookout	2.2	2.7	11.3	81	19	12
Port Arthur	1.9	2.8	8.0	68	24	11
Kenora	1.5	1.7	4.8	88	31	9
Geraldton	1.4	2.1	6.8	67	21	8
Sub-Total	7.0	9.3	30.9	75	23	40
Kapuskasing	2.4	2.7	8.7	89	28	13.6
Cochrane	1.1	1.4	5.4	79	20	6.2
Gogama	.9	1.3	3.6	69	25	5.2
White River	.8	1.6	3.7	50	22	4.5
Chapleau	.8	1.4	3.7	57	22	4.5
Temiskaming	.7	1.0	2.1	70	33	4.0
Sub-Total	6.7	9.4	27.2	71	25	38.0
Other Areas	3.9	17.4	39.2	22	10	22
Total	17.6	36.1	97.3	49%	18%	100%

Note: Volume of all trees in the 4-inch dbh class and over.

Major Area

Inventory Subdivisions

Ontario
Volume - 17.6 billion cu. ft.
AAC. - 444 million cu. ft.

Quebec
Volume - 2.5 billion cu. ft.
AAC. 63 million cu. ft.

Scale in Miles
0 100 200

3

TABLE 6. THE POPLAR RESOURCE IN QUEBEC

Areas	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hard-woods	All Species	Total Poplar Volume
Chiefly in the North-western part of the Province	2.5	23.4	106.8	11%	2%	100%

Note: Volume of all trees in the 4-inch dbh class and over.

COMPARISON OF POPLAR RESOURCE TO UTILIZATION IN CANADA

A comparison of the poplar resource in Canada with the commercial utilization of poplar shows that of the 65.6 billion ft^3 of poplar, with an estimated annual allowable cut of 1.5 billion ft^3, only an average of 76.2 million ft^3 were used annually during the 5-year period, 1961-65, (Fig. 6). Annual commercial use of poplar is, therefore, 5.2% of the total allowable annual cut of net merchantable poplar in Canada. Insufficient data are available to estimate the quantity of poplar used by region, however, it is estimated that three-quarters of all poplar cut for commercial use is from Ontario and Quebec. Even here, only 13% of the allowable annual cut of net merchantable poplar is being utilized.

Major commercial use of poplar is as follows: pulp and paper mills - 57.6% (Anon. 1960-1965a -- 5-year avg); veneer and plywood mills - 13.2% (Anon. 1960-1965b -- 5-year avg); particleboard mills - 12.3% (Anon. 1966b); exports of poplar plywood - 10.7% (Dominion Bureau of Statistics, Cat. 65-004, Ottawa); sawmills - 6.2% (Anon. 1960-1965c -- 5-year avg. Convert at 85 ft^3/cord and 200 ft^3/1,000 bd ft).

In addition to the above uses, poplar is also used, for example, as firewood and posts. While no data are available, the quantity used for other uses is considered to be small.

COMMENTS BY MAJOR USERS

Underutilization of poplar is of prime concern to Canadian forestry. In order to obtain further insight into: (a) the use of the poplar resource; (b) price differentials between poplar and other species; (c) problems encountered in its use and (d) the likely change in poplar requirements 5 years

Figure 5 (Page 231). Major poplar area, net merchantable volume, and allowable annual cut of poplar for British Columbia.

TABLE 7. THE POPLAR RESOURCE IN BRITISH COLUMBIA

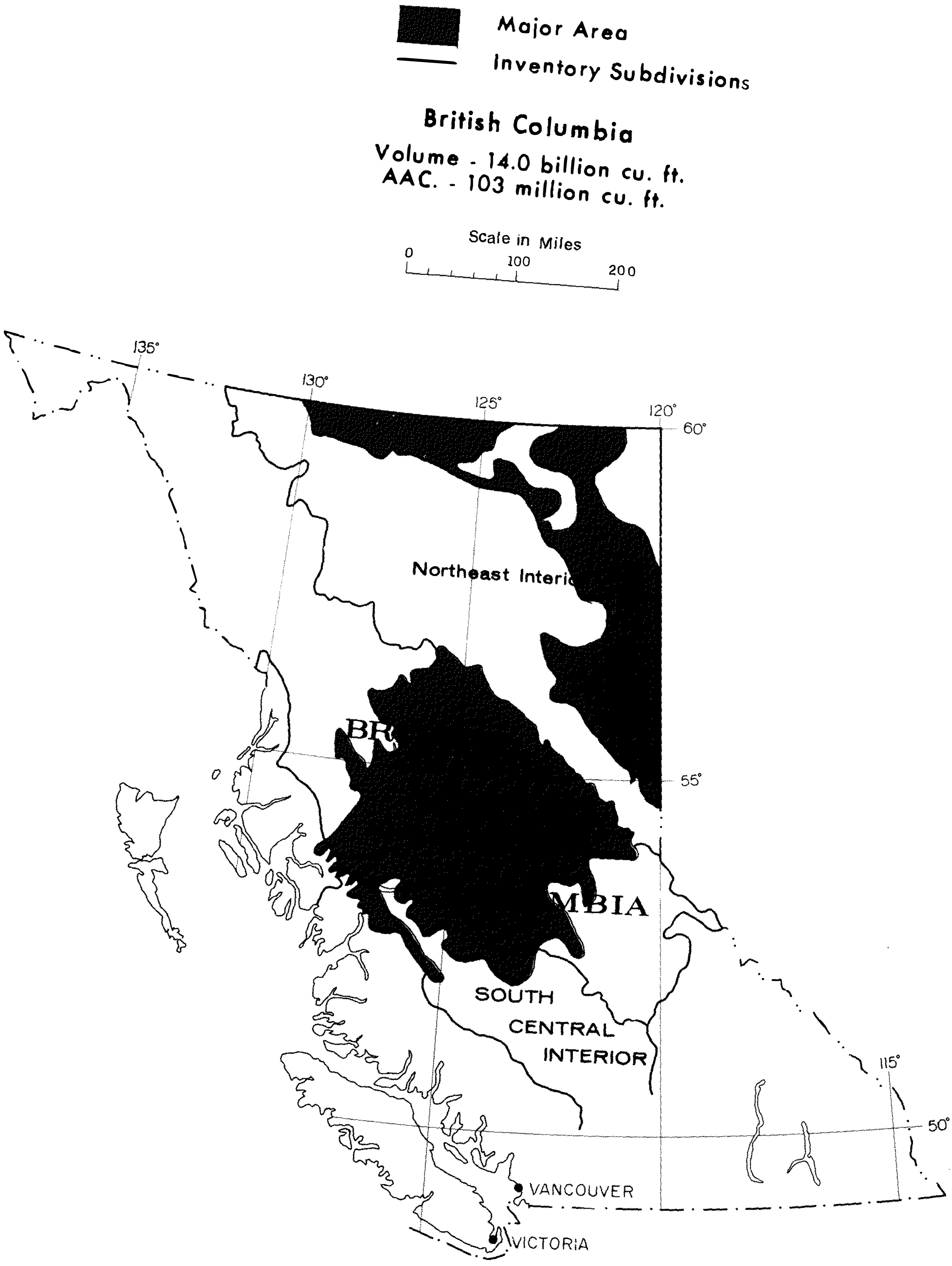
Areas	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hardwoods	All Species	Total Poplar Volume in British Columbia
Major Areas						
North East	9.1	11.0	81.0	83	11	65
North Central	2.1	3.4	85.2	62	2.5	15
South Central	1.5	2.0	31.4	75	4.8	11
Total	12.7	16.4	197.6	77	6.4	91
Other Areas	1.3	3.2	168.1	41	.8	9
Total	14.0	19.6	365.7	71%	3.8%	100%

Note: Volume of all trees in the 4-inch dbh class and over.

TABLE 8. THE POPLAR RESOURCE IN THE ATLANTIC REGION

Areas	Net merchantable volume, billion ft^3			Poplar as a Percentage of		
	Poplar	Total Hardwoods	All Species	Total Hardwoods	All Species	Total Poplar Volume in the Atlantic Region
New Brunswick	.5	3.9	14.4	13	3.5	83
Nova Scotia	.1	2.6	8.4	3.8	1.2	17
Prince Edward Island	-	.7	.9	-	-	-
Newfoundland	Nil	.5	13.5	Nil	Nil	Nil
Total	.6	7.7	37.2	7.8%	1.6%	100%

Note: Volume of all trees in the 4-inch dbh class and over.



Major Area
Inventory Subdivisions
British Columbia
Volume - 14.0 billion cu. ft.
AAC. - 103 million cu. ft.
Scale in Miles
0
100
200
135°
130°
125°
120°
60°
55°
50°
115°
Northeast Interi
BR
MBIA
SOUTH
CENTRAL
INTERIOR
VANCOUVER
VICTORIA

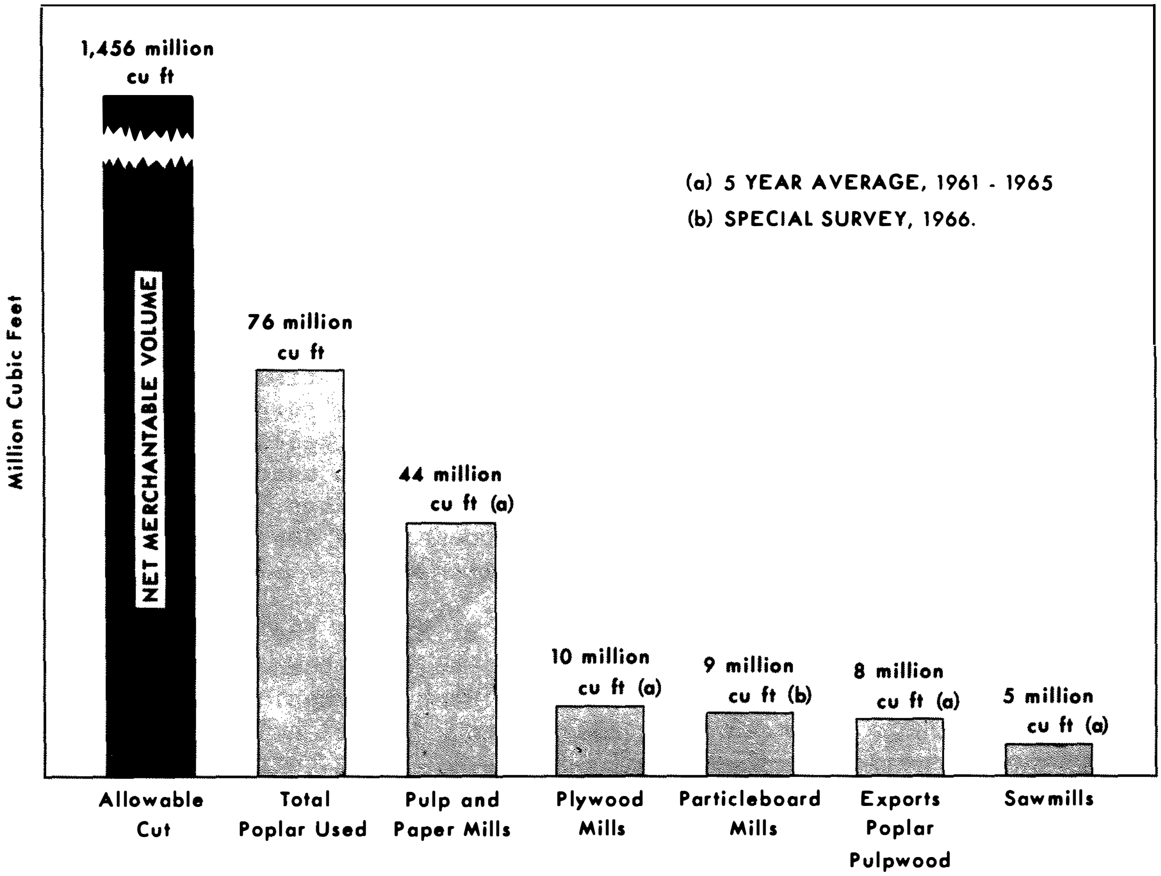


Figure 6. A comparison of allowable annual cut to commercial poplar utilization for Canada.

hence, a special survey of major poplar users was conducted by the Department of Forestry and Rural Development. The comments of major poplar users in the pulp and paper, plywood and particleboard industries are summarized for this paper.

In the lumber industry, there are a large number of sawmills using poplar across Canada. However, in 1964, there were only 11 mills with a poplar production of 500 thousand board feet or more. While insufficient comments have been received from sawmill owners in the special survey, the Dominion Bureau of Statistics' annual survey of sawmills shows that poplar lumber shipments declined from 1960 to 1963 but showed a moderate increase for 1964 and 1965. Poplar lumber and dimension stock may play a role of increasing importance in the future. In a survey of export opportunities for Manitoba forest products in the Mid-West United States (Anon. 1965) it was found that "there is an excellent potential for aspen poplar dimension stock provided that it is well manufactured to conform to grades specified. This market is not well supplied at the present time, but an active program to improve manufacturing is underway by Government agencies. A degree of urgency exists to become well established as a supplier before competition increases."

Pulp and paper mills

Twenty-six of the major poplar users in the pulp and paper industry have commented on their use of poplar in the special survey by the Department of Forestry and Rural Development. The poplar users in the special survey account for over three-quarters of all the poplar pulpwood used. Two mills are located in New Brunswick, nine in Quebec, ten in Ontario, three in the Prairie Provinces and two in British Columbia.

Poplar used in pulp and paper mills falls into three categories (Table 9): (a) poplar used for specialty paper products such as napkins, tissue, towelling, paperboard, fine paper and sanitary tissue. Sixty per cent of 226 thousand cords of poplar was used for this purpose; (b) poplar used for building boards, including insulating board, ceiling tiles and hardboard. Seventy-eight thousand cords of poplar was used for this purpose and (c) poplar used in the general pulping processes. Seventy-six thousand of the total 380 thousand cords of poplar was consumed as groundwood, kraft, semi-chemical and bleached sulfite pulp.

Three hundred and fifteen thousand or 83% of the poplar pulpwood used in the 26 plants was purchased; over one-half of these plants reported purchasing their total poplar requirements. When purchasing poplar pulpwood, the maximum allowable cull per cord ranged from 3 to 5% but two companies stated they would allow up to 10% cull per cord. When cutting poplar bolts, most companies culled out poplar if 50% or more of the face of a poplar bolt was unusable. Companies estimated that an average of 8 cords of usable poplar per acre in pure stands would be required before they considered it worthwhile cutting the stand. The maximum distance poplar could be economically hauled from the stand to the mill averaged 54 miles.

Generally, peeled poplar was purchased at the mill at a cost of $2.00 to $3.00 less per cord than the mill price for rough spruce or balsam fir. A price differential of $7.00 to $8.00 per cord existed between the price per cord of rough poplar and rough spruce or balsam fir.

Poplar is suitable for pulping by all commercial methods and is now being commercially pulped by mechanical, semi-chemical, sulfate, sulfite and defibration processes. Where plants had adapted to using hardwoods, 50 to 100% of the pulp mix could have been poplar. Where plants used mainly softwoods, 20% or less poplar was the maximum that could be used in the pulping process. There were a number of plants producing specialty paper products, building boards and using poplar in the general pulping processes, where up to 100% poplar could have been used, using present pulping methods.

Major problems in using poplar were: (a) the difficulty in purchasing peeled poplar; (b) the difficulty in obtaining labor for peeling poplar; (c) the heavy and unpredictable cull due to overmaturity and excessive rot; and (d) the increasing costs of cutting and hauling poplar from more distant stands. Since a high proportion of poplar pulpwood for use in pulp and paper mills was purchased, either peeled or rough, the major concern expressed was either related to the purchasing of peeled bolts or to the difficulty in obtaining manpower to do the peeling.

TABLE 9. MAJOR USES FOR POPLAR PULPWOOD AND REQUIREMENTS, SPECIAL SURVEY, PULP AND PAPER MILLS, 1966

Main uses for poplar	No. of plants	Poplar		
		Pulpwood purchased	Pulpwood cut on own limits	Total
		- - - - - - cords - - - - - - - - -		
Special paper products				
napkins, tissue, towels, paperboard, fine paper, sanitary tissue, roofing felt	12	174,661	51,804	226,465
Building boards				
insulating board, ceiling tiles and hardboard	7	77,600	-	77,600
Pulp - general use				
groundwood, kraft, semi-chemical, bleached sulfite	7	63,079	13,242	76,321
Total	26	315,340	65,046	380,386

Poplar requirements in pulp and paper mills, 5 years from now, were estimated by the plant managers as follows:

Product	1966	1971	Increase in poplar requirements
	- - - cords - - -		- per cent -
Special paper products	226,465	254,703	12.5
Building boards	77,600	85,650	10.4
Pulp - general use	76,321	78,491	2.8
Total	380,386	418,844	10.1

Veneer and plywood mills

Eight veneer and plywood mills reported using poplar in the special survey. These plants used 55 million board feet of poplar in 1966 (Table 10). The Dominion Bureau of Statistics' annual survey of veneer and plywood mills, 1964, estimated total utilization of poplar at 56 million board feet.

Poplar utilization for plywood has increased about 16 million board feet in the past 5 years. One of the newest plants to produce poplar plywood is the $1.5 million automated plywood plant at Longlac, Ontario (Anon. 1966c). Plywood is produced in 4 x 4 sheets in 1/4-, 3/8-, 1/2-, 5/8- and 3/4-inch thick sheets. Approximately 70% of production is unsanded and sold for sheathing. The remaining sanded output is sold for floor underlay. This plant is expected to produce 150,000 ft^2 (1/4-inch basis) of plywood per day.

Minimum diameters of poplar logs required for plywood operations in eastern Canada, according to plant managers, was from 8 to 9 inches. In western Canada, it ranged from 10 to 15 inches. Logs were considered cull when the center cull defect in a 9- to 11-inch diam log exceeded 3 inches and in 12-inch diam logs when it exceeded 4 inches. Companies purchased 62% of poplar requirements and estimated that from 5 to 8 cords per acre of usable poplar would be required to warrant cutting on their own limits. From this study, a price differential between poplar logs and other species for plywood operations could not be determined. Generally, the price paid for veneer bolts of poplar was lower than for other species purchased, however, some companies were paying more for poplar veneer bolts than for other species.

Major problems in the use of poplar in eastern and western Canada were:

Eastern Canada - (1) Poplar veneer bolts are becoming difficult to obtain in sufficient quantities. A number of plant managers stated that poplar veneer bolts were only available as other species were cut and the quantity of poplar bolts was unpredictable.

TABLE 10. POPLAR USED IN VENEER AND PLYWOOD MILLS, EASTERN AND WESTERN CANADA, SPECIAL SURVEY, 1966

Area	No. of plants	Poplar		
		Purchased	Cut on own limits	Total
		- - - - - thousand board feet - - - - -		
Eastern Canada	4	20,075	13,500	33,575
Western Canada	4	14,100	7,700	21,800
Total	8	34,175	21,200	55,375

(2) Wastage of poplar was high due to overmaturity and rot.

(3) Transportation costs were becoming a major problem. One company estimated that freight costs were 30% of the delivered price of poplar when the haul exceeded 50 miles.

Western Canada - (1) Overmaturity and the excessive rot in poplar is forcing companies to use other species entirely or restrict the use of poplar.

(2) The volume per acre of usable poplar is considered too low in many new areas for companies to even attempt to implement a cutting program.

(3) Logging and milling costs for poplar were considered high. One company estimated that the recovery of plywood from poplar was 20% less than for coniferous species.

Poplar requirements for plywood plants, 5 years from now, were estimated by the plant managers to be as follows:

Area	1966	1971	Change in poplar requirements
	- thousand board feet -		- per cent -
Eastern Canada	33,575	51,350	+52.9
Western Canada	21,800	19,125	-12.3
Total	55,375	70,475	+27.3

Particleboard plants

Six particleboard plants reported using poplar in the special survey. Of the 110 thousand cords used, approximately one-half was purchased and the remainder cut from plant limits. The preferred diameter of poplar bolt was from 9 to 12 inches, however, plants reported using poplar bolts from 4 inches in diameter and up as long as the bolts were chippable.

For those cutting poplar on their own limits, it was estimated that a minimum of 8 to 10 cords of usable poplar was necessary for an economic cutting operation. The maximum distance that poplar could be economically transported was 40 to 50 miles. Generally, poplar sold from $3.50 to $6.00 per cord less than for other species used in particleboard plants. However, one plant considered all wood of the same value for particleboard production.

It was estimated, by plant managers, that poplar requirements for particleboard will increase from the present 110 thousand cords to about 164 thousand cords 5 years from now, or by 49%.

CONCLUSIONS

The challenge of the poplar resource to Canadian forestry can now be looked at in full focus. Nationally, there is an estimated 65.6 billion ft^3 of poplar and an allowable annual cut of net merchantable poplar of 1.5 billion ft^3. Only 78 million ft^3 of poplar are now being used commercially with a possibility of 94 million ft^3 being used in 5 years time. This is only a projected increase of from 5.4 to 6.5% of the allowable annual cut of net merchantable poplar.

The reasons why poplar has not been used more are multifold. One major point is that there has been little need to use poplar when spruces and firs have been readily available and in abundance. A second is that much of the poplar is within the Prairie Provinces and these provinces are just now beginning to overcome the transportation barrier for wood products. A third point, is that poplar has been bypassed for so long that many of the stands are overmature,decadent and consumed with rot. High-grading poplar has assisted many stands in becoming less productive.

The challenge of the poplar resource to Canadian forestry is one in which this Symposium can take the important initial step in meeting. The challenge is to establish overall guidelines as to what should be the long run policy for poplar utilization in Canada. Hardwoods, and particularly poplar, will be playing a stronger commercial role as technological developments in Canada, the United States and many other countries of the world are applied to hardwood problems. Will our poplar stands of the future be in such a condition that when newer techniques in the profitable application of poplar are developed, suitable timber will not be available?

Answers to a number of questions may assist in developing guidelines. For example, are there young stands of poplar that should be set aside to form part of the resource for new companies willing to risk their capital in its development? Should those who cut on Crown lands assume some of the responsibility for developing and using the poplar resource? Should incentives be given to companies to further encourage the research and use of poplar? Should effective regeneration be promoted through clear cutting, thus encouraging suckering in the first three years? What other means of rehabilitation are needed? What types of forestry complexes are best suited for the development of the poplar resource?

These are but a few of the questions to consider in establishing guidelines. If we do plan and set long term guidelines for poplar, the dividends can be rewarding. The stakes are high: 9% of our entire net merchantable forest resources. What guidelines are needed to assist in the future development of the poplar resource? This is indeed the challenge we are faced with today.

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APPENDIX I

BOTANICAL AND COMMON NAMES OF POPLARS CITED IN THIS REPORT

BOTANICAL NAME	COMMON NAME	SCIENTIFIC OR CULTIVAR NAME: DERIVATION
P. acuminata	Lanceleaf cottonwood	*P. acuminata* Rydb. (Anon. 1961). (Putatively considered as a hybrid between *P. angustifolia* James and *P. deltoides* Marsh. var. *occidentalis* Rydb. by Brayshaw 1965).
P. alba	European white poplar	*P. alba* L. (Anon. 1958).
P. alba var. *nivea*	Silver poplar	*P. alba* L. var. *nivea* Willd. (Anon. 1958).
P. angulata		*P. deltoides* Marsh. subsp. *angulata* Ait. (Anon. 1958).
P. angustifolia	Narrowleaf cottonwood	*P. angustifolia* James (Anon. 1961).
P. 'AS # 2'		*P. deltoides* Marsh. subsp. *angulata* Ait. x *P. simonii* Carr. (Heimburger 1968).
P. balsamifera	Balsam poplar	*P. balsamifera* L. (Anon. 1961). (Syn. *P. tacamahaca* Mill (Little 1953); Brayshaw (1965) considers this to be a sub-species, *P. balsamifera* L. subsp. *balsamifera* Brayshaw).
P. balsamifera var. *subcordata*		*P. balsamifera* L. var. *subcordata* Hylander (Fernald 1950). (Brayshaw (1965) considers this to be a variety of a sub-species, *P. balsamifera* L. subsp. *balsamifera* Brayshaw var. *subcordata* Hylander).
P. 'Bassano'		*P. deltoides* x "Russian" poplar (Heimburger 1968).
P. berolinensis		*P.* x *berolinensis* Dippel (=*P. laurifolia* Ledeb. x ? *P. nigra* L. cv. 'italica' (Anon. 1958). Sometimes referred to as one of the "Russian"[1] poplars).

BOTANICAL NAME	COMMON NAME	SCIENTIFIC OR CULTIVAR NAME; DERIVATION
P. 'BNW # 4'		*P.* x *berolinensis* Dippel x *P.* x *jackii* Sarg. (Cram 1960).
P. 'Brooks # 1'	Griffin poplar	*P. deltoides* x "Russian" poplar? (Cram 1968).
P. 'Brooks # 4'		*P. deltoides* x "Russian" poplar? (Cram 1960).
P. 'Brooks # 7'		*P. deltoides* x "Russian" poplar? (Cram 1960).
P. 'Brooks # 10'		*P. deltoides* x "Russian" poplar? (Cram 1960).
P. x *canadensis*	Carolina poplar	*P.* x *euramericana* (Dode) Guinier (=*P. deltoides* Marsh. x *P. nigra* L. and reciprocal (Anon. 1958)).
P. candicans	Balm of Gilead	*P. candicans* Ait. (Anon. 1958). (A pistillate clone of *P. balsamifera* L. or of a hybrid involving this species (Little 1953)).
P. canescens	Gray poplar	*P.* x *canescens* Sm. Generally regarded to be of hybrid origin; derived from the crossing of *P. tremula* L. with *P. alba* var. *nivea* Willd. (Anon. 1958).
P. 'cardeniensis' (?)		No certain identification. Probably not a misspelt rendering of *P. canadensis* as is sometimes thought (Walker 1968).
P. davidiana		*P. davidiana* Dode (an Asiatic aspen) (Anon. 1958).
P. deltoides	Eastern cottonwood	*P. deltoides* Marsh. (Anon. 1961). (Listed by Little (1953) as *P. deltoides* Bartr.).
P. deltoides var. *occidentalis*	Plains cottonwood	*P. deltoides* Marsh. var. *occidentalis* Rydb. (Anon. 1961). (Listed by Little (1953) as *P. sargentii* Dode, with *P. deltoides* Bartr. var. *occidentalis* Rydb. given as a synonym. Listed by Brayshaw (1965) as *P. deltoides* Bartr. ex Marsh. var. *occidentalis* Rydb.).

BOTANICAL NAME	COMMON NAME	SCIENTIFIC OR CULTIVAR NAME; DERIVATION
P. 'Dunlop'		This poplar has obvious affinites with *P. deltoides* Marsh. although Cram (1960) states that it is a male of "Russian" type. A clone developed from cuttings taken by Dunlop from an established shelterbelt on a farm near Conquest, Saskatchewan (Walker 1968).
P. 'Eugenei'		*P.* x *euramericana* (Dode) Guinier cv. 'eugenei' (Anon. 1958).
P. 'FNS # 44-52'		A clone developed from a selection made by Walker from open pollinated progeny of a *P. deltoides* Marsh. tree growing near "Russian" poplars at Forest Nursery Station, Indian Head, Saskatchewan. Almost certainly a hybrid (Walker 1968).
P. 'Gelrica'		*P.* x *euramericana* (Dode) Guinier cv. 'gelrica' (Anon. 1958).
P. grandidentata	Largetooth aspen	*P. grandidentata* Michx. (Anon. 1961).
P. 'IH-78B'		*P.* x *euramericana* (Dode) Guinier cv. 'Jacometti 78B' (Müller and Sauer 1961).
P. 'I-214'		*P.* x *euramericana* (Dode) Guinier cv. 'I-214' (Anon. 1958).
P. 'Incrassata'		*P. nigra* hybrid (Cram 1960).
P. 'Italica'	Lombardy poplar	*P. nigra* L. cv. 'italica' (Anon. 1958).
P. jackii		*P.* x *jackii* Sarg. (=*P. balsamifera* L. x *P. deltoides* Marsh. (Little 1953). Heimburger (1968) has noted that *P. jackii* also includes the product of the reciprocal cross and its derivates).
P. laurifolia		*P. laurifolia* Ledeb. (a balsam poplar native to Siberia) (Anon. 1958).

BOTANICAL NAME	COMMON NAME	SCIENTIFIC OR CULTIVAR NAME; DERIVATION
P. maximowiczii		*P. maximowiczii* Henry (a balsam poplar native to northeastern Asia) (Anon. 1958).
P. monilifera		*P. deltoides* Marsh. subsp. *monilifera* Henry (Anon. 1958).
P. nigra	European black poplar	*P. nigra* L. (Anon. 1958).
P. nigra var. *caudina*		*P. nigra* L. var. *caudina* Tenore (Anon. 1958).
P. nigra var. *plantierensis*		*P. nigra* L. var. *plantierensis* (Simon-Louis) Schneid. (Houtzagers 1937).
P. 'Northwest'		*P.* x *jackii* Sarg. (Anon. 1958, Heimburger 1968). Introduced as a clone from the U.S.A. via Prairie Nursery, Estevan, Sask. (Walker 1968).
P. petrowskyana		*P.* x *petrowskyana* Schr. (=*P. laurifolia* Ledeb. x *P. nigra* L.) One of the "Russian" poplars. Rehder (1951) indicates that it is a hybrid of *P. laurifolia* Ledeb. x *P. deltoides* Marsh. and cites the authority as Schneid.
P. rasumowskyana		*P.* x *rasumowskyana* Schr. (=*P. laurifolia* Ledeb. x *P. nigra* L.); one of the "Russian" poplars (Anon. 1958). (Rehder (1951) lists the authority as Schneid.).
P. 'Raverdeau'		*P.* x *euramericana* (Dode) Guinier cv. 'robusta raverdeau'. A clone of 'robusta' from France (Heimburger 1968).
P. 'Regenerata'		*P.* x *euramericana* (Dode) Guinier cv. 'regenerata' (Anon. 1958).
P. 'Robusta'		*P.* x *euramericana* (Dode) Guinier cv. 'robusta' (Anon. 1958).
P. 'Saskatchewan'		*P.* x *jackii* Sarg. (Heimburger 1968). The ortet of this clone was found growing on the banks of the South Saskatchewan River near Saskatoon (Ross 1939).

BOTANICAL NAME	COMMON NAME	SCIENTIFIC OR CULTIVAR NAME; DERIVATION
P. sieboldii		*P. sieboldii* Miq. (a Japanese aspen) (Anon. 1958).
P. simonii		*P. simonii* Carr. A balsam poplar occurring from Western China to Korea (Anon. 1958).
P. songarica		An asiatic Tacamahaca male clone imported from The Kew Gardens (Heimburger 1968).
P. 'Sutherland 4'		Selected clone of *P. balsamifera* L. (Heimburger 1968).
P. '38P38'		A clone of *P. balsamifera* L. x *P. simonii* Carr. (Cram 1960).
P. tremula	European aspen	*P. tremula* L. (Anon. 1958).
P. tremuloides	Trembling aspen	*P. tremuloides* Michx. (Anon. 1961).
P. tremuloides var. *aurea*		*P. tremuloides* Michx. var. *aurea* (Tid.) Dan. (Little 1953).
P. tremuloides f. *pendula*		*P. tremuloides* Michx. form *pendula* Jaeger Beissner (Fernald 1950).
P. tremuloides f. *reniformis*		*P. tremuloides* Michx. form *reniformis* Tid. (Fernald 1950).
P. tremuloides var. *magnifica*		*P. tremuloides* Michx. var. *magnifica* Vict. (Fernald 1950).
P. tremuloides var. *vancouveriana*		*P. tremuloides* Michx. var. *vancouveriana* (Trel.) Sarg. (Sudworth 1934).
P. trichocarpa	Black cottonwood	*P. trichocarpa* Torr. & Gray (Anon. 1961). (Listed by Brayshaw (1965) as *P. balsamifera* L. subsp. *trichocarpa* (Torr. & Gray) Brayshaw).
P. trichocarpa var. *hastata*		*P. trichocarpa* Torr. & Gray var. *hastata* (Dode) Henry (Moss 1959). (Listed by Brayshaw (1965) as *P. balsamifera* L. subsp. *trichocarpa* (Torr. & Gray) Brayshaw var. *hastata* (Dode) Henry).

	COMMON NAME	SCIENTIFIC OR CULTIVAR NAME; DERIVATION
P. tristis		*P. tristis* Fisch. A central Asian balsam poplar (Rehder 1951).
P. 'Tristis # 1'		Heimburger (1968) considers this to be a clone of *P. tristis* Fisch., but Cram (1960) has described it as a cross of *P. balsamifera* L. and *P. tristis* Fisch. possibly produced by Dr. F.L. Skinner.
P. 'Vernirubens'		*P.* x *euramericana* (Dode) Guinier cv. 'vernirubens' (Anon. 1958).
P. 'Volunteer'		A female clone of "Russian" (*P. laurifolia* Ledeb. x *P. nigra* L.) origin (Heimburger 1968). The ortet was selected by Kerr at the Forest Nursery Station, Sutherland (Walker 1968).
P. 'Wheeler # 4'		The Wheeler clones are derived from selections made by Kerr among naturally occurring seedlings on the farm of Sigurd Wheeler at Rosthern, Sask., where native balsam poplars and other varieties, introduced in shelterbelt plantings, occurred (Walker 1968). It is clear that this clone is derived at least in part from *P. balsamifera* L. although Cram (1960) states the parentage as *P. deltoides* Marsh. x ?

[1]"Russian" poplar is the name commonly applied to hybrids of which one of the parent species is *P. laurifolia* Ledeb. Examples include *P.* x *berolinensis*, *P.* x *rasumowskyana*, and *P.* x *petrowskyana*. Ross (1939) referred to three species of "Russian" poplar as having been introduced into the Prairie Provinces of Canada. He listed them as *P. petrovski*, *P. certinensis* and *P. wobstiriga*. Rehder (1951) records that *P. certinensis* Dieck. is associated with *P.* x *berolinensis* Dippel as derivatives of the hybrid *P. laurifolia* Ledeb. x *P. nigra* L. cv. 'italica'. He lists *P. woobstii* (Reg.) Dode (which Walker (1968) believes to be synonymous with Ross' "*P. wobstiriga*") as a hybrid of *P. laurifolia* Ledeb. and *P. tristis* Fisch. It is evident that the term "Russian" poplar is very general and ill-defined.

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APPENDIX II

COMMON AND BOTANICAL NAMES OF TREES OTHER THAN POPLARS

COMMON NAME	BOTANICAL NAME
Alder, red	*Alnus rubra* Bong.
Ash	*Fraxinus* L.
Basswood	*Tilia americana* L.
Beech	*Fagus grandifolia* Ehrh.
Birch, white	*Betula papyrifera* Marsh.
Birch, yellow	*Betula alleghaniensis* Britt.
Butternut	*Juglans cinerea* L.
Cedar, eastern white	*Thuja occidentalis* L.
Cedar, western red	*Thuja plicata* Donn
Cucumber-tree	*Magnolia acuminata* L.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Elm, white	*Ulmus americana* L.
Fir	*Abies* Mill.
Fir, alpine	*Abies lasiocarpa* (Hook.) Nutt.
Fir, amabilis	*Abies amabilis* (Dougl.) Forb.
Fir, balsam	*Abies balsamea* (L.) Mill.
Gum	*Nyssa* L.
Hemlock	*Tsuga* (Endl.) Carr.
Hemlock, eastern	*Tsuga canadensis* (L.) Carr.
Hemlock, western	*Tsuga heterophylla* (Raf.) Sarg.
Juniper, red	*Juniperus virginiana* L.
Larch	*Larix* Mill.
Maple	*Acer* L.
Maple, broadleaf	*Acer macrophyllum* Pursh
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak	*Quercus* L.
Papaw	*Asimina triloba* (L.) Dunal
Pine	*Pinus* L.
Pine, eastern white	*Pinus strobus* L.

COMMON NAME	BOTANICAL NAME
Pine, jack	*Pinus banksiana* Lamb.
Pine, lodgepole	*Pinus contorta* Dougl.
Pine, ponderosa	*Pinus ponderosa* Laws.
Pine, red	*Pinus resinosa* Ait.
Pine, western white	*Pinus monticola* Dougl.
Spruce	*Picea* A. Dietr.
Spruce, black	*Picea mariana* (Mill.) BSP.
Spruce, Engelmann	*Picea engelmannii* Parry
Spruce, red	*Picea rubens* Sarg.
Spruce, Sitka	*Picea sitchensis* (Bong.) Carr.
Spruce, white	*Picea glauca* (Moench) Voss
Sycamore	*Platanus occidentalis* L.
Tamarack	*Larix laricina* (Du Roi) K. Koch
Tulip-tree	*Liriodendron tulipifera* L.
Walnut, black	*Juglans nigra* L.
Willow	*Salix* L.

SUBJECT INDEX

1205-7-68-5M.