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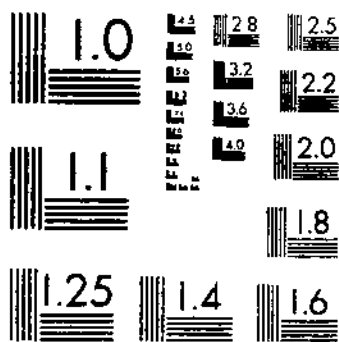
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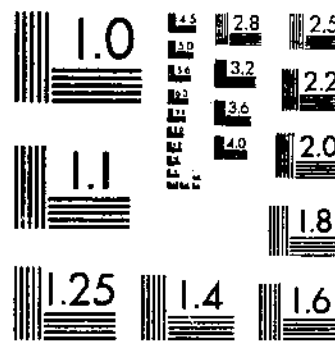
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BOTANICAL DESCRIPTIONS OF FORTY ARTIFICIAL PINE HYBRIDS
LITTLE, E. L. RIGTER, F. I. 1 OF 1

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Botanical Descriptions of Forty Artificial

Pine Hybrids

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INTRODUCTION

Botanical descriptions of 40 artificial first-generation pine hybrids (genus *Pinus*) growing at the Institute of Forest Genetics, Placerville, Calif.,¹ are recorded here. These include 34 first-generation (F_1) interspecific hybrids from 32 species, 5 additional crosses involving a different variety of one of the parent species, and 1 intervarietal hybrid.

Many of these hybrids and other hybrids from the Institute are being tested to determine their adaptability and economic performance in various localities. Those found superior to the standard, or commonly used, form in a particular locality may be planted widely. For example, one hybrid has been under mass production since 1964 in South Korea (22, 23).² Others may serve as breeding stock for additional crosses and for further tests to determine inheritance of characters.

These botanical or taxonomic descriptions, accompanied by herbarium specimens, will document these artificial hybrids, will designate them by formulas, will aid in identification of supposed or artificial hybrids and, by comparison with similar crosses elsewhere, will form the bases for studies of inheritance of various morphological characters.

Needle characteristics of most of these hybrid pines and their parental species are compared in tables presented by Keng and Little (25).

Performance tests of these hybrids will be published later. Several other F_1 hybrids, including some too small in 1962 for adequate comparison and description, will be reported later.

The Institute has other hybrids not reported here. Some are between varieties of the same species. Others are backcrosses, second-generation (F_2) hybrids, and hybrids with three and four species in their pedigrees. No attempt will be made to describe these because of their variability. Individuals within progenies are highly variable as a result of expected segregation and recombination of parental characters.

Records on the parents, including geographical source, of these hybrids are on file at the Institute. Some of the parent trees are growing in the Eddy Arboretum. Some of these crosses have been made at other places, and a few are known also as natural hybrids. We have not compared these hybrids with others elsewhere. However, the descriptions would serve that purpose. Minor or major differences in certain traits might occur in the same hybrid if it was made from parents or races other than those used at the Institute.

Acknowledgment is due the staff of the Institute for their painstaking work in producing these pine hybrids. Their critical attention to cross-pollination, seed handling, sowing in the nursery, outplanting, and care in the arboretum was basic to the success of the hybridization program at the Institute.

¹ The Institute is a field branch of the Pacific Southwest (formerly California) Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. The Institute was founded by James G. Eddy in 1925.

² Italic numbers in parentheses refer to Literature Cited, p. 44.

REVIEW OF LITERATURE

Several detailed summaries of interspecific hybrids in the genus *Pinus* have been made. Duffield (14) made a taxonomic revision of subsection *Pinaster* of the hard pines that was based chiefly on crossing results obtained at the Institute. Wright (48) compiled the species crosses in the 5-needle white pines. Wright and Gabriel (49) summarized data on numerous characters of species hybrids in series *Lariciones* (*Sylvestres*) of the hard pines. Critchfield (12) summarized the crossability of the pines of Southeastern United States. Schütt (40), in a comprehensive review, presented a compilation of hybrids in this genus.

The Eddy Arboretum of the Institute probably contains the most inclusive collection of pines in the world: About 75 species, numerous varieties of various species, and some 90 hybrid combinations, including first-generation (F_1), second-generation (F_2), backcrosses, and multispecies hybrids (26). More than 30 artificial F_1 species hybrids have been mentioned in previous articles (12-15, 25, 26, 37).

Two of these interspecific hybrids previously described formally with Latin names have been included here for comparison and reference. They are *Pinus* \times *attenuaradiata* Stockwell & Righter (46)—or *P. attenuata* Lemm. \times *P. radiata* D. Don.—and *Pinus* \times *murraybanksiana* Righter & Stockwell (39)—or *P. contorta* var. *murrayana* (Grev. & Balf.) Engelm. \times *P. banksiana* Lamb.

Entomologists have investigated the susceptibility of hybrids and their parents at the Institute to several destructive forest insects. Miller (30), Callahan (9), and Smith (43) have reported on resistance and susceptibility of 11 F_1 hybrids, other hybrids, and species to the pine reproduction weevil, *Cylindrocopturus eutoni* Buch. Smith (44) has studied resistance of hybrids and their parents to *Dendroctonus* bark beetles. He (42) and Stevens (45) reported on relative resistance of several F_1 hybrids and parent species to the pine needle-sheath miner, *Zelleria himbuchi* Busek.

Hybrids produced at the Institute have been subjects for sundry studies. These are reviewed following the description of the hybrid to which they pertain.

PROCEDURE

Botanical descriptions are based upon living plants growing at the Institute. They were prepared largely by the senior author while he was working at the Institute in June-August 1956, August-September 1957, and April-May 1962. He added a few additional details, mostly about cones, in June-July 1964. The junior author made or helped make many of these hybrids, identified and selected most of them in the nursery, and for many years supervised the Institute's pine hybridization reconnaissance.

Numerous plants of most hybrids were available for study, though several hybrids were represented by only a few individuals. Many crosses had been made more than once from parents of different localities. Several reciprocal crosses were represented. Usually, hybrids and nonhybrid progeny of the same seed parent and same age were planted side by side; therefore, they could be readily compared. In

the study of needle characters of these hybrids by Keng and Little (25), the samples were selected at random.

Herbarium specimens were collected by the senior author from one representative tree of each hybrid. Where possible, trees bearing cones were selected. Most collections were made in August and September, when twigs had formed dormant buds. A few collections of old cones were made later. To document these hybrids, duplicate sets of specimens have been deposited in the following herbaria: Institute of Forest Genetics, Placerville, Calif.; Forest Service Herbarium, Washington, D.C.; Arnold Arboretum, Harvard University; and Bailey Hortorium, Cornell University.

DESIGNATING HYBRID FOREST TREES

Interspecific plant hybrids may be designated by a formula or, when useful or necessary, by a Latin binary or "specific" name, according to the International Code of Botanical Nomenclature. Hybrids of cultivated plants are given distinctive variety (cultivar) names, or common names, in modern languages, based on the International Code of Nomenclature for Cultivated Plants. Many natural interspecific hybrids of forest trees and a few artificial hybrids have been given Latin or scientific names. Both methods have been compared by Little (28). He reported that most forest geneticists in the United States, including those serving on the Committee on Forest Tree Improvement of the Society of American Foresters, preferred formulas, opposed Latin binomials, and endorsed the International Code of Nomenclature for Cultivated Plants for naming varieties (cultivars) in modern languages.

Thus, no new Latin names are proposed here, though two hybrids reported here had been previously named and a few others already possess Latin binomials. The International Code of Nomenclature for Cultivated Plants (Article 45) requests that a variety (cultivar) name be given to the particular described plants when an interspecific hybrid or similar hybrid is introduced into cultivation. This original hybrid can then be distinguished from other, and perhaps different, crosses made later from the same parent species.

As cultivation and commercial production are just beginning for a few Placerville hybrids, it seems unnecessary to assign variety (cultivar) names now. Of course, those hybrids of demonstrated value that are worthy of production in quantity will be given distinctive variety (cultivar) names in due course. Meanwhile, the term "Placerville hybrid" will, when desirable, distinguish these from crosses of similar parentage made elsewhere.

It is hoped that plant taxonomists likewise will refrain from publishing Latin binary names for the interspecific hybrids described in this bulletin and thereby avoid loading the scientific nomenclature with unnecessary names.

Formulas designate the hybrids described here. The female parent, or seed parent, is listed first, followed by the male parent, or pollen parent. Reciprocal crosses made at the Institute are mentioned also. In such cases the formula corresponds to the cross as it was first made at the Institute. Any binary names previously given to interspecific hybrids are cited as synonyms. Common names

and ranges of parents are included. Citations of place of publication of accepted scientific names of parents have been added for reference and for precision in nomenclature.

Nomenclature of the species and varieties of *Pinus* native to the United States follows the Forest Service Check List (27) with three exceptions. The white pine of the Mexican border region is designated as a separate species, *Pinus strobiformis* Engelm., southwestern white pine, instead of *P. flexilis* var. *reflexa* Engelm. The Rocky Mountain variation of ponderosa pine is distinguished here as a variety, *P. ponderosa* var. *scopulorum* Engelm., Rocky Mountain ponderosa pine. Lodgepole pine in Sierra Nevada is distinct, according to Critchfield (11), and is accepted here as a variety, *P. contorta* var. *murrayana* (Grev. & Balf.) Engelm., Sierra lodgepole pine. Also, *P. muricata* D. Don, bishop pine, of the Check List and this bulletin, includes the form separated by some authors as *P. remorata* Mason.

DESCRIPTIONS

The hybrids are listed and described approximately as in the natural classification by Shaw (41) and the groups by Duffield (14). This order was followed also by Keng and Little (25) in their tabulations of the needle anatomy of most of these hybrids. The botanical or taxonomic descriptions emphasize characters in which the two parent species differ. Parts described include bark, twig, bud, leaves, and needle anatomy in cross section (middle portion). Some hybrid plants were young and had not produced cones. However, for most of these hybrids, male strobili (male cones or pollen cones), female or ovulate strobili at pollination, the year-old conelets, cones, and seed are described.

The general statement "tree intermediate between parents" could have been inserted in each botanical description. These hybrids can be identified and recognized by their taxonomic or morphological characters partly between the well-known, published descriptions of the parent species (or varieties). The overall impression of each hybrid from an integration of all characters is intermediacy. Undoubtedly most traits, and particularly those governing overall tree size and form, are governed by a number of genes with additive effects. However, many traits of hybrids having taxonomic value are not intermediate between the parent species. In some characters the hybrids may be nearer or like one parent or the other.

After each description the herbarium specimen of a representative hybrid tree is cited by Little's collection number. The Institute's symbols for the parent species, individual tree number, and row/line position of the tree in the arboretum are given in parentheses. These symbols, numbers, and locations are described by Liddicoet and Righter (26).

Also, each hybrid and its parents are compared briefly with respect to the characters by which the parents differ. No attempt has been made to tabulate similarities or differences. The history of this hybrid at the Institute is mentioned with years of pollinations and sowing of seeds. Information on the approximate numbers of progeny and the sizes of the oldest when studied or when measured at the age of 10 or 20 years usually is given. Measurements in the botanical

descriptions follow the metric system, but tree heights and diameters are in feet and inches, according to forestry practice in the United States.

Cones of 22 hybrids are compared with cones of the parents (figs. 1-8). One fairly typical cone is used to illustrate the intermediate character of the cones in size, shape, and number of scales.

SOFT PINE HYBRIDS, *PINUS* SUBGENUS *STROBUS* (*HAPLOXYLON*)

Eleven hybrids and 1 reciprocal cross involve 9 species of soft pines (*Pinus* subgenus *Strobus*, formerly *Haploxyylon*). One of these, *P. peuce* × *strobus*, was not produced at the Institute. Five of the 12 species of soft pines native in the United States are represented. The other 4 species crossed are introduced.

Pinus lambertiana × *armandii* Sugar pine × Armand pine (fig. 1)

Artificial hybrid between *Pinus lambertiana* Dougl. (Linn. Soc. London Trans. 15: 500, 1827), of Pacific coast region of North America, and *Pinus armandii* Franch. (Paris Mus. Hist. Nat. Nouv. Arch. Sér. 2, 7: 95-96, t. 12, 1885), of China, Taiwan, and Japan. Bark of small trunks slaty gray, smooth. Twigs light greenish to tan and slightly glaucous, nearly glabrous but slightly and minutely puberulent, becoming light brownish gray and glabrous. Buds conic, acuminate, slightly or not resinous. Leaves 5 in a fascicle, slender, flexible, and spreading, 7-11 cm. long, acuminate, serrulate, green; stomata none on dorsal surface, 3-5 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of cells; resin canals 2 dorsal external and sometimes also 1 ventral medial.

Male strobili cylindric or ovoid, 7-13 mm. long, 4-5 mm. in diameter, light yellow, becoming light pink on drying. Conelets single or paired, after pollination erect, long-stalked, cylindric. Cone (description based upon 1 maturing in 1962) pendent on stout peduncle 4 cm. long, narrow cylindric, 18 cm. long, 9.5 cm. across when open; apophyses slightly thickened, with lines and grooves and usually a weak central ridge, rounded and slightly curved outward at apex, fulvous brown, with terminal obtuse umbo slightly raised and usually bearing resin; basal scales spreading to reflexed. Seeds dark brown, composed of ovoid body about 8 mm. long and oblong wing 10-14 mm. long. Specimens: Little 17123 (Tree LAm 4, 169/42); 18818 (Tree LAm 1, 169/40).

The hybrid resembles *Pinus armandii* in absence of dorsal stomata on leaves and in the slightly glaucous, nearly glabrous twigs but is like *P. lambertiana* in having usually 2 resin canals in the leaves. The single hybrid cone is intermediate in size and has lines and ridge on apophyses as in *P. armandii*. Seeds have a relatively short wing intermediate between the rudimentary wing in *P. armandii* and the long wing in *P. lambertiana*.

Four seeds resulted from pollination in 1946 but failed to germinate. The 7 seeds from pollination in 1947 were germinated in 1949 by Stone and Duffield (47) after the seedcoat was removed. The 5

surviving plants were normal and up to 6 feet in height by June 1956 and 2-10 feet high at 10 years of age. Two plants from another pollination in 1947 were germinated in 1951 by a similar technique and were 2 and 5 feet in height at 10 years. Three more plants were obtained without special culture from pollination in 1957. Seed were sown and germinated in 1959.

Pinus lambertiana* × *koraensis
Sugar pine × Korean pine

Artificial hybrid between *Pinus lambertiana* Dougl. (Linn. Soc. London Trans. 15: 200. 1827), of the Pacific coast region of North America, and *Pinus koraensis* Sieb. & Zucc. (Fl. Jap. 2: 28, t. 116, fig. 5-6. 1844), of northeastern Asia from Manchuria and eastern Siberia to Korea and Japan. Twigs tan, densely puberulent, later light gray and glabrous. Buds conic, acuminate, slightly or not resinous. Leaves 5 in a fascicle, slender, flexible, spreading, 5-7 cm. long (small plant), acuminate, serrulate, green; stomata none on dorsal surface, 3-4 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of cells; resin canals 3, 2 dorsal external, or 1 external and 1 medial (or often subexternal), and also 1 ventral medial, the epithelial cells thin-walled, sometimes thick-walled. Specimen: 17124 (Tree LK 1, 169/45).

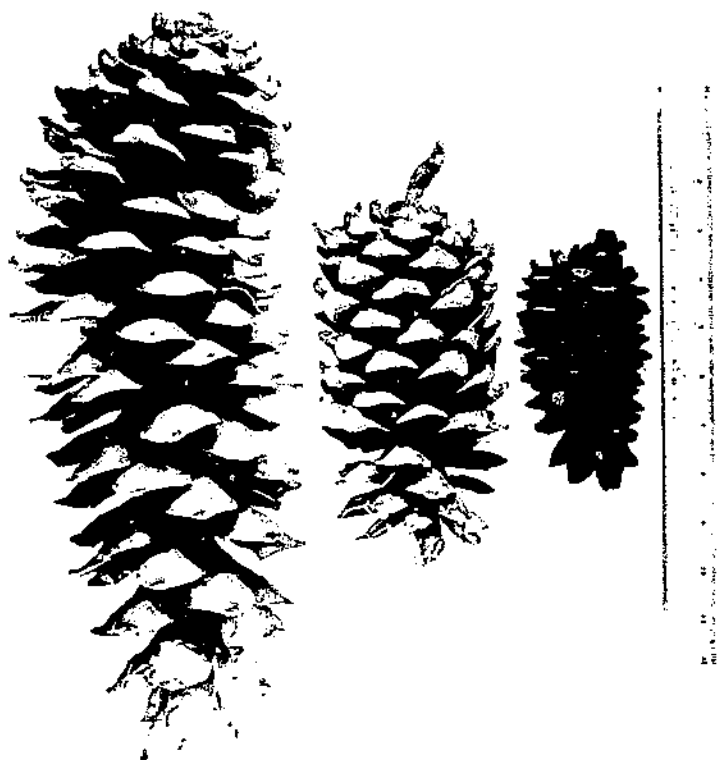
The hybrid resembles *Pinus koraensis* in the tan twigs, absence of dorsal stomata on leaves, and needle anatomy with hypodermis of 1 layer of cells and with 3 resin canals bordered by usually thin-walled epithelial cells. The position of the 3 resin canals in the hybrid is distinctive and intermediate between the medial position of *P. koraensis* and the external position of *P. lambertiana*.

Stone and Duffield (47), after removing the seedcoat, succeeded in germinating in 1949 the single seed resulting from pollination in 1947. In June 1956 this plant was less than 3 feet high and in 1959, at 10 years of age it was 5.2 feet high.

Pinus flexilis* × *strobiformis
Limber pine × southwestern white pine

Artificial hybrid between *Pinus flexilis* James (Exped. Rocky Mts. 2: 27. 35. 1823), of western North America, and *Pinus strobiformis* Engelm. (in Wisliz., Mem. Tour North. Mex. 102. 1848); *P. flexilis* var. *reflexa* Engelm.), of northern Mexico and adjacent Arizona and New Mexico. Twigs slender, glaucous, whitish green when young, minutely puberulent or glabrous, the second year becoming light gray, older twigs gray, smooth. Buds light brown, the attenuate scales whitish bordered, not resinous. Leaves 5 in a fascicle, slender, flexible, straight, spreading, 5-8 cm. long, 0.9-1.2 mm. wide, acuminate, slightly serrulate at and near apex, whitish green; stomatal rows 1-3 on deep dorsal surface and 3-5 on each glaucous, whitish ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of slightly thick-walled cells; resin canals external, 2, sometimes 3 or 4, 2 dorsal and sometimes also 1 or 2 smaller ventral; transfusion tissue without thick-walled cells or these scattered. Specimen: 19133 (Tree FStr 6, 175/46).

The two related species, often regarded as varieties of one, are similar in needle characters. *Pinus flexilis* usually has entire needles



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FIGURE 1.—Cones, left to right, *Pinus lambertiana*, *P. lambertiana* × *armandii*, and *P. armandii*. One-fourth natural size.

with 2-4 rows of dorsal stomata, while *P. strobiformis* usually has serrulate, more slender needles without dorsal stomata or sometimes with 1 or 2 rows. Small plants of the hybrid are intermediate in having needles slightly serrulate at apex and often in the apical one-fourth and with 1-3 rows of dorsal stomata. The parents and hybrid are scarcely distinguishable in needle anatomy.

This cross with female parent from California and male parent from Chiricahua Mountains, Ariz., was made in 1955. Five plants from seed sown in 1957 were about 1.5 feet high by the end of 1961.

Pinus monticola* × *strobiformis
Western white pine × southwestern white pine

Artificial hybrid between *Pinus monticola* Dougl. (ex D. Don in Lamb., Descr. Genus Pinus. Ed. 3 (8°), v. 2, unnumbered p. between pp. 144-145. 1832), of Western United States and southern British Columbia, and *Pinus strobiformis* Engelm. (in Wislitz., Mem. Tour North. Mex. 102. 1848; *P. flexilis* var. *reflexa* Engelm.), of northern Mexico and adjacent Arizona and New Mexico. Twigs light brownish green, densely reddish-brown puberulent, the second year becoming

light gray and glabrous. Buds conic, acuminate, not resinous. Leaves 5 in a fascicle, slender, flexible, 6-8 cm. long, acuminate, slightly serrulate, green; stomata none or 1 row on dorsal surface, 2-4 rows on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis uniform, of 1 or sometimes 2 layers of slightly thick-walled cells; resin canals external, 2, sometimes 3 or 1, dorsal or sometimes 1 ventral. Specimen: 17122 (Tree MtStr 5, 182/57).

Hybrid plants resemble *Pinus monticola* in most characters, such as the densely puberulent twigs, but have lighter green foliage and greatly exceed in vigor the nonhybrid progeny of that parent. Though needle anatomy of parents is similar, the hybrid is like *P. monticola* in variability of resin canals.

The male parent came from the Chiricahua Mountains of Arizona. Eight normal plants obtained from pollination in 1946 and seed sown in 1949 were about 4 feet high in June 1956 and about 12 feet high by the end of 1961.

Pinus monticola* × *flexilis
Western white pine × limber pine

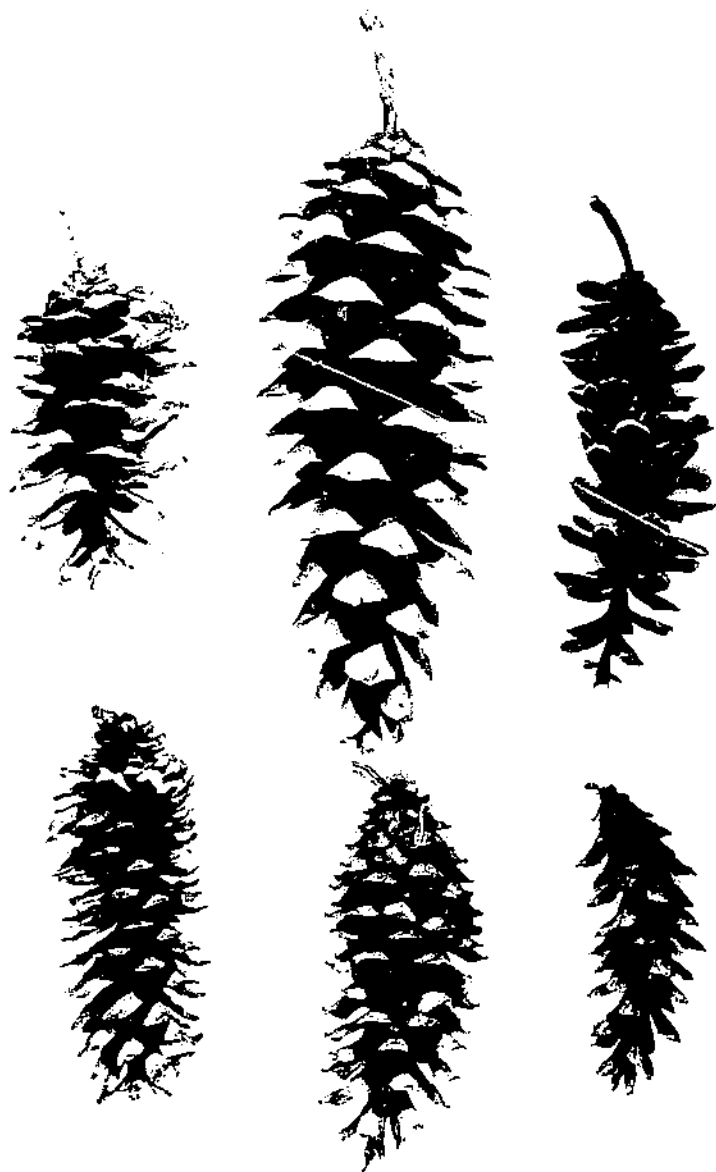
Artificial hybrid between *Pinus monticola* Dougl. (ex D. Don in Lamb., Descr. Genus *Pinus*. Ed. 3 (8°), v. 2, unnumbered p. between pp. 144-145. 1832), of Western United States and southern British Columbia, and *Pinus flexilis* James (Exped. Rocky Mts. 2:27, 35. 1823), of western North America. Twigs slender, glaucous, whitish green when young, minutely puberulent with pinkish hairs when young, becoming tan and the second year light gray, smooth. Buds light brown, conic, acuminate, not resinous. Leaves 5 in a fascicle, slender, flexible, straight, spreading, 4-6 cm. long (small plants), acuminate, with few teeth near apex or entire, whitish green; stomatal rows 1-2 (3) dorsal and 3-5 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of slightly thick-walled cells; resin canals external, 2 dorsal, transfusion tissue without thick-walled cells. Specimen: 19141 (Tree MtF 1, 178/41).

The parent species and hybrid are similar in most needle characters. Needles of small hybrid plants have dorsal stomata as in *Pinus flexilis*, though fewer, but are like *P. monticola* in having usually a few teeth near apex, hypodermis of 1 layer of cells, and no thick-walled cells in transfusion tissue.

This cross was made in 1955. Two plants from seed sown in 1957 averaged about 2 feet high in 1964.

Pinus monticola* × *strobus
Western white pine × eastern white pine (fig. 2)

Also reciprocal cross. Artificial hybrid between *Pinus monticola* Dougl. (ex D. Don in Lamb., Descr. Genus *Pinus*. Ed. 3 (8°), v. 2, unnumbered p. between pp. 144-145. 1832), of Western United States and southern British Columbia, and *Pinus strobus* L. (Sp. Pl. 1001. 1753), of eastern North America. Bark of small trunks slaty gray, smooth. Twigs when young light green and minutely pinkish or reddish brown puberulent, becoming light gray. Buds conic, acuminate, not resinous. Leaves 5 in a fascicle, slender, flexible, 5-9 cm. long (small plants), acute-acuminate, serrulate, green; stomata



8-510124

FIGURE 2.—Cones, left to right, top row, *Pinus monticola* \times *griffithii*, *P. griffithii*, *P. strobus* \times *griffithii*; bottom row, *P. monticola*, *P. monticola* \times *strobus*, *P. strobus*. One-third natural size.

none on dorsal surface, 3-5 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 (rarely 2) layer of slightly thick-walled cells; resin canals external, 2 dorsal, sometimes also 1 ventral, with thin- or thick-walled epithelial cells.

Year-old conelets erect, short cylindric, about 2 cm. long, 1 cm. in diameter. Cones single or paired, sometimes in whorls of 3 or 4, pendent on peduncles 2-4 cm. long, narrow cylindric, often slightly curved, 8-15 cm. long, 2-2.5 cm. in diameter when closed, 5.5-6 cm. in diameter when open; apophyses thin, smooth, flat and conforming to surface of closed cone, fulvous brown, with terminal obtuse umbo slightly raised; basal scales narrowly oblong, becoming reflexed. Seed, including narrowly oblong dark brown wing, about 2 cm. long. Specimens: 17117 (Tree MtSt 71, 209/46); reciprocal cross, 18817 (Tree StMt 15, 204/59).

First-generation hybrids of several crosses including reciprocal are similar, as vegetative differences of the closely related parents are minor. Though the parents are scarcely distinguishable by needle anatomy, the hybrid is like *Pinus monticola* in sometimes having 1 ventral resin canal. Cones of the small hybrid trees are intermediate in diameter. According to Shaw (41, p. 30), the phyllotaxis in *P. strobus* is 5/13 and in *P. monticola*, 8/21. In the narrowly oblong reflexed basal cone scales, the hybrid resembles *P. monticola*, while *P. strobus* has broader, slightly spreading basal scales.

About 90 plants of this hybrid are growing at the Institute. Pollination with *Pinus monticola* as seed parent was made as early as 1939. Sources of *P. monticola* from Idaho, Washington, and California were tested. Eight plants from seeds sown in 1941 averaged 12.6 feet in height and 1.9 inches d.b.h. at 20 years, while 8 plants from sowing in 1942 averaged 10.2 feet and 1.3 inches d.b.h. at 20 years. More than 50 younger plants from seeds sown in 1949 were 3-5 feet high in 1956, when some bore cones or conelets, and averaged 7.8 feet in height at 10 years. The reciprocal cross was made in 1947, and seed were sown in 1949. At 10 years 16 plants averaged 7.9 feet high and 1.0 inches d.b.h.

This hybrid was included in a study by Righter (35) of the relation of seed weight and seedling size to inherent vigor. Elsewhere, Bingham, Squillace, and Patton (6) and others have made detailed investigations of the same interspecific hybrid, particularly in relation to resistance to blister rust.

Pinus monticola × *peuce* Western white pine × Balkan pine

Artificial hybrid between *Pinus monticola* Dougl. (ex D. Don in Lamb., Descr. Genus *Pinus*. Ed. 3 (8°), v. 2, unnumbered p. between pp. 144-145. 1832), of Western United States and southern British Columbia, and *Pinus peuce* Griseb. (Spicil. Fl. Rumel. Byth. 2: 349. 1844), Balkan pine, known also as Macedonian pine, of the Balkan Mountains. Twigs light green and glabrous, becoming brownish gray. Buds conic, acuminate, slightly or not resinous. Leaves 5 in a fascicle, slender, flexible, 5-8 cm. long (small plants), acute-acuminate, serrulate, green to yellow green, slightly shiny; stomata none on dorsal surface, 3-4 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 (rarely 2) layer of cells; resin canals external, 2 dorsal, sometimes also 1 ventral with thin- or thick-walled epithelial cells.

Year-old conelets erect, short cylindric, about 18 mm. long and 8 mm. in diameter. Cones single or paired, pendent on peduncles 1.5-2 cm. long, narrow cylindric, slightly curved, 8-9 cm. long, 2.3 cm. in

diameter when closed; apophyses smooth, slightly convex and in part weakly keeled, the apex with obtuse rufous brown umbo flat against scale beneath; basal scales broadly oblong, slightly spreading. Specimen: 17118 (Tree MtPe 10, 195/54).

In the light green, glabrous twigs, this hybrid is like *Pinus peuce*. Needle anatomy of parents is similar, the hybrid being like *P. monticola* in sometimes having 1 ventral resin canal and like *P. peuce* in the epithelial cells partly thin-walled. Cones of the hybrid are intermediate, having slightly convex scales and slightly spreading basal scales, but like *P. peuce* in the umbo, flat against the scale beneath. Peduncle length is intermediate, longer than in *P. peuce*.

Sixteen plants were raised from seed sown in 1949 following pollination in 1947. In June 1956 they were about 3 feet high; 1 had cones and 5 bore conelets. At 10 years they averaged 5.9 feet in height.

***Pinus peuce* × *strobis*
Balkan pine × eastern white pine**

Artificial hybrid between *Pinus peuce* Griseb. (Spicil. Fl. Rumel. Byth. 2: 349. 1844), Balkan pine, known also as Macedonian pine, of the Balkan Mountains, and *Pinus strobus* L. (Sp. Pl. 1001. 1753), of eastern North America. Twigs tan and glabrous, later light brownish gray. Buds conic, acuminate, not resinous. Leaves 5 in a fascicle, slender, flexible, 4-9 cm. long (small plants), acute, serrulate, green; stomata none on dorsal surface, 3-4 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of cells; resin canals external dorsal, 2, sometimes 1 or 3, with thin- or thick-walled epithelial cells. Specimen: 17125 (Tree PeSt G1, 170/44).

This hybrid retains the glabrous twigs of *Pinus peuce*. Though needle anatomy of parents is scarcely distinguishable, the hybrid has the more variable number of resin canals like *P. strobus* and variation in epithelial cells like *P. peuce*.

Although not produced at the Institute, this hybrid was propagated through grafting scions on stocks of *Pinus monticola* in 1951, and outplanting in 1952. In June 1956 the 3 plants were 1.5-3 feet high; the largest bore a conelet. The 2 survivors at 10 years were 4.6 and 6.0 feet high.

Seven scions were received from Carl L. Heimburger, Research Branch, Ontario Department of Lands and Forests, Maple, Ontario. Fowler and Heimburger (17) compared in detail this hybrid with the parent species, using the hybrid index method.

***Pinus flexilis* × *griffithii*
Limber pine × Himalayan pine (fig. 3)**

Artificial hybrid between *Pinus flexilis* James (Exped. Rocky Mts. 2: 27, 35. 1823), of western North America, and *Pinus griffithii* McClelland (in Griffith, Notul. Pl. Asiat. 4: 17. 1854; Icon. Pl. As. 4, t. 365. 1854; *P. excelsa* Wall., not Lam., *P. wallichiana* A. B. Jackson) of Himalaya Mountains and from Afghanistan to Burma. Twigs glaucous, glabrous, light brownish green when young, becoming light gray. Buds conic, acuminate, not resinous. Leaves 5 in a

fascicle, slender, flexible, spreading, 7-9 cm. long, acuminate, serrulate, green to blue green; stomata none (rarely 1 row) on dorsal surface, 4-6 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of slightly thick-walled cells; resin canals external dorsal, 2 or sometimes 1, with thin-walled or slightly thick-walled epithelial cells.

Male strobili (old and dry) cylindric but tapering, 9-12 mm. long, 4-5 mm. in diameter, pinkish tinged. Young female or ovulate strobili 1-3, erect on stout stalks, cylindric. Cones usually single or paired, pendent on peduncles 2 cm. long, narrow cylindric, 13-18 cm. long, 4.5 cm. in diameter when closed; apophyses smooth, with terminal obtuse umbo; basal scales oblong, slightly reflexed. Specimens: 17121, 19160 (Tree FEx 1, 191/53).

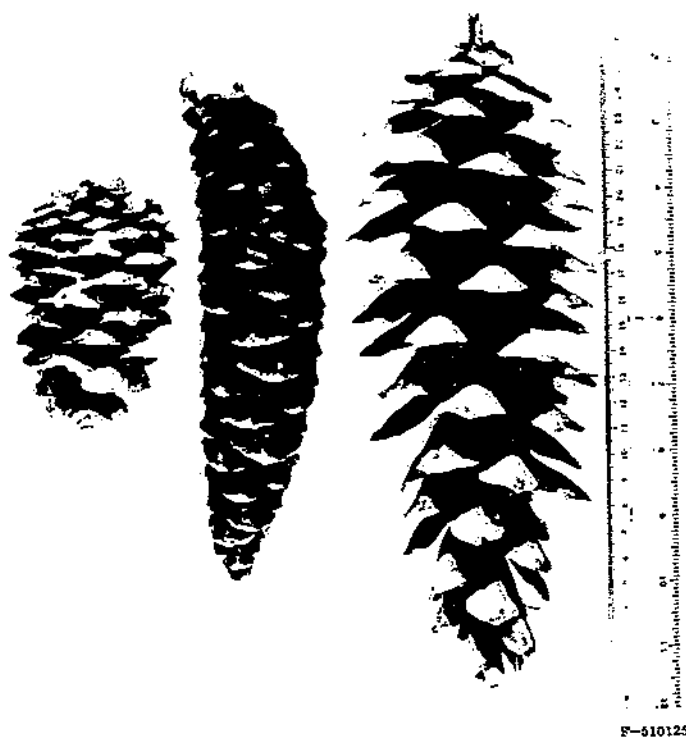
The hybrid has spreading leaves of intermediate length between the straight erect ones of *Pinus flexilis* and the slightly drooping, longer ones of *P. griffithii*. The serrulate leaf margin of the hybrid is characteristic of the latter. In number of stomatal rows the hybrid is intermediate though like *P. griffithii* in usually lacking dorsal stomata. Parents and hybrid are scarcely distinguishable in needle anatomy. The cones are intermediate in size but have the slightly reflexed basal scales of *P. flexilis*.

Six plants from pollination in 1947 and seed sown in 1949 were about 6 feet high and vigorous in June 1956 and at 10 years averaged 10.8 feet high.

Pinus strobus × *griffithii* Eastern white pine × Himalayan pine (fig. 2)

Artificial hybrid between *Pinus strobus* L. (Sp. Pl. 1001. 1753), of eastern North America, and *Pinus griffithii* McClelland (in Griffith, Notul. Pl. Asiat. 4: 17. 1854: Icon. Pl. As. 4, t. 365. 1854: *P. excelsa* Wall., not Lam., *P. wallichiana* A. B. Jackson) of Himalaya Mountains and from Afghanistan to Burma. (*Pinus* × *scheuchzeri* Fitch.) Bark of small trunks slaty gray, smooth. Twigs glaucous, when young almost glabrous or minutely puberulent and light green, becoming light brownish gray. Buds conic, acuminate, slightly or not resinous. Leaves 5 in a fascicle, slender, flexible, spreading, 8-12 cm. long, acute-acuminate, serrulate, green to blue green; stomata none on dorsal surface, 3-6 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of slightly thick-walled cells; resin canals external dorsal, 2.

Male strobili (old and dry) cylindric but tapering, 8-12 mm. long, 4 mm. in diameter, pale yellow, pinkish tinged. Female or ovulate strobili at pollination 1-4, erect on stout stalks 1-3 cm. long, cylindric, 10-15 mm. long, 4 mm. in diameter. Year-old conelets erect, short cylindric, 1.8-2 cm. long, 8 mm. in diameter. Cones single or paired, sometimes in whorls of 3, pendent on peduncles 2-4 cm. long, narrow cylindric, often slightly curved, 11-19 cm. long, about 2 cm. in diameter when closed, 6 cm. in diameter when open; apophyses smooth, slightly convex, fulvous brown, with terminal obtuse umbo flat against scale beneath in closed cone; basal scales broadly oblong, slightly spreading. Seed, including narrowly oblong dark brown wing, about 2.5 cm. long. Specimens: 17119 (Tree StEx 27, 207/57); 18819 (Tree StEx 24, 207/54).



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FIGURE 3.—Cones, left to right, *Pinus flexilis*, *P. flexilis* × *griffithii* (immature, closed cone), *P. griffithii*. One-third natural size.

The hybrid is characterized by spreading needles of intermediate length. Young twigs have the glaucous light green color of *Pinus griffithii* and a trace of the puberulence of *P. strobus*. Needles of hybrid and parents are not distinguishable in cross section. The intermediate cones with slightly convex scales have the umbo flat against the scale beneath, as in *P. griffithii*.

Pollination was made here first in 1940 and again in 1947. Seven plants from the first pollination averaged 11.8 feet (maximum 22.3 feet) at 20 years. Eight plants in their eighth growing season in June 1956 were 3-6 feet tall and vigorous, 4 bearing cones and 3 also conelets. At 10 years they averaged 10.0 feet high.

Callaham (10) reported this hybrid to be highly resistant to white pine blister rust (*Cronartium ribicola* Fischer). A spontaneous hybrid tree in Germany about 24 years old in 1930 was given the binary name *Pinus* × *schweerinii* Fitschen (in Beissner, Handb. Nadelh. Ed. 3, 729. 1930).

Pinus monticola* × *griffithii
Western white pine × Himalayan pine (fig. 2)

Artificial hybrid between *Pinus monticola* Dougl. (ex D. Don in Lamb., Descr. Genus *Pinus*. Ed. 3 (8°), v. 2, unnumbered p. between pp. 144–145. 1832), of Western United States and southern British Columbia, and *Pinus griffithii* McClelland (in Griffith, Notul. Pl. Asiat. 4: 17. 1854; Icon. Pl. As. 4, t. 365. 1854; *P. excelsa* Wall., not Lam., *P. wallichiana* A. B. Jackson), of Himalaya Mountains and from Afghanistan to Burma. Bark slaty gray, smooth. Twigs light brownish green and slightly puberulent or almost glabrous when young, becoming light brownish gray. Buds conical, acuminate, not or slightly resinous. Leaves 5 in a fascicle, slender, flexible, spreading, 5–12 cm. long, acute-acuminate, serrulate, green to blue green; stomata none on dorsal surface, 4–6 rows on each ventral surface. Needle anatomy in cross section: Hypodermis uniform, of 1 layer of slightly thick-walled cells; resin canals external dorsal, 2, sometimes 1 or 3, with thick- or thin-walled epithelial cells.

Male strobili (old and dry) cylindric but tapering and slightly curved, 8–15 mm. long, 5 mm. in diameter, pale yellow, pinkish tinged. Female or ovulate strobili at pollination 1 or 2, erect on stout stalks 1–3 cm., cylindric, 10–15 mm. long, 3–4 mm. in diameter, pink red. Year-old conelets erect, narrow cylindric, about 2 cm. long and 1 cm. in diameter. Cones single or paired, sometimes in whorls of 3, pendent on peduncles 2–3 cm. long, narrow cylindric, often slightly curved, 8–12 cm. long, 2.3–2.7 cm. in diameter when closed, 6 cm. in diameter when open; apophyses smooth, slightly convex, fulvous brown, with terminal obtuse umbo flat against scale beneath in closed cone; basal scales narrowly oblong, becoming reflexed. Specimens: 17120 (Tree MtEx 30, 217/50), 18820 (Tree MtEx 55, 208/54).

Pinus griffithii has drooping, blue-green, relatively long needles, while the hybrid is recognized by its spreading needles of intermediate length and is also intermediate in its slightly puberulent twigs and slightly resinous buds. The hybrid resembles *P. griffithii* in lacking dorsal stomata but is intermediate in number of rows of ventral stomata and in the thick- or thin-walled epithelial cells of the resin canals. Cones are intermediate in the slightly convex cone scales, are like *P. griffithii* in the umbo flat against scale beneath, and are like *P. monticola* in the slightly reflexed basal scales.

About 40 plants were grown at the Institute from this cross made in 1941, 1942, 1944, and 1947 with seed parents from Idaho, Washington, and California. Twelve plants from seed sown in 1946 averaged 12.2 feet high and 1.9 inches d.b.h. at 15 years. Twenty-four hybrids from seeds sown in 1949 were 4–5 feet high in June 1956 and normal to vigorous. Cones or conelets were present on 6 and absent from plants of both parent species of the same age. At 10 years these plants averaged 8.8 feet in height.

Callaham (10) reported that this hybrid is susceptible to white pine blister rust (*Cronartium ribicola* Fischer).

HARD PINE HYBRIDS, *PINUS* SUBGENUS *PINUS* (*DIPLOXYLON*)

Twenty-nine hybrids and 7 reciprocal crosses involve 23 species (1 with 3 varieties) of hard pines (*Pinus* subgenus *Pinus*, formerly *Diploxyylon*). The hybrids may be grouped as follows: 23 first-generation (F_1) interspecific hybrids, 5 additional interspecific hybrids involving another variety of 1 parent species, and 1 intervarietal hybrid.

Two of the 23 species, *Pinus nigra* and *P. montezumae*, are exotics. The 21 others represent all the 24 hard pine species native in the United States except *P. leiophylla*, *P. subiniana*, and *P. torreyana*.

Pinus nigra × *resinosa* Austrian pine × red pine (fig. 4)

Artificial hybrid between *Pinus nigra* Arnold (Reise Mariazell. 8, t. 1785), of southern Europe and Asia Minor, and *P. resinosa* Ait. (Hort. Kew. 3: 367. 1789), of Northeastern United States and southeastern Canada. Spring shoots uninodul. Twigs slender, glabrous, when elongating glaucous to yellow green, year-old lateral twigs 6-8 mm. in diameter, light brown, the bases of bracts decurrent, smoothish, and forming narrow rectangular plates; older twigs light gray or

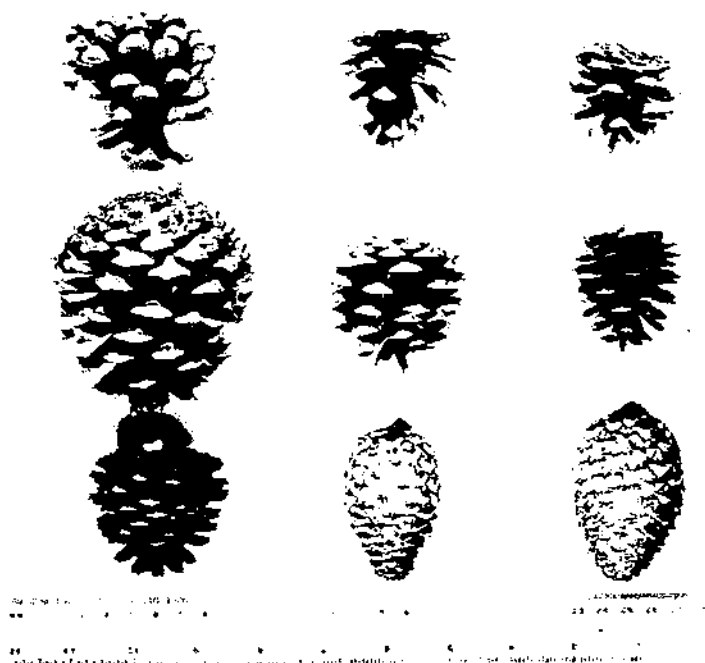


FIGURE 4.—Cones, left to right, top row, *Pinus nigra*, *P. nigra* × *resinosa*, *P. resinosa*; middle row, *P. pungens*, *P. pungens* × *echinata*, *P. echinata*; bottom row, *P. rigida*, *P. rigida* × *serotina*, *P. serotina*. One-third natural size.

light gray brown, smoothish, becoming slightly fissured. Buds acuminate, often slightly resinous, reddish brown, the scales with white fringed margins.

Leaves 2 in a fascicle, straight, slightly stiff, erect, 5-11 cm. long, 1.3-1.5 mm. wide, acuminate, serrulate, green; stomatal rows 8-13 dorsal and 7-10 ventral; basal sheath 10-15 mm. long in bud, becoming 5-8 mm. long, gray brown. Needle anatomy in cross section: Epidermis of nearly square cells, stomata slightly sunken; hypodermis uniform, of 1 or 2 layers of slightly thick-walled cells, inner border straight; resin canals 2-5, external and medial, or external, all dorsal, usually 2 large near angles, medial, 1 external and 1 medial, or 2 external, and usually 1-3 smaller external or medial, bordered by thick-walled cells; endodermis in outline elliptic, of thin-walled cells; trans-fusion tissue with thick-walled cells outside phloem.

Year-old conelets with stout stalk about 7 mm. long, ovoid, about 1 cm. long, umbo with weak keel and minute weak point or prickle or almost none on basal scales. Mature cones ovoid, about 5 cm. long, 2.5 cm. in diameter closed, 5.5 cm. in diameter open, tawny yellow, slightly shiny, opening and shedding soon after maturity. Cone scales weakly keeled, umbo with minute weak point or prickle or almost none on basal scales. Seed about 22 mm. long, including obovoid body about 5 mm. long and 2.5 mm. wide and long membranous wing. Specimen: 19135 (Tree NiRe 2, 159/79).

The hybrid has slightly stiff needles intermediate between the very stiff ones of *Pinus nigra* and the flexible ones of *P. resinosa*. Needles of the hybrid and *P. resinosa* have similar green color, while those of *P. nigra* are dark green. In needle anatomy the two parent species differ conspicuously, while the intermediate hybrid is easily separated from both. The greater stiffness of needles of *P. nigra* apparently is related to the thicker hypodermis and to the slightly thickened epidermis of mostly rectangular, long and narrow cells in cross section. *P. nigra* has a well-developed hypodermis of 2-4 layers of thick-walled cells, *P. resinosa* has a weak hypodermis of 1 layer of thin-walled cells, and the hybrid is intermediate with 1-2 layers of slightly thick-walled cells. *P. resinosa* is recognized by 2 large external ventral resin canals and often 2-5 additional external and medial, dorsal and ventral, while *P. nigra* has medial resin canals, 2 dorsal near angles and up to 8-14 additional dorsal and ventral (rarely 1 external or internal). The hybrid has resin canals of several intermediate combinations but none external ventral, 2 large dorsal resin canals near angles, usually both external or 1 or both medial, and usually 1-3 smaller dorsal external or sometimes medial. Some are subexternal and almost medial, being connected to hypodermis by a single cell in cross section. Thick outer endodermal cell walls characterize *P. resinosa*, though small plants of both parent species and the hybrid have thin-walled endodermal cells.

Cones and conelets of the hybrid are intermediate between the larger cones of *Pinus nigra*, having keeled scales with small prickle, and the smaller ones of *P. resinosa*, having scales not or weakly keeled without prickle. Cone color in *P. nigra* and the hybrid is tawny yellow and in *P. resinosa* nut brown.

Critchfield (19) has described this distinctive rare hybrid and its history and has compared it with its parent species. This is the first successful cross between hard pines of the Eastern and Western Hemispheres as well as the first interspecific hybrid of *Pinus resinosa*.

Other attempts to make this cross have been unsuccessful, both at the Institute and elsewhere. From cross pollination at the Institute in 1955 and seeds planted in 1957, out of 42 seedlings, 4 with superior height growth and of lighter green than seedlings of *P. nigra* apparently were hybrids. After 5 years these 4 plants averaged 4.7 feet high, considerably taller than nearby plants of both parent species.

Pinus elliottii* × *palustris
Slash pine × longleaf pine

Also reciprocal cross. Artificial hybrid between *Pinus elliottii* Engelm. (Acad. Sci. St. Louis Trans. 4: 186, t. 1-3. 1880) and *Pinus palustris* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 14. 1768), both of Southeastern United States. Bark rough, thick, furrowed into long scaly, slightly shaggy plates, blackish gray with brown exposed in deep furrows and where scaled off. Spring shoots uninodal. Twigs stout, glabrous, light yellow green the first year, becoming light brown the second year. Buds large, reddish brown and whitish, the scales whitish fringed. Leaf sheaths whitish, light tan toward base, 2-3 cm. long, in age only about 1 cm. long. Leaves 3 and 2 in a fascicle, stout, stiff, straight to curved or drooping, 15-30 cm. long, acute-acuminate, serrulate, green; stomatal rows of leaves in 3's 8-12 dorsal and 3-6 on each ventral surface, of leaves in 2's 10-15 dorsal and 6-10 ventral. Needle anatomy in cross section: Hypodermis biform, of 2-4 layers of cells, the inner border curved or straight; endodermis of thin-walled cells; resin canals internal and medial, or internal, 2, sometimes 3-4. Specimens: 17226 (Tree ElPa 4, 199/88); reciprocal cross, 17145 (Tree PaEl 2, 8/7).

Parentage of *Pinus palustris* is indicated by the stout twigs, large buds with white-fringed scales, whitish leaf sheaths, very long leaves, and uninodal spring shoots. Leaves partly in 2's suggest *P. elliottii*. In needle anatomy the parents and hybrid are similar and not readily separated, but the hybrid has hypodermis often intermediate in thickness.

The first seed was supplied by Philip C. Wakeley, Southern Forest Experiment Station, New Orleans, La., who made the cross in Louisiana in 1929 with *Pinus palustris* as female parent. From seed planted in 1933, 19 progeny trees were grown. These averaged 12.7 feet high at 10 years, were 10-25 feet high and 3-5 inches d.b.h. in 1956, and apparently had not borne cones. Five plants were raised from the reciprocal cross made at the Institute. Pollination was in 1950, and seeds were sown in 1952. The hybrid trees have not grown well at the Institute. Some have broken crowns, perhaps from snow damage, or slender narrow form.

Pinus elliottii* × *taeda
Slash pine × loblolly pine (fig. 5)

Also reciprocal cross. Artificial hybrid between *Pinus elliottii* Engelm. (Acad. Sci. St. Louis Trans. 4: 186, t. 1-3. 1880; typical variety, *P. elliottii* var. *elliottii*) and *Pinus taeda* L. (Sp. Pl. 1000. 1753), both of Southeastern United States. Bark rough, thick, furrowed into scaly plates, blackish gray with brown exposed in deep furrows. Spring shoots multinodal. Twigs glabrous, glaucous when young, light yellow green the first year, becoming brown the second

year. Buds reddish brown, the scales whitish fringed. Leaves 3 and 2 in a fascicle, stout, stiff, 10-19 cm. long, acuminate, serrulate, green; stomatal rows of leaves in 3's 7-12 dorsal and 4-8 on each ventral surface, of leaves in 2's 12-14 dorsal and 9-10 ventral. Needle anatomy in cross section: Hypodermis biform, of 2, sometimes 3, layers of cells, the inner border straight; endodermis of thin-walled cells; resin canals medial, internal and medial, or partly subinternal, 2-7, 2 large usually medial at angles and often 1-5 additional smaller.

Cones 1-4 at a node, almost sessile, ovoid conic, symmetrical, 7-11 cm. long, 5-7 cm. across when open at maturity, persistent 1 year or more; apophyses dull nut brown, elevated along a transverse keel, umbo raised and about 3 mm. high including the sharp spine. Specimens: 17147, 18843 (Tree EIT 10, 7/12); reciprocal cross, 18842 (Tree TEI 4, 9/3).

The occurrence of leaves partly in 2's is similar to *Pinus elliotii*, as *P. taeda* has needles uniformly 3 in a fascicle. Parents have similar needle anatomy except that resin canals are mostly medial in *P. taeda*, mostly internal in *P. elliotii*, and intermediate in the hybrid. Hybrid cones are intermediate between the small cone with stout spines in *P. taeda* and the large cone with smaller prickles in *P. elliotii*. Cones of *P. taeda* and the hybrid are dull nut brown, while those of *P. elliotii* are shiny reddish brown.

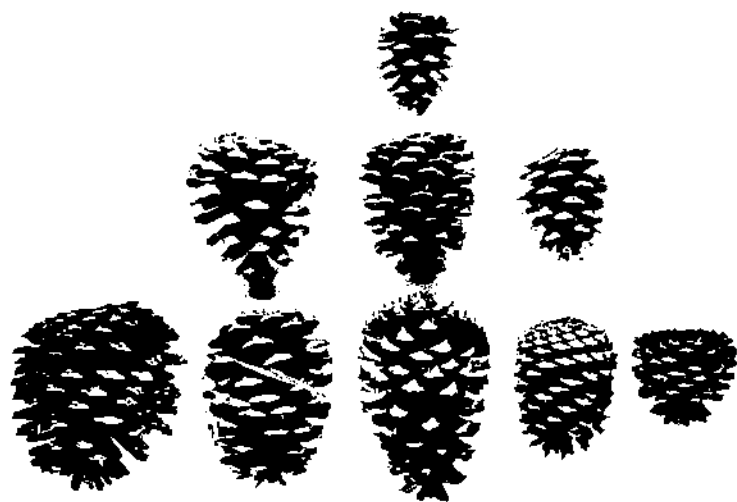
Four trees at the Institute were from pollination in 1931 with *Pinus taeda* as female parent and from seed sown in 1933. Three trees with *P. elliotii* as female parent were from pollination in 1933 and seed sown in 1935. In 1956 these trees were about 80 feet high and 6 inches d.b.h.

Pinus echinata × *elliotii* Shortleaf pine × slash pine (fig. 5)

Artificial hybrid between *Pinus echinata* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 12. 1768), of Eastern United States, and *Pinus elliotii* Engelm. (Acad. Sci. St. Louis Trans. 4: 186, t. 1-3. 1880; typical variety, *P. elliotii* var. *elliotii*), of Southeastern United States. Bark rough, thick, furrowed into scaly plates, blackish gray. Spring shoots multinodal. Twigs glabrous, glaucous when young, light yellow green and shiny the first year, becoming brown the second year. Leaves 2 or sometimes 3 in a fascicle, stout, stiff, 11-20 cm. long, acute-acuminate, serrulate, green; stomatal rows of leaves in 2's 13-16 dorsal and 10-12 ventral, of leaves in 3's 11-14 dorsal and 5-7 on each ventral surface. Needle anatomy in cross section: Hypodermis biform, of 2 or sometimes 3 (rarely 4) layers of cells; endodermis of thin-walled cells; resin canals medial, or medial and internal, 2 large medial at angles and often 1-4 additional, about 0.03-0.06 mm. in diameter.

Cones 1-4 at a node, almost sessile, ovoid conic, symmetrical, 5-7 cm. long, 3.5 cm. in diameter when closed, 5-6 cm. across when open, persistent 1 or 2 years; apophyses elevated along a transverse keel, the umbo raised and ending in a sharp prickle about 1 mm. long. Specimen: 17146 (Tree EEI 10, 8/6).

In needle length and cone size the hybrid is intermediate, though with smaller organs nearer to *Pinus echinata*. The two species differ but slightly in needle anatomy. The hybrid resembles *P. echinata* in the resin canals mostly medial.



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FIGURE 5.—Cones, top, *Pinus echinata*; middle row, left to right, *P. echinata* × *elliottii*, *P. echinata* × *taeda*, *P. rigida* × *echinata*; bottom row, left to right, *P. elliottii*, *P. elliottii* × *taeda*, *P. taeda*, *P. rigida* × *taeda*, *P. rigida*. One-fourth natural size.

Five trees were planted in 1933 from the cross made in 1931. When 23 years old these trees were 30–35 feet high and 6–9 inches d.b.h., mostly with good form and narrow crowns.

Pinus echinata* × *taeda
Shortleaf pine × loblolly pine (fig. 5)

Artificial hybrid between *Pinus echinata* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 12. 1768), of Eastern United States, and *Pinus taeda* L. (Sp. Pl. 1000. 1753), of Southeastern United States. Bark rough, thick, furrowed into long scaly plates, gray. Spring shoots multinodal. Twigs glabrous, glaucous when young, light yellow green and shiny the first year, becoming light reddish brown the second year. Buds acuminate, light reddish brown, resinous. Leaves 3, sometimes mostly 3 and less frequently 2, in a fascicle, slightly stout and stiff, 7–12 cm. long, acute-acuminate, serrulate, green; stomatal rows 9–15 dorsal and 5–7 on each ventral surface or 10–12 on ventral surface of leaves in 2's. Needle anatomy in cross section: Hypodermis usually bifiform with 2 (rarely 3) layers of cells, sometimes uniform with 1 layer, the inner border straight; endodermis of thin-walled cells; resin canals medial, sometimes medial and internal, 2 large medial at angles and often 1–4 additional, about 0.04–0.08 mm. in diameter.

Male strobili (dry) 10–18 mm. long, 3–5 mm. in diameter, orange brown. Cones single or paired, sometimes in whorls of 3 or 4, almost

sessile, ovoid conic, symmetrical, 6-8 cm. long, 4.5-7 cm. across when open, often persistent for several years on old branches; apophyses dull pale fulvous brown, elevated along a transverse keel, the nut-brown umbo forming a sharp stout curved prickle or spine about 3 mm. long. Winged seeds 17-27 mm. long, the detachable wing nut-brown, body ovoid, 5-6 mm. long, blackish. Specimen: 17148 (Tree ET 5, 2/16).

The hybrid might appear to be a variation of *Pinus taeda* with small cones, having the sharp stout prickles of the cone scales. In needle length and cone size the hybrid is intermediate. The number of needles in a fascicle, 3 and 2, distinguish the hybrid, because *P. taeda* has 3 uniformly, while *P. echinata* has usually 2. In needle anatomy the hybrid is intermediate between the slightly differing parents.

This cross was made at the Institute as early as 1933. The reciprocal backcross with *Pinus taeda* was made in 1948. The hybrid occurred spontaneously there prior to its artificial production. More than 90 plants of this interspecific hybrid are growing at the Institute, a few having arisen spontaneously. Additional plants are progeny of hybrid trees by open pollination. Twenty-two trees from seed sown in 1939 averaged 30.4 feet high and 6.7 inches d.b.h. at 20 years.

Intermediate plants or natural hybrids have been reported as common in eastern Texas and probably occur at other localities where the parental species grow together in the Southeastern United States. Zobel (51) noted that seedlings found in nature resembled artificially produced hybrids. Though differences in time of pollination prevent crossing, he suggested that unusual weather may induce early pollen shedding in *Pinus echinata* while the female strobili of *P. taeda* are still receptive. Hybrids tested at Bogalusa, La., from seed supplied by the Institute were reported by Henry and Bercaw (20) to be resistant to fusiform rust (*Cronartium fusiforme* (Arth.) Hedge).

Pinus pungens × *echinata* Table-Mountain pine × shortleaf pine (fig. 4)

Artificial hybrid between *Pinus pungens* Lamb. (Ann. Bot. 2: 198. 1805), of mountains of Eastern United States, and *P. echinata* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 12. 1768), of wide range in Eastern United States. Spring shoots multinodal. Twigs slender, glabrous, glaucous, light yellow green when elongating, becoming whitish purplish brown, year-old lateral twigs 5-7 mm. in diameter, the bases of bracts decurrent and forming narrow rectangular plates. Bark of branches and trunk light gray brown, scaly. Buds acuminate, often resinous, reddish brown, the scales with white, slightly fringed margins.

Leaves in fascicles of both 2 and 3, stout, slightly flattened, stiff, slightly twisted, 7-10 cm. long (as short as 5 cm. on late summer twigs), 1.1-1.8 mm. wide, acuminate and appearing sharp-pointed when touched owing to stiffness, serrulate, dull yellow green; stomatal rows 17-20 dorsal and 9-15 ventral on needles in 2's, 10-14 dorsal and 5-8 on each ventral surface on needles in 3's; basal sheath 4-6 mm. long. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform, of 2 or 3 layers; resin canals usually 2 dorsal medial at angles, sometimes also 1 ventral internal, small and large, bordered by thin- or thick-walled cells; endodermis in outline elliptic, sometimes constricted elliptic or triangular, of thin-walled cells; transfusion tissue with thick-walled cells outside phloem.

Male strobili (old and dry), cylindric but tapering and slightly curved, 10-16 mm. long, 3-4 mm. in diameter, orange brown. New female or ovulate strobili or conelets 1-5 in a whorl, sometimes in 2 whorls on vigorous shoots, on stout, scaly, slightly ascending stalk 8 mm. long, ovoid, when closed after pollination 12 mm. long, light yellow green, the scales with soft slender tapering point 2-3 mm. long. Year-old conelets with umbo about 4-5 mm. long, light brown, with long prickle 2-3 mm. long and pointed toward apex. Cones sessile, ovoid, conic, symmetrical or nearly so, 5-5.5 cm. long, 5-6 cm. across when open at maturity, persistent 1 or 2 years; apophyses dull fulvous brown, much raised along a transverse keel, the umbo forming a stout, flattened, sharp spine 2-5 mm. long, slightly incurved. Seed with 3-angled blackish body 5 mm. long and membranous, light brown detachable wing 15-18 mm. long. Specimens: 18804, 19139 (Tree PuE 1, 191/83).

Hybrid plants resemble those of *Pinus pungens* of the same age in branching habit, with broader crown of fewer, long, coarse, spreading branches, in the slightly stout twigs of larger diameter, in the deeper green needle color, and absence of the short twigs and needles along the trunk. The needles of the hybrid are long and 2 or 3 in number as in *P. echinata*, mostly intermediate in width, and twisted as in *P. pungens*. Needles of *P. pungens* are stiff and cause pain when touched, those of *P. echinata* are flexible, while the intermediate needles of the hybrid are stiff and short-pointed but do not produce pain. The needle serrulation consists of minute teeth close together in *P. echinata*, larger teeth farther apart in *P. pungens*, and intermediate teeth nearer the latter in the hybrid. The stomata of the needles appear on the surface as minute white dots in *P. echinata* and are larger in the hybrid and largest in *P. pungens*, being slightly sunken in last two. Needle anatomy is similar in all three, though the hypodermis in the hybrid is intermediate between the weak, uniform or biform hypodermis of 1-3 layers in *P. echinata* and the well-developed, biform hypodermis of 2-4 layers in *P. pungens*. Conelets show the influence of *P. pungens* in the long pointed scales. The cones are small as in *P. echinata* but intermediate and nearer *P. pungens* in keel of apophyses and length of spines.

From pollination made here in 1955 and from seeds sown in 1957, 2 plants were raised. In 1962, after 5 growing seasons, they were about 5 feet high, slightly larger than adjacent plants of *Pinus pungens* of the same age and slightly smaller than average plants of the other parent species. Plants of *P. pungens* and the hybrid began needle elongation before those of the other parent in the growing season of 1962.

Pinus rigida × *echinata* Pitch pine × shortleaf pine (fig. 5)

Also reciprocal cross. Artificial hybrid between *Pinus rigida* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 10. 1768), of Northeastern United States and southeastern Canada, and *P. echinata* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 12. 1768), of Eastern United States. Bark of branches and trunk reddish brown, scaly, the trunk sometimes bearing a few short twigs with needles. Spring shoots multinodal. Twigs slender, glabrous, when elongating yellow green and slightly shiny or glaucous and whitish green, becoming purplish brown, year-old lateral

twigs 4-6 mm. in diameter, the bases of bracts decurrent and forming narrow, rectangular plates. Buds acuminate, often slightly resinous, reddish brown, the scales with white, slightly fringed margins.

Leaves 3 or sometimes 2 in a fascicle, straight, erect, 6-9 cm. long, 1.1-1.9 mm. wide, acuminate, serrulate, dull yellow green; stomatal rows 10-17 dorsal and 5-9 on each ventral surface (8-10 ventral in paired leaves); basal sheath becoming 5-8 mm. long. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform, of 2 or 3 layers; resin canals 2-10, usually 2 or 3 medial at angles and additional smaller medial and internal, small or sometimes large, bordered by thin- or thick-walled cells; endodermis in outline elliptic or sometimes triangular, of thin-walled cells; transfusion tissue with thick-walled cells outside phloem or none.

Male strobili (old and dry) cylindric, about 15 mm. long and 4-5 mm. in diameter, orange brown. New female or ovulate strobili on young plants 1-3 in a whorl on stout, scaly, slightly ascending stalk 5-7 mm. long, ovoid, after pollination about 6 mm. long, dark red, turning light green, the scales with soft point more than 1 mm. long. Mature cones sessile, ovoid, about 5-5.5 cm. long and broad when open, 3.5 cm. broad when closed, dark brown weathering to gray, opening at maturity, persistent; scales with weak prickle less than 1 mm. long. Specimen: 18805 (Tree RiE 3, 165/79).

The hybrid plants resemble those of *Pinus rigida*, having often slightly crooked axis and broader crown of fewer, long, coarse, spreading branches and slightly stout twigs of larger diameter. Adjacent plants of *P. echinata* have better form with straight axis and narrower crown and begin growth later. In needle number the hybrid is intermediate in sometimes having 2 in a fascicle, though generally 3. The hybrid has broader needles like *P. rigida*, though the single plant of the reciprocal cross has narrow needles like *P. echinata*. *P. echinata* has needle serrulation of minute teeth close together, while *P. rigida* and the hybrid have slightly larger and fewer teeth. Stomata appear as minute white dots on needles of *P. echinata* and are slightly larger in the other two. In needle anatomy all three are similar. The hybrid is intermediate in having the biform hypodermis of 2 or 3 layers.

Plants of both the hybrid and *Pinus rigida* were producing cones when examined. Conelets and cones were similar except that mature cones of the latter, originating from a closed cone variation in southern New Jersey, remained closed after maturity. Male cones produced by one hybrid plant were similar to those of *P. rigida*.

This cross pollination was made here in 1941, 1954, and 1957. Five plants from seeds sown in 1956 averaged 3.1 feet high at 5 years. Nine others were grown from seeds planted in 1959. One plant of the reciprocal cross, *Pinus echinata* \times *rigida*, from pollination in 1954 and seed sown in 1956, was 4.3 feet high at 5 years. This plant of the reciprocal cross was similar to the others; however, it was perhaps of below normal vigor, later in beginning growth, and with the new elongating twigs glaucous whitish green. From the reciprocal cross repeated a year later the single surviving plant was poor.

S. Little and Somes (29) reported that hybrids in a New Jersey field test from Institute seed were mostly of very poor form and of no exceptional vigor. Similar results were observed in southern Illinois (1). According to Austin (2, 3), natural hybrids between these species occur.

Pinus rigida* × *taeda
Pitch pine × loblolly pine (fig. 5)

Artificial hybrid between *Pinus rigida* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 10. 1768), of Eastern United States, and *Pinus taeda* L. (Sp. Pl. 1000. 1753), loblolly pine, of Southeastern United States. Bark rough, thick, furrowed into scaly plates, blackish gray, the trunk sometimes bearing short twigs with needles. Spring shoots multinodal. Twigs glabrous, light yellow green and shiny the first year, becoming light brown the second year. Buds acute, reddish brown, resinous. Leaves 3 in a fascicle, stout and stiff, 10–20 cm. long, acute-acuminate, serrulate, green; stomatal rows 10–15 dorsal and 5–8 on each ventral surface. Needle anatomy in cross section: Hypodermis bifiform, of 2–5 layers of cells, the inner border often angled; endodermis of thin-walled cells; resin canals medial (rarely also internal), 2 (rarely 3), about 0.04–0.08 mm. in diameter; a line of thick-walled cells often outside phloem in transfusion tissue.

Male strobili (old and dry) 17–25 mm. long, 4–5 mm. in diameter, orange brown. Cones 3, 2, or 1 at a node, almost sessile, ovoid-conic, symmetrical, 7–8 cm. long, 4–4.5 cm. in diameter closed, serotinous, opening after 1 or more years, long persistent in quantity for several years; apophyses pale fulvous brown or tawny yellow, dull or slightly shiny, elevated along a transverse keel, the nut-brown umbo forming a sharp stout prickle or spine about 3 mm. long. Winged seeds about 25 mm. long, the detachable wing nut-brown, body ovoid, 5 mm. long, blackish. Specimen: 17150 (Tree RiT 3, 8/16).

In needle anatomy the hybrid and both parents are similar. The hybrid is like *Pinus taeda* in the large resin canals, while *P. rigida* has diameters of about 0.02–0.04 mm. Needle length is intermediate. The intermediate cones have the larger, stout prickles of *P. taeda* and the slightly serotinous habit of *P. rigida* in this variation from southern New Jersey.

This hybrid with *Pinus rigida* as female parent was made at the Institute first in 1933 and was backcrossed with *P. rigida* in 1942. The cross has been repeated in 1941 and later years, and 13 trees are growing here as well as plants from open pollinated seeds of a hybrid tree. Nine trees from seed sown in 1945 averaged 22.6 feet high and 5.2 inches d.b.h. at 15 years.

Hyun and Ahn (24) described this hybrid as made in Korea, recording its principal characteristics there in comparison with the parent species. They further designated this hybrid as *Pinus* × *rigitaeda* but did not publish a formal Latin diagnosis for that binomial. The hybrid is under mass production in Korea (22, 23).

In southern Illinois, hybrids from seed supplied by the Institute were reported to be vigorous, of good form, and more frost hardy than *P. echinata* and *P. taeda* (1, p. 88).

Pinus rigida* × *serotina
Pitch pine × pond pine (fig. 4)

Artificial hybrid between *Pinus rigida* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 10. 1768), of Northeastern United States, and *P. serotina* Michx. (Fl. Bor.-Amer. 2: 205, 1803), of the Coastal Plain of Southeastern United States. Bark of branches and trunk becoming rough and thick, composed of gray brown scaly plates and exposing brown

in crevices, the trunk sometimes bearing a few short twigs with needles. Spring shoots multinodal. Twigs slender, glabrous, glaucous, light green when young, becoming pinkish brown, year-old lateral twigs 6-7 mm. in diameter, purplish brown, the bases of bracts decurrent, rough, and forming narrow rectangular plates long persistent. Buds cylindric, acuminate or acute, often resinous, reddish brown, the scales with white, slightly fringed margins.

Leaves 3 in a fascicle, straight, stiff, erect, 9-12 cm. long, 1.4-1.7 mm. wide, acuminate, serrulate, slightly flattened, dull green; stomatal rows 16-20 dorsal and 6-10 on each ventral surface; basal sheath becoming 7-13 mm. long, gray brown. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform, of 2 or 3, sometimes 4, layers; resin canals 3-7, usually 3 medial at angles and additional smaller medial and internal, small, bordered by thin- or thick-walled cells; endodermis in outline elliptic or sometimes triangular, of thin-walled cells; transfusion tissue with thick-walled cells outside phloem.

Male strobili (old and dry) cylindric, 8-24 mm. long and 4-5 mm. in diameter, orange brown. New female or ovulate strobili 1-3 in a whorl and sometimes 2 whorls in a year, on stout, scaly, brown, slightly ascending stalk about 1 cm. long, ovoid, shortly after pollination about 8 mm. long, pink purple, turning light green, the scales with soft point 2 mm. long. Year-old conelets ellipsoidal or subglobose, 15-20 mm. long and 12-15 mm. in diameter, pinkish red and green, scales with prickles nearly 2 mm. long. Mature cones sessile or nearly so, ovoid, symmetrical, about 6-6.5 cm. long and 3.5-4.5 cm. broad when closed, tawny yellow but weathering to light gray, persistent and remaining closed; apophyses nearly flat, umbo raised and ending in straight, sharp, weak prickles 1-2 mm. long. Specimens: 18806, 19158 (Tree RiSe 5, 181/75).

These hybrids are slightly larger than adjacent plants of *Pinus rigida* of the same age. The only significant difference in the two groups is in needle length, 6-10 cm. in *P. rigida* and 9-12 cm. in the hybrid, while the parent plant of *P. serotina* has needles 12-20 cm. long. The parent species and hybrid are indistinguishable in needle anatomy. Cones of the hybrid and adjacent plants of *P. rigida* are similar.

Five plants from pollination in 1952 and seeds sown in 1954 averaged 5.7 feet high at 5 years and were about 11 feet high after 9 growing seasons. The female parent was from Atlantic City, N.J., and the male parent from near Starke, Fla.

Pinus rigida and *P. serotina* are closely related species, or according to a few authors, geographical varieties of the same species. *P. serotina* has longer needles spreading to slightly drooping in age and broader, nearly spherical, closed cones. However, *P. rigida* sometimes has closed cones, for example, in these plants from near the range of *P. serotina*.

***Pinus ponderosa* var. *ponderosa* × var. *arizonica*
Ponderosa pine (typical variety) × Arizona pine**

Artificial intervarietal hybrid between *Pinus ponderosa* Laws. var. *ponderosa* (Laws., Agr. Man. 354. 1836), of western North America, and *P. ponderosa* var. *arizonica* (Engelm.) Shaw (Pines Mex. 24, t. 17, figs. 4-5. 1909), Arizona pine, of northern Mexico and adjacent Arizona and New Mexico. Bark of dark gray scaly plates, becoming rough, cracking off, and rusty brown beneath. Spring shoots

uninodal. Twigs glabrous, glaucous when young, whitish or yellowish to brownish green, becoming brown the second year, later light brownish gray and rough. Buds conic, acuminate, reddish brown, resinous, the basal scales whitish fringed.

Leaves 4 or 5, sometimes 3, in a fascicle, slightly slender or stout, mostly spreading or slightly drooping, 11–22 cm. long, 1–1.5 mm. wide, acuminate, serrulate, dull green; stomatal rows 4–9 dorsal and 3–6 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform, of 2–3, sometimes 4, layers of cells, the inner border straight or sometimes curved; resin canals medial, 2 at dorsal angles and rarely 1 also at ventral angle; endodermis elliptic or sometimes circular in outline, cells with thick outer walls; thick-walled cells in transfusion tissue forming lines outside phloem and xylem.

Cones single or paired, sessile, ovoid conic, symmetrical, 6–8.5 cm. long, 5.5–7.5 cm. across when open at maturity, early deciduous and usually leaving a few basal scales on twig; apophyses dull yellow brown, with prominent transverse keel, the umbo raised and 1–2 mm. high including the weak prickle. Specimens: 17201 (Tree PAr 21, 193/35), 18840 (Tree PAr 54, 212/65).

This intervarietal hybrid is intermediate in needle number and associated character such as needle width and also cone size, by which the parents are distinguished. The glaucous young twigs suggest var. *arizonica*.

With the typical variety from the Eldorado National Forest, Calif., as seed parent, this cross was made at the Institute in 1946, 1948, and 1954. Pollen for the first cross came from Mount Lemmon, Pima County, Ariz. Pollen parents in later crosses were grown from seed collected in the Chiricahua Mountains, Cochise County, Ariz. About 70 of these hybrids are growing at the Institute, and many are under test for performance on the Eldorado National Forest, Calif. At 10 years, 10 plants from seed sown in 1949 averaged 8.6 feet in height, and 30 from 1950, 8.3 feet. In an investigation of natural attack by the weevil *Cylindrocopturus eatoni* Buch. on plants in nursery tests, Callahan (9) found the hybrid to be more susceptible than *P. ponderosa* var. *ponderosa*.

Pinus ponderosa* var. *ponderosa* × *montezumae
Ponderosa pine (typical variety) × Montezuma pine (fig. 6)

Artificial hybrid between *Pinus ponderosa* Laws. var. *ponderosa* (Laws., Agr. Man. 354. 1836), of western North America, and *Pinus montezumae* Lamb. (Descr. Genus *Pinus*. Ed. 3 (8°), 1: 39, t. 22. 1832), of Mexico. Bark rough, thick, furrowed longitudinally into gray scaly plates, exposing rusty brown inner layers; bark on branches smoothish, brown or gray. Spring shoots uninodal. Twigs glabrous, glaucous when young, becoming shiny greenish brown, the second year brown and smoothish. Buds cylindric, acuminate, reddish brown, resinous, the scales slightly whitish fringed.

Leaves 4, sometimes 3 or 5, in a fascicle, slender, flexible, drooping, 14–27 cm. long, more than 1 mm. wide, acuminate, serrulate, dull green; stomatal rows 5–12 dorsal and 3–5 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis multi-form or sometimes biform, of 2–4 layers of cells; resin canals medial, 2

at dorsal angles and sometimes also 1 at ventral angle; endodermis elliptic, sometimes circular, in outline, cells with thick outer walls.

Cones (1 pair seen) almost sessile, ovoid conic, slightly asymmetrical, 10-11 cm. long, 9.5 cm. across when open at maturity, scales numerous, apophyses dull or slightly shiny, yellow brown, thick with prominent keel, the raised umbo including weak prickles 2 mm. high or less. Specimens: 17139 (Tree PMz 3, 218/47), 18841 (Tree PMz 26, 226/66).

The intermediate character of the hybrid is shown by the 4 leaves in a fascicle, though their slender, drooping appearance suggest *Pinus montezumae*. Needle anatomy likewise is intermediate. Cones also are intermediate in the weak prickles.

This hybrid was first produced at the Institute in 1946 and again in 1948, 1951, and 1954. From seed sown from 1948 to 1956, more than 50 plants were grown. Twenty-two plants from seed sown in 1950 averaged 12.8 feet high after 10 growing seasons. The source of the female parent, the typical variety of ponderosa pine, was the nearby Eldorado National Forest, Calif. The hybrid is under test for field performance in several places in California. Seedling vigor of the hybrid was discussed by Righter (36). Callaham (9), observing natural attack by the weevil *Cylindrocopturus eatoni* Buch. in nursery tests, found the hybrid to be more susceptible to the weevil than *Pinus ponderosa*.

Pinus ponderosa* var. *scopulorum* × *montezumae

Rocky Mountain ponderosa pine × Montezuma pine (fig. 6)

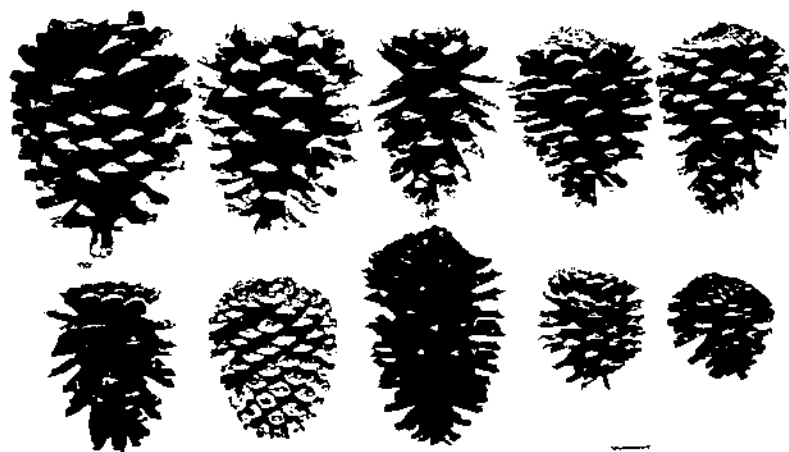
Artificial hybrid between *Pinus ponderosa* var. *scopulorum* Engelm. (in S. Wats., Bot. Calif. 2: 126. 1879), of the Rocky Mountain region, and *Pinus montezumae* Lamb. (Descr. Genus Pinus. Ed. 3 (8°), 1: 39, t. 22. 1832), of Mexico. Bark on small trunks gray, becoming rough and furrowed into scaly plates, with orange brown furrows. Spring shoots uninodal. Twigs glabrous, glaucous when young, becoming shiny brown, the second year light brownish gray and slightly fissured. Buds cylindric, acuminate, reddish brown, resinous, the scales slightly whitish fringed.

Leaves 3-4, sometimes 5, in a fascicle, slender, flexible, curved and spreading to drooping, 10-22 cm. long, more than 1 mm. wide, acuminate, serrulate, dull green or slightly shiny yellow green when young; stomatal rows 6-10 dorsal and 3-5 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis multiform, sometimes bifurcated, of 2-4 layers of cells; resin canals medial, 2 at dorsal angles and sometimes also 1 at ventral angle or rarely 1 dorsal; endodermis elliptic in outline, section, the outer cell walls often thick.

Cones sessile, ovoid conic, symmetrical or nearly so, 7-8 cm. long, 6-7 cm. across when open at maturity, early deciduous and usually leaving a few basal scales on twig; apophyses dull yellow brown, with prominent keel, the raised umbo including weak prickles 1-2 mm. high. Specimen: 17141 (Tree PScopMz 5, 176/65).

Leaves of the hybrid are intermediate in length, number in a fascicle, curved and spreading position, and anatomy. Cones also are intermediate in the weak prickles.

This cross with *Pinus ponderosa* var. *scopulorum* as female parent was made here in 1948. Seven vigorous plants from seed sown in 1950 averaged 8.4 feet high after 10 growing seasons.



F-510128

FIGURE 6.—Cones, left to right, top row, *Pinus jeffreyi*, *P. jeffreyi* × *ponderosa* var. *ponderosa*, *P. ponderosa* var. *ponderosa*, *P. ponderosa* var. *ponderosa* × *engelmannii*, *P. engelmannii*; bottom row, *P. ponderosa* var. *ponderosa*, *P. ponderosa* var. *ponderosa* × *montezumae*, *P. montezumae*, *P. ponderosa* var. *scopulorum* × *montezumae*, *P. ponderosa* var. *scopulorum*. One-fifth natural size.

***Pinus engelmannii* × *montezumae*
Apache pine × Montezuma pine**

Artificial hybrid between *Pinus engelmannii* Carr. (Rev. Hort., Sér. 4, 3: 227. 1854; known also as *P. latifolia* Sarg. and *P. apachea* Lemm.), of northern Mexico and adjacent Arizona and New Mexico, and *Pinus montezumae* Lamb. (Descr. Genus *Pinus*. Ed. 3(8°), 1: 39, t. 22. 1832), of Mexico. Bark on small trunks gray, thick, rough, becoming irregular furrowed into scaly plates. Spring shoots uninodal; on leader shoots the twigs stout and buds large. Twigs glabrous, glaucous when young, becoming purplish brown and the second year light brownish gray. Buds cylindric, acuminate, reddish brown, resinous, the scales slightly whitish fringed.

Leaves 3, often 4, sometimes 5, in a fascicle, slender, flexible, spreading to drooping, 19–29 cm. long, more than 1 mm. wide, acuminate, serrulate, dull green; stomatal rows 5–10 dorsal and 3–4 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform or multiform, of 2–4 layers of cells, the inner border straight or curved; resin canals medial, 2 at dorsal angles and sometimes also 1 at ventral angle and (or) 1 dorsal; endodermis elliptic, sometimes nearly circular in outline, the outer cell walls thin or thick. Specimen: 17136 (Tree ApMz 6, 214/71).

Young hybrid plants have twigs and buds of normal size, except on leader shoots, not like the very large ones of *Pinus engelmannii*.

Leaves are intermediate in number, width, and position. Needle anatomy, though intermediate, is more like *P. montezumae*.

This cross was made at the Institute in 1951. Twenty plants were raised from seed sown in 1953. When studied after 4 growing seasons the young plants were 1.5 feet high, but at 9 years they had grown rapidly to about 10-15 feet (minimum 6 feet).

***Pinus jeffreyi* × *montezumae*
Jeffrey pine × Montezuma pine**

Artificial hybrid between *Pinus jeffreyi* Grev. & Balf. (in A. Murr., Bot. Exped. Oreg. [Rpt. No. 8] 2, t. 1853), of the Pacific coast region, and *Pinus montezumae* Lamb. (Descr. Genus *Pinus*. Ed. 3 (8°), 1: 39, t. 22. 1832), of Mexico. Bark on small trunks gray, smoothish, becoming furrowed into scaly plates with orange brown furrows. Spring shoots uninodal. Twigs glabrous, glaucous when young, later brownish tinged, the second year light gray, smoothish, and slightly fissured; crushed twigs with slight odor and taste of lemon. Buds cylindric, acuminate, reddish brown, resinous, the scales whitish fringed.

Leaves 3, sometimes 4, in a fascicle, slender, flexible, spreading to drooping, 14-34 cm. long, about 1 mm. wide, acuminate, serrulate, dull green; stomatal rows 5-8 dorsal and 2-5 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis multiform, sometimes biform, of 2-4 layers of cells, the inner border curved; resin canals medial, 2-6, 2 at dorsal angles and often also 1 at ventral and 1-3 dorsal; endodermis elliptic in outline, the outer cell walls thick. Male strobili (dry) cylindric, 25-35 mm. long, 5-6 mm. in diameter, orange brown. Conelet and immature cone with prominent prickle. Specimen: 17140 (Tree JMz 3, 176/69).

The hybrid's smoothish twigs with slight odor of lemon suggest *Pinus jeffreyi*, while the resinous buds and dull green color of leaves are characteristic of *P. montezumae*. Leaves are intermediate in number, length, position, and anatomy.

This cross with *Pinus jeffreyi* as female parent was made at the Institute in 1951. Three young plants from seeds sown in 1953 were vigorous and almost 3 feet high after 3 growing seasons. At 9 years they were 7-16 feet high. In 1962 the largest produced a few male strobili. The long drooping needles, smoothish gray branches, and long internodes give these trees a handsome appearance. This attractive hybrid should rank among the best for ornamental planting in mild climates.

***Pinus ponderosa* var. *ponderosa* × *engelmannii*
Ponderosa pine (typical variety) × Apache pine (fig. 6)**

Also reciprocal cross. Artificial hybrid between *Pinus ponderosa* Laws. var. *ponderosa* (Laws., Agr. Man. 354. 1836), of western North America (California), and *Pinus engelmannii* Carr. (Rev. Hort., Sér. 4, 3: 227. 1854; known also as *P. latifolia* Sarg. and *P. apachea* Lemm.), of northern Mexico and adjacent Arizona and New Mexico. Tree with straight axis and thin crown of whorled horizontal branches. Bark rough, thick, furrowed longitudinally into scaly plates, blackish gray, rusty brown in furrows; bark on stout older branches dark gray,

rough, in regular plates. Spring shoots uninodal, the internodes mostly long and on leaders mostly with fascicled leaves from base of each year's growth upward and without a bare basal zone; branching coarse, with relatively few stout branches. Twigs mostly stout, 1 cm. or more in diameter, glabrous, shiny yellow green to brownish green, the second year brown. Buds conic to cylindric, acuminate, reddish brown, resinous, the scales slightly whitish fringed.

Leaves 3 (rarely 4 or 5) in a fascicle, stout, stiff, erect to spreading, 17-30 cm. long, acuminate, serrulate, dull green; stomatal rows 10-15 dorsal and 4-8 on each ventral surface. Needle anatomy in cross section: Stomata slightly to deeply sunken; hypodermis biform, sometimes multiform, of 2-5 layers of cells, the inner border curved, sometimes angled; resin canals medial, 2 at dorsal angles, sometimes also 1 at ventral angle (rarely 1-4 more dorsal); endodermis often with thick outer cell walls.

Year-old conelets 1-3 on scaly stalk about 1 cm. long, about 22 mm. long and 18 mm. broad, ellipsoidal, light brown, glaucous, scales with slender, straight, slightly incurved or recurved prickle about 1 mm. long. Cones nearly sessile, large, conic, symmetrical, 11-13 cm. long, 8-9 cm. broad open, yellow green when immature: the scales with apophysis tawny brown, slightly shiny, about 5-6 mm. thick including horizontal keel, the light gray umbo, and straight, sharp prickle about 1 mm. long. Specimens: 17228 (Tree PAP 1, 13/5); reciprocal cross, 17138 (Tree AP 7, 184/67).

The leader shoots of the hybrid and *Pinus engelmannii* mostly bear fascicled leaves from base of each year's growth upward, while in *P. ponderosa* var. *ponderosa* a bare zone is present above the whorl of branches. However, the hybrid has a leafless zone on lateral shoots and sometimes also on the leader. Twigs of the hybrid are stout, as in *P. engelmannii*. In needle length and anatomy and in cone, the hybrid is intermediate.

Differences between seedlings of the hybrid and of *Pinus ponderosa* var. *ponderosa* have been recorded by Righter and Duffield (38). Hybrid 1-0 and 2-0 seedlings differed from the seedlings of *P. ponderosa* in shorter tops, longer and heavier roots, larger stem-caliper at ground level, thicker bark, longer primary leaves, longer needles pointing upward, heavier foliage, and much higher water content. In these characters the hybrid appears intermediate between the parent species. *P. engelmannii* produces needle fascicles the first year, *P. ponderosa* mostly not until the second year, and the hybrid partly the first year. The third year the hybrids started needle growth earlier and without a bare length of twigs. Though shorter the first year, the hybrids were taller than plants of *P. ponderosa* the third to sixth years.

With more than 20 trees of *Pinus ponderosa* var. *ponderosa* from California as seed parents, this hybrid was made at the Institute mainly in 1943, 1948, and 1951, and more than 100 of the progeny were planted at the Institute. There is also 1 hybrid tree planted in 1933 from the first cross in 1929. The reciprocal cross with *P. engelmannii* from southeastern Arizona as seed parent was made at the Institute in 1948, from which 9 plants grown from seed sown in 1950 averaged 14.8 feet high at 10 years. Additional crosses with the hybrid as parent have been made.

In one test hybrid plants were about 6 feet tall after 7 growing seasons, and in another they averaged about 15 feet in height and 4 inches

d.b.h. after 12 growing seasons. The oldest tree was about 40 feet tall and 10 inches d.b.h. at 23 years of age. The hybrid is under test at numerous places in California. In an investigation of natural attack by the weevil *Cylindrocopturus eatoni* Buch. on plants in nursery tests, Callaham (9) found the hybrid to be more susceptible than *Pinus ponderosa*.

Pinus engelmannii* × *ponderosa* var. *arizonica
Apache pine × Arizona pine

Artificial hybrid between *Pinus engelmannii* Carr. (Rev. Hort., Sér. 4, 3: 227. 1854; known also as *P. latifolia* Sarg. and *P. apachea* Lemm.), and *Pinus ponderosa* var. *arizonica* (Engelm.) Shaw (Pines Mex. 24, t. 17, figs. 1-5. 1909), both of northern Mexico and adjacent Arizona and New Mexico. Bark on small trunks gray, thick, rough, becoming furrowed into scaly plates with orange brown furrows. Spring shoots uninodal, the internodes mostly long and on leaders mostly with fascicled leaves from base of each year's growth upward and without a bare basal zone; branching coarse. Twigs stout, 1 cm. or more in diameter, glabrous, glaucous, becoming pinkish brown, the second year light gray brown. Buds large, conic, acuminate, reddish brown, resinous, the scales slightly whitish fringed.

Leaves 4-3, sometimes 5, in a fascicle, slender, flexible, spreading, 15-28 cm. long, more than 1 mm. wide, acuminate, serrulate, dull green; stomatal rows 7-11 dorsal and 3-6 on each ventral surface. Needle anatomy in cross section: Stomata slightly to deeply sunken; hypodermis biform, often multiform, of 2-5 layers of cells, the inner border angled, resin canals medial. 2 at dorsal angles, sometimes also 1 at ventral angle and 1-2 more dorsal; endodermis elliptic, sometimes circular in outline, often with thick outer cell walls.

Cones sessile, ovoid conic, symmetrical, 6.5-7 cm. long, 6.5-7 cm. broad open, deciduous and leaving a few basal scales on tree; apophyses dull yellow brown with prominent transverse keel, the umbo raised and 2-3 mm. high including the weak sharp prickle. Specimens: 17136 (Tree ApAr 7, 192/67), 18828 (Tree ApAr 8, 192/68).

The hybrid has the stout twigs and large buds of *Pinus engelmannii* and also the leaders with fascicled leaves from base of each year's growth upward. Leaves are intermediate in number and length. In needle anatomy the hybrid is intermediate though possessing the well-developed hypodermis with angled inner border as in *P. engelmannii*. Cones are small as in *P. ponderosa* var. *arizonica*.

This cross was made at the Institute in 1948 and 1953 with *Pinus engelmannii* from southeastern Arizona as female parent. Twelve plants from seed sown in 1950 averaged 9.3 feet high at 10 years. One of these matured a whorl of 3 cones in 1961. The 2 surviving plants from seed sown in 1955 were about 3 feet high after 7 years.

Pinus engelmannii* × *ponderosa* var. *scopulorum
Apache pine × Rocky Mountain ponderosa pine

Also reciprocal cross. Artificial hybrid between *Pinus engelmannii* Carr. (Rev. Hort., Sér. 4, 3: 227. 1853; known also as *P. latifolia* Sarg. and *P. apachea* Lemm.), of northern Mexico and adjacent Arizona and New Mexico, and *Pinus ponderosa* var. *scopulorum* Engelm. (in S. Wats., Bot. Calif. 2: 126. 1879), of the Rocky Mountain region. Bark gray, becoming rough and furrowed into scaly plates

with brown exposed in furrows. Spring shoots uninodal. Twigs not stout, glabrous, glaucous, becoming shiny yellow green, the second year light brown, older twigs light gray, smoothish to rough. Buds cylindric, acuminate, reddish brown, resinous, the scales slightly whitish fringed.

Leaves 3, sometimes 2, in a fascicle, stout, stiff, erect to spreading, 14-23 cm. long, acuminate, serrulate, dull green; stomatal rows of leaves in 3's 9-12 dorsal and 3-6 on each ventral surface, of leaves in 2's 10-13 dorsal and 7-9 ventral. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform, of 2-5, sometimes 6, layers of cells, the inner border curved, sometimes angled; resin canals medial, 2-4 (rarely 6), 2 at dorsal angles, often also 1 at ventral angle and 1 (rarely 3) dorsal; endodermis mostly with thick outer cell walls.

Cones nearly sessile, ovoid conic, symmetrical, 5.5-7 cm. long, 5.5-6.5 cm. broad open, deciduous and usually leaving a few basal scales on tree; apophyses dull yellow brown with prominent transverse keel, the umbo raised and 1-2 mm. high including the weak prickle. Specimens: 17137 (Tree ApPScop 4, 182/69), 18830 (Tree ApPScop 10, 177/70); reciprocal cross, 19159 (Tree PScopAp 7, 211/67).

Lacking the stout twigs of *Pinus engelmannii*, the hybrid has leaves intermediate in length and number. In needle anatomy the hybrid is intermediate though with deeply sunken stomata and well-developed hypodermis as in *P. engelmannii*. Like both parents, the hybrid produces fascicles mostly the first year. Cones are small as in *P. ponderosa* var. *scopulorum*.

With *Pinus engelmannii* from southeastern Arizona as seed parent and with pollen parent from the Monument Nursery in Colorado, the cross was made at the Institute in 1948. Ten plants from seed sown in 1950 averaged 10.0 feet high at 10 years. From the reciprocal cross made at the same time, 20 plants averaged 7.0 feet.

***Pinus jeffreyi* × *ponderosa* var. *ponderosa*
Jeffrey pine × ponderosa pine (typical variety; fig. 6)**

Also reciprocal cross. Artificial and natural hybrid between *Pinus jeffreyi* Grev. & Balf. (in A. Murr., Bot. Exped. Oreg. [Rpt. No. 8] 2, t. 1853), of the Pacific coast region, and *Pinus ponderosa* Laws. var. *ponderosa* (Laws., Agr. Man. 354. 1836), ponderosa pine (typical variety), of western North America. Tree with straight axis and narrow crown. Bark rough, thick, furrowed longitudinally into scaly plates, blackish gray, light brown in furrows and where plates have been shed. Spring shoots uninodal. Twigs glabrous, glaucous when young, yellow green, becoming gray brown the second year, later gray and rough; crushed twigs and resin with odor and taste of lemon. Buds cylindric, acuminate, reddish brown, resinous, the scales whitish fringed.

Leaves 3 (rarely 2) in a fascicle, stout, stiff, erect and spreading to slightly drooping, 14-25 cm. long, acuminate, serrulate, dull green; stomatal rows 8-12 dorsal and 3-7 on each ventral surface. Needle anatomy in cross section: Stomata deeply sunken, hypodermis multi-form or biform, of 2-5 layers of cells, the inner border curved, resin canals medial, 2-5 (7), 2 at dorsal angles and often 1-3 (5) additional ventral and dorsal; endodermis with thick outer cell walls; thick-walled cells in transfusion tissue forming lines outside phloem and xylem and sometimes nearly continuous between vascular bundles.

Male strobili cylindric, 4-5 cm. long, 7 mm. in diameter. Year-old conelets single or paired on stout scaly stalk less than 1 cm. long, about 20-22 mm. long, 16-18 mm. broad, ellipsoidal, light brown, scales with slender, straight, sharp prickle 2-3 mm. long. Cones sessile, ovoid-conic, symmetrical, about 12 cm. long and 9 cm. in diameter (sometimes smaller) when open, deciduous and leaving a few basal scales on tree; apophyses slightly shiny brown with prominent transverse keel, the umbo raised and about 3 mm. high, including the stout prickle. Specimens: 17229 (Tree JP 9, 10/12): reciprocal cross, 18827 (Tree PJ 1, 13/4).

This intermediate hybrid has the resinous buds, green, slightly longer needles, and rough twigs of *Pinus ponderosa* var. *ponderosa* and the resin with odor and taste of lemon from *P. jeffreyi*. Needle anatomy of parents and hybrid is similar, though the hybrid resembles *P. jeffreyi* in the fewer rows of dorsal stomata, the deeply sunken stomata, and usually multiform hypodermis. The cone in size and phyllotaxis is between that of *P. ponderosa* and the larger one of *P. jeffreyi* with more scales.

The Institute has one natural hybrid planted in 1929 from seed of an open-pollinated tree of *Pinus jeffreyi*; specimen: Little 17149 (Tree 70/33). Five plants were produced in 1956 from open-pollinated seed of this tree.

With *Pinus jeffreyi* as female parent, cross pollinations were made at the Institute in 1929, 1931, and 1946. Seed from the first two was planted in 1933 and from the last in 1949. From these crosses 23 trees were raised, 10 from the last averaging 10.0 feet at 10 years. There is also one tree of the reciprocal cross made in 1929 and from seed planted in 1933. The progeny at 23 years of age were about 40 feet high and 1 foot d.b.h.

Mirov (31) first recorded this natural hybrid in California in 1929 and has studied the chemical and other differences. This hybrid was included in analyses by Callahan (8) of needle oils of certain pines and pine hybrids. Haller (19) made a comprehensive study of the variation and natural hybridization of ponderosa and Jeffrey pines and of the hybrids at the Institute.

Backcrosses of this hybrid with both parents were made in 1948. Also, trihybrids were obtained by pollination from *Pinus engelmannii* Carr. first in 1947 and from the hybrid *P. jeffreyi* × *coulteri* in 1949. Pollen from this hybrid was used to pollinate the cross *P. ponderosa* × *engelmannii* in 1952, producing the presumed 3-species hybrid: (*P. ponderosa* × *engelmannii*) × (*P. jeffreyi* × *ponderosa*).

Pinus jeffreyi* × *ponderosa* var. *scopulorum
Jeffrey pine × Rocky Mountain ponderosa pine

Artificial hybrid between *Pinus jeffreyi* Grö. & Balf. (in A. Murr., Bot. Exped. Oreg. [Rpt. No. 8] 2, t. 1853), of the Pacific coast region, and *Pinus ponderosa* var. *scopulorum* Engelm. (in S. Wats., Bot. Calif. 2: 126. 1879), of the Rocky Mountain region. Bark on young plants smoothish light gray, becoming rough, furrowed into scaly plates and orange brown furrows. Spring shoots uninodal. Twigs glabrous, glaucous, becoming greenish brown, the second year light brownish gray and smoothish; crushed twigs and resin with odor and taste of lemon. Buds cylindric, acuminate, reddish brown, resinous, the lowest scales whitish fringed.

Leaves 3, sometimes 2, in a fascicle, stout, stiff, erect and spreading, (11) 15-20 cm. long, acuminate, serrulate, dull green; stomatal rows of leaves in 3's 7-9 dorsal and 4-5 on each ventral surface, of leaves in 2's 9-11 dorsal and 5-6 ventral. Needle anatomy in cross section: Stomata deeply sunken; hypodermis multiform, sometimes biform, of 3-5 layers of cells; resin canals medial, 2, sometimes 3, at angles; endodermis of thin-walled cells. Male strobili cylindrical, about 15-25 mm. long, and 7-8 mm. (5 mm. dry) in diameter, pink red and pale yellow, turning orange brown on drying. Specimen: 17133 (Tree JPScop 4, 200/69).

The habit of the hybrid is that of *Pinus ponderosa* var. *scopulorum*, as adjacent plants of *P. jeffreyi* have fewer and coarser branches, stouter twigs, larger nonresinous buds, gray green foliage, and longer needles. However, the hybrid does have a weak lemon odor of twigs from *P. jeffreyi*. In needle length the hybrid is intermediate. The needle anatomy of the hybrid is like *P. jeffreyi* in fewer rows of dorsal stomata, deeply sunken stomata, and usually multiform hypodermis. Small hybrid plants differ from both parents in having thin-walled endodermal cells.

Pollination with *Pinus jeffreyi* as female parent was made at the Institute in 1948. From seed sown in 1950, 14 plants were 3-5 feet high in 1956 and averaged 8.2 feet at 10 years.

Pinus jeffreyi* × *washoensis
Jeffrey pine × Washoe pine

Artificial hybrid between *Pinus jeffreyi* Grev. & Balf. (in A. Murr., Bot. Exped. Oreg. [Rpt. No. 8] 2, t. 1853), of the Pacific coast region, and *Pinus washoensis* Mason & Stockwell (Madroño 8: 62. 1945), rare and local on Mount Rose, Washoe County, Nev., and north to southern Warner Mountains in California (18). Bark of branches and small trunks smoothish, brownish gray to gray, becoming rough and furrowed into scaly plates. Spring shoots uninodal. Twigs glabrous, glaucous when young, becoming brown, the second year brownish gray and smoothish; crushed twigs and resin with odor and taste of lemon. Buds cylindric, acuminate, reddish brown, resinous, the scales whitish fringed. Leaves 3 (rarely 2) in a fascicle, stout, stiff, erect and spreading, 10-20 cm. long, acuminate, serrulate, dull green; stomatal rows 8-12 dorsal and 3-5 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis multiform, sometimes biform, of 2-4 layers of cells; resin canals medial, 2 at dorsal angles and sometimes 1 at ventral angle; endodermis with thin-walled cells. Specimen: 19138 (Tree JW 2, 221/62).

The lemon odor of twigs is from *Pinus jeffreyi*, while the resinous buds are from *P. washoensis*. The foliage color of the hybrid was recorded as green, different both from the slightly gray green in *P. washoensis* and the distinctive gray green of *P. jeffreyi*. Both parent species differ only slightly in needle anatomy. The hybrid resembles *P. jeffreyi* in the prominent, usually multiform hypodermis (biform in *P. washoensis*) and small number of resin canals and is like *P. washoensis* in having stomata only slightly sunken. Small hybrid plants have thin-walled endodermal cells, while in the parents the outer cell walls usually are thickened.

With *Pinus jeffreyi* as seed parent, this cross was made at the Institute in 1948. Five progeny from seeds planted in 1950 were 3-4 feet high by 1956 and averaged 5.8 feet at 10 years.

Pinus washoensis* × *ponderosa* var. *ponderosa
Washoe pine × ponderosa pine (typical variety)

Also reciprocal cross. Artificial hybrid between *Pinus washoensis* Mason & Stockwell (Madroño 8: 62. 1945), rare and local on Mount Rose, Washoe County, Nev., and north to southern Warner Mountains in California, and *Pinus ponderosa* Laws. var. *ponderosa* (Laws., Agr. Man. 354. 1836), of western North America. Bark of branches and small trunks smoothish, gray or brownish gray, becoming dark gray, rough, and furrowed into scaly plates and orange brown in furrows. Spring shoots uninodal. Twigs stout, glabrous, glaucous when young, greenish brown the first year, becoming brownish gray and smoothish the second year. Buds cylindric, acuminate, reddish brown, resinous, the lowest scales slightly whitish fringed.

Leaves 3 (rarely 2) in a fascicle, stout, stiff, erect and spreading, 11-23 cm. long, acuminate, serrulate, dull green; stomatal rows 8-13 dorsal and 4-6 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform or multiform, of usually 3, sometimes 2 or 4, layers of cells, the inner border straight or slightly curved; resin canals medial, 2, sometimes 3, at angles; endodermis with outer cell walls thin or slightly thickened. Specimens: 19136 (Tree WP 37, 231/41); reciprocal cross, 17131 (Tree PW 9, 228/44).

Older twigs and branches of the hybrid are smoothish and gray as in *Pinus washoensis*, not rough and dark gray as in *P. ponderosa* var. *ponderosa*. In needle anatomy the parents and hybrid are similar, though in both parent species the outer cell walls of endodermis usually are thickened. In the hybrid and *P. ponderosa* the hypodermis is biform or multiform.

With *Pinus washoensis* as female parent and pollen from localities in California, this cross was first made at the Institute in 1941 and 1946. Twenty-nine trees were grown from seeds planted in 1943 and 1948. The progeny were mostly 6-8 feet high at 13 years of age. The reciprocal cross was made in 1946, and 5 plants were raised from the seed sown in 1948.

Pinus washoensis* × *ponderosa* var. *scopulorum
Washoe pine × Rocky Mountain ponderosa pine

Artificial hybrid between *Pinus washoensis* Mason & Stockwell (Madroño 8: 62. 1945), rare and local on Mount Rose, Washoe County, Nev., and north to southern Warner Mountains in California, and *Pinus ponderosa* var. *scopulorum* Engelm. (in S. Wats., Bot. Calif. 2: 126. 1879), of the Rocky Mountain region. Bark of small trunks light gray, smoothish, becoming furrowed into scaly plates. Spring shoots uninodal. Twigs glabrous, glaucous and greenish brown the first year, becoming light brownish gray and smoothish the second year, later light gray. Buds cylindric, acuminate, reddish brown, resinous, the lowest scales slightly whitish fringed. Leaves 3 in a fascicle, stout, stiff, erect and spreading, 10-16 cm. long, acuminate, serrulate, dull green; stomatal rows 8-11 dorsal and 3-5 on each ventral surface. Needle anatomy in cross section: Stomata slightly sunken; hypodermis biform, of 2-4 layers of cells; resin canals medial, 2, sometimes 3, at angles; endodermis of thin-walled cells. Specimen: 19137 (WPScop 2, 221/67).

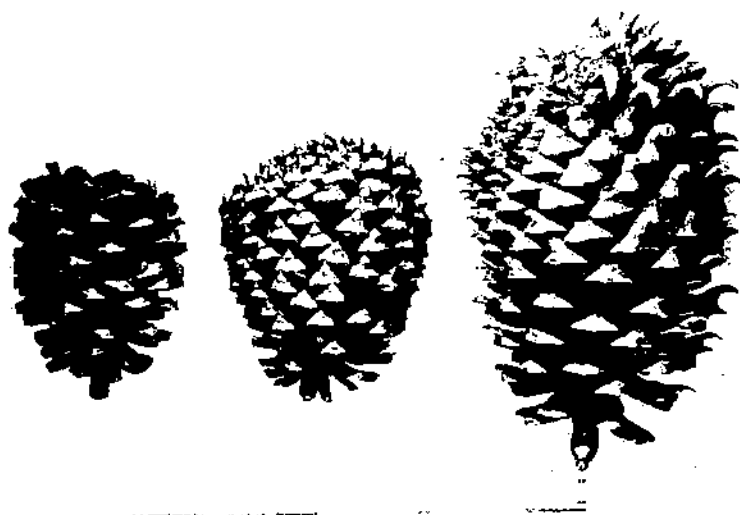
The hybrid has leaves intermediate in length between the parents and uniformly 3 in a fascicle as in *Pinus washoensis* but dull green as in *P. ponderosa* var. *scopulorum*. In needle anatomy the hybrid scarcely is distinguishable from the two species. However, in both parent species the outer cell walls of endodermis usually are thickened.

This cross was made at the Institute in 1948 with *Pinus washoensis* as seed parent. From seeds sown in 1950, 5 plants averaged 4.6 feet in height at 10 years.

Pinus jeffreyi × *coulteri*
Jeffrey pine × Coulter pine (fig. 7)

Artificial hybrid between *Pinus jeffreyi* Gray. & Balf. (in A. Murr., Bot. Exped. Oreg. [Rpt. No. 8] 2, t. 1853), of the Pacific coast region, and *Pinus coulteri* D. Don (Linn. Soc. London Trans. 17: 440. 1836), of California and northern Baja California, Mexico. Tree with straight axis and whorls of ascending branches. Bark on older branches smoothish and light gray, on trunk rough and becoming fissured into loose, slightly curled, thin scaly plates and exposing orange brown inner bark. Spring shoots uninodal. Twigs glaucous when young, glabrous, whitish blue, becoming light brownish gray the second year, older twigs smoothish. Buds cylindric, acuminate, reddish brown, resinous, the scales whitish fringed.

Leaves 3 in a fascicle, stout, stiff, erect to spreading or slightly drooping in age, 16-25 cm. long, acuminate, serrulate, dull gray green; stomatal rows 7-10 dorsal and 3-5 ventral, the stomata appearing as



F-510129

FIGURE 7.—Cones, left to right, *Pinus jeffreyi*, *P. jeffreyi* × *coulteri*, *P. coulteri*. One-fifth natural size.

minute white dots; membranous sheath about 20 mm. long, light brown, persistent but in age only about 7 mm. long. Needle anatomy in cross section: Stomata deeply sunken in a U-shaped cavity; hypodermis multiform, of 3-5 layers of cells, the inner border curved; resin canals medial, 2 at dorsal angles; endodermis of thin-walled cells; thick-walled cells of transfusion tissue forming lines outside phloem and xylem.

Male strobili (old and dry) cylindric, 20-22 mm. long and 4-5 mm. in diameter, pale yellow with pinkish tinge. Cones sessile, very large, ovoid-oblong, slightly oblique and asymmetrical at base, large and heavy, about 16 cm. long and 12 cm. in diameter when open; scales numerous, apophyses tawny yellow, very thick with prominent keel, the umbo together with stout spine 5-6 mm. long. Specimen: 17219 (Tree JCI 91, 232/45).

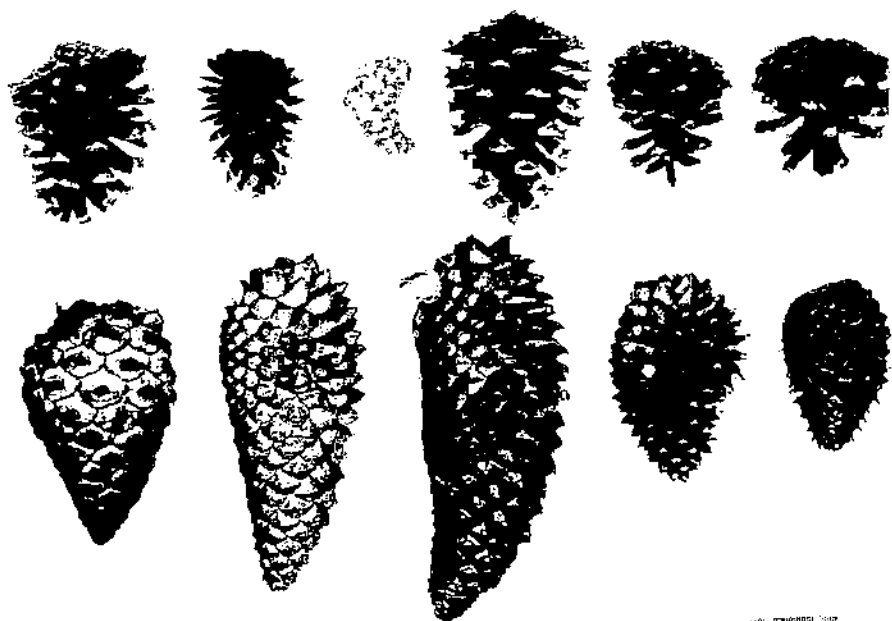
This intermediate hybrid has reddish brown resinous buds, as does *Pinus coulteri*, with scales slightly whitish fringed but lacking the whitish color of the conspicuously white-fringed bud scales of *P. jeffreyi*. In needle length the hybrid is intermediate. The stomata are as in *P. jeffreyi*, deeply sunken in U-shaped notches and under a hand lens appearing as minute white dots close together or on young leaves connected in longitudinal white lines along the needle surfaces. *P. coulteri* has distinctive stomata deeply sunken in large V-shaped notches and under a hand lens appearing as larger white squares, fewer and farther apart but also in lines. In needle anatomy the parents and hybrid are similar, but the hybrid has the thin-walled endodermal cells of *P. coulteri*. The cone is intermediate in size, shape, and phyllotaxis, having many flat scales as in *P. jeffreyi* but oblique and with stout, short spines, indicating relationship with *P. coulteri*.

The artificial cross with *Pinus jeffreyi* as seed parent was made at the Institute in 1944, 1946, and 1953 but has yielded very low proportions of sound seed. About 35 first-generation hybrid trees are growing at the Institute, though many others were produced and planted in field tests elsewhere. Five trees from seed sown in 1946 averaged 22.6 feet in height and 7.1 inches d.b.h. at 15 years. Eleven trees from seed sown in 1949 averaged 12.8 feet in height and 3.0 inches d.b.h. at 10 years.

The natural hybrid between these species in southern California was studied in detail, described, and illustrated by Zobel (50). Callahan (8) reported characteristics of the needle oils of backcross and other hybrids.

***Pinus contorta* var. *murrayana* × *banksiana*
Sierra lodgepole pine × jack pine (fig. 8)**

Artificial hybrid between *Pinus contorta* Dougl. var. *murrayana* (Grev. & Balf.) Engelm. (in S. Wats., Bot. Calif. 2: 126. 1879), Sierra lodgepole pine, of Sierra Nevada of California, and *P. banksiana* Lamb. (Descr. Genus *Pinus* 1: 7, t. 3. 1803), jack pine, of Canada and Northeastern United States. (*P. ×murraybanksiana* Righter & Stockwell, Madroño 10: 69. figs. 1, 2. 1949.) Bark dark gray, rough, with scaly plates. Branches stiff, ascending, straight, gray brown, scaly and slightly rough. Spring shoots multinodal. Twigs slender, glabrous, glaucous and yellow green when young, becoming purplish brown, year-old lateral twigs 4 mm. in diameter, the



F-510130

FIGURE 8.--Cones, left to right, top row, *Pinus contorta* var. *murrayana*, *P. contorta* var. *murrayana* \times *banksiana*, *P. banksiana*, *P. virginiana*, *P. virginiana* \times *clausa*, *P. clausa*; bottom row, *P. radiata*, *P. attenuata* \times *radiata*, *P. attenuata*, *P. attenuata* \times *maritima*, *P. maritima*. One-third natural size.

bases of bracts decurrent and forming narrow, rectangular plates. Buds acuminate, resinous, reddish brown.

Leaves 2 in a fascicle, straight or slightly twisted, slightly divergent, stiff, erect, 3-5 cm. long, 1.2-1.6 mm. wide, slightly flattened, acute, serrulate, slightly shiny dark green; stomatal rows 9-14 dorsal and 7-10 ventral; basal sheath about 7 mm. in bud, becoming 3 mm. long, gray brown. Needle anatomy in cross section: Stomata not sunken; epidermal cells nearly square to slightly rectangular; hypodermis biform, of 2, sometimes 3, layers of cells; resin canals 2 (sometimes 3) medial at angles, small to large, with thick-walled epithelial cells; endodermis elliptic, usually constricted, outer cell wall usually slightly thickened; vascular bundles 2, widely separated by thin-walled transfusion tissue.

Male strobili cylindric, 8-14 mm. long and 3-4 mm. in diameter, yellow brown, becoming orange brown when dry. Cones single or paired, sessile, reflexed or spreading, ovoid conic, nearly symmetrical, 4-7 cm. long, 4-4.5 cm. across when open, opening at maturity but persistent 1 or 2 years; apophyses slightly shiny, tawny yellow, flat, umbo flat usually with weak prickles less than 1 mm. long. Seed with slightly triangular brown body 3 mm. long and narrow membranous wing about 15 mm. long. Specimen: 18844 (Tree MyBa 14, 198/49).

Both parent species and the hybrid are similar in many vegetative

characters. The hybrid is like *Pinus contorta* var. *murrayana* in the stiff, ascending, straight branches. The needles are slightly divergent as in that parent but often short as in *P. banksiana*. In needle anatomy all are similar in most characters, but the hybrid approaches *P. contorta* var. *murrayana* in shape of epidermal cells. In cone characters the hybrid is intermediate in the short weak prickles, nearer *P. contorta* var. *murrayana* in the almost symmetrical reflexed or spreading cones opening completely at maturity, and like *P. banksiana* in the flat apophyses and early abundant cone production.

This cross was made at the Institute first in 1939 on *Pinus contorta* var. *murrayana*, and the seeds were planted in 1941. In 1944 and later years the cross was repeated. About 50 trees of this cross are growing there. At the age of 20 years, 13 of the original hybrids averaged 21.3 feet in height and 5.1 inches d.b.h.

Righter and Stockwell (39) named and described this hybrid and compared it with the parent species in a table. Mirov (32) compared the chemistry of the turpentines from this hybrid and its parents. Buchholz (7) included this hybrid in a study of embryological aspects of hybrid vigor, and Righter (35) included it in a study of the relation of seed weight and seedling size to inherent vigor.

Where the ranges of the parent species meet in central and northwestern Alberta, Moss (34) observed this natural interspecific hybrid, and Mirov (32, 33), analyzing chemical composition of the turpentine, found turpentine of the hybrids to be intermediate between the parent species. However, the parent of the natural hybrid represents a different variety, *Pinus contorta* var. *latifolia* Engelm., Rocky Mountain lodgepole pine, as separated by Critchfield (11).

The Institute has made also this artificial interspecific hybrid with a third variety, *Pinus contorta* var. *contorta*, shore pine, as *P. contorta* var. *contorta* × *banksiana*. Seed from this cross was first planted in 1949.

Pinus virginiana × *clausa* Virginia pine × sand pine (fig. 8)

Artificial hybrid between *Pinus virginiana* Mill. (Gard. Dict. Ed. 8, *Pinus* No. 9. 1768), of Eastern United States from New York to Indiana, Mississippi, and Georgia, and *P. clausa* (Chapm.) Vasey (ex Sarg., U.S. Census, 10th, 1880, v. 9 (Rpt. Forests No. Amer.): 199. 1884), of Florida. Bark of small trunks gray, rough, with scaly plates. Spring shoots multinodal. Twigs slender, glabrous, glaucous, whitish green when young, becoming purplish brown, smoothish. Buds acuminate, nonresinous, reddish brown, the attenuate scales with white margins becoming fringed.

Leaves 2 (rarely 3) in a fascicle, stout, often slightly flattened, slightly twisted, stiff, spreading at nearly right angle, 4-6 (7) cm. long (as short as 2.5 cm. on late summer twigs), 1.2-1.6 mm. wide, acute, serrulate, dull green to yellow green; stomatal rows 10-17 dorsal and 8-12 ventral (6-8 ventral on leaves in 3's). Needle anatomy in cross section: Outer epidermal cell walls slightly arched; hypodermis biform, sometimes uniform, of 2 or 1 layer; resin canals 2, medial, dorsal near angles, bordered by thin- or thick-walled cells; endodermis elliptic, of thin-walled cells; vascular bundles separated slightly less than bundle width; thick-walled cells mostly absent in transfusion tissue.

Male strobili (old and dry) cylindric, 7-12 mm. long and 3-4 mm.

in diameter, orange brown. New female or ovulate strobili or conelets on horizontal brown scaly stalks 5-8 mm. long, after pollination 1 cm. long, ovoid, scales with weak prickles more than 1 mm. long. Cones sessile, ovoid conic, 4.5-5 cm. long, 4-4.5 cm. across when open at maturity, persistent; apophyses shiny nut-brown, raised along a transverse keel, the umbo forming a prickle about 1 mm. long. Specimen: 18803 (Tree VCl a 4, 164/74); 19140 (Tree VCl a 5, 164/75).

As both parent species are closely related and similar, the hybrid is distinguished from the parents with difficulty by partly variable characters. Study of older plants shows a few changes in needle characters reported on 2-year seedlings by Keng and Little, (25, table 17). *Pinus virginiana* and the hybrid have the needles often slightly flattened and slightly broader than the semicircular needles of *P. clausa*. The hybrid is intermediate in the outer epidermal cells slightly arched, less than in *P. clausa*, and in the 2 vascular bundles separated by only slightly less than bundle width, less than in *P. virginiana*. It is like *P. virginiana* in the hypodermis usually bifurcated, rather than mostly uniform, and like *P. clausa* in the endodermis elliptic in outline, not constricted. Cones of hybrid and parents are similar. Though *P. clausa* typically is characterized by closed cones, the pollen parent was from Pensacola, within the range of the western open-cone race.

Five plants of this hybrid from cross pollination in 1953 and from seeds sown in 1955 averaged 5.2 feet high after 5 years.

Pinus patula × *greggii* Mexican weeping pine × Gregg pine

Artificial hybrid between *Pinus patula* Schiede & Deppe (in Schlecht. & Cham., Linnaea 6: 354. 1831), of eastern and central Mexico, and *P. greggii* Engelm. ex Parl. (in DC., Prodr. 16(2): 396. 1868), of northeastern Mexico. Bark of small trunks light brownish gray, smoothish but becoming furrowed into plates with orange brown furrows. Spring shoots multinodal. Twigs slender, glabrous, glaucous, whitish brown, becoming light orange or reddish brown and slightly scaly on larger branches and trunk. Buds conic to cylindric, acuminate, resinous or nonresinous, reddish brown, the long attenuate scales with white margins becoming fringed.

Leaves 3 in a fascicle, slender, flexible, slightly drooping, 10-15 cm. long (as short as 5 cm. on late summer twigs), 0.9-1.2 mm. wide, acuminate, serrulate, yellow green; stomatal rows 7-9 dorsal and 2-5 on each ventral surface; basal sheath 7-12 mm., the scales brown with whitish borders, the longest whitish and spreading at end. Needle anatomy in cross section: Stomata slightly sunken; hypodermis weak, uniform, of 2 or sometimes 1 layer; resin canals 2-4, medial or medial and internal, usually 2 dorsal near angles, bordered by thin-walled cells; endodermis of thin-walled cells; transfusion tissue with lines of thick-walled cells outside phloem and xylem.

Male strobili (old and dry) cylindric, 9-20 mm. long, 4-5 mm. in diameter, orange brown. Year-old conelets (in 1962 a single plant with 2 at different nodes) reflexed on stout, light brown, scaly stalks about 1 cm. long, ovoid, about 2 cm. long, the umbo glaucous, light brownish gray, weakly keeled, with minute prickles about 1 mm. long. Specimen: 18802 (Tree PatGr 15, 189/81).

The hybrid is intermediate in leaf characters and has slightly or half-drooping needles of intermediate length and width between the

shorter, straight, erect needles of *Pinus greggii* and the longer, weak, drooping or weeping needles of *P. patula*. *P. greggii* has smooth gray branches, while the hybrid and *P. patula* have reddish brown, scaly branches. The basal sheath of leaf fascicles is intermediate in length between the longer sheath (10–15 mm.) of *P. patula* and the shorter (5–8 mm.) of *P. greggii*. In needle anatomy the parents and hybrid are similar in most characters.

Fifteen plants of this hybrid were produced at the Institute from a cross pollination made in 1953 and from seeds planted in 1956. At 5 years they averaged 6.3 feet in height. In 1962, after 6 growing seasons, they were mostly vigorous and slightly larger than plants of the two parent species the same age and in adjacent rows. In 1962 plants of *Pinus patula* and the hybrid began needle elongation before those of *P. greggii*.

Fielding and Nicholson (16) made this cross in Australia in 1950. The hybrids were intermediate between the parents in foliage characters and grew more rapidly than open-pollinated progenies of the parents.

Pinus patula × *radiata* Mexican weeping pine × Monterey pine

Artificial hybrid between *Pinus patula* Schiede & Deppe (in Schlecht. & Cham., *Linnaea* 6: 354. 1831), of eastern and central Mexico, and *Pinus radiata* D. Don (Linn. Soc. London Trans. 17: 442. 1836), native locally on the coast of central California and Guadalupe Island of Mexico. Bark on small plant orange brown, scaly. Spring shoots multinodal. Twigs slender, glabrous, orange or reddish brown, becoming scaly. Buds conic, acuminate, non-resinous, reddish brown, the long attenuate scales with whitish margins. Leaves 3, sometimes 4 or 5, in a fascicle, slender, flexible, slightly drooping to spreading, (8) 11–15 cm. long on young plant, 1.2–1.3 mm. wide, acuminate, the serrulate margins hyaline, yellow green; stomatal rows 8–10 dorsal and 4–5 on each ventral surface; basal sheath 9–12 mm. long. Needle anatomy in cross section: Stomata slightly sunken; hypodermis weak, bifurciform or sometimes uniform, of 2 or 1 layer; resin canals medial, 2 dorsal near angles, bordered by thin-walled cells; endodermis of thin-walled cells; transfusion tissue with scattered thick-walled cells. Specimen: 19134 (Tree PatR 2, 214/88).

The single hybrid plant was compared with nearby plants of both parent species of the same age. The hybrid is intermediate, conspicuously in the slightly drooping needles between the lengths of parent species, partially displaying the weeping characteristics of *Pinus patula*. Both *P. patula* and the hybrid sometimes have 4 or 5 needles, while *P. radiata* sometimes has 2. The orange or reddish brown twigs resemble those of *P. radiata*, though lacking the glaucous color when young. The basal sheath of leaf fascicles is intermediate in length between the longer sheath (10–15 mm.) of *P. patula* and the shorter sheath (5–10 mm.) of *P. radiata*. The serrulate teeth of the leaf margins are intermediate between the short, weak teeth of *P. patula* and the large, stout, curved teeth of *P. radiata*. These minute differences in teeth can be felt by running the fingers down the needles.

In needle anatomy the hybrid has the small stomata of *Pinus patula* and not the modified epidermal cells conspicuously arched over the

stomatal court characteristic of *P. radiata*. Both parents and hybrid are similar in most details. The hypodermis is biform or sometimes uniform in the hybrid, biform in *P. radiata*, and uniform in *P. patula*. *P. patula* has 2-5 resin canals in cross section, *P. radiata* usually 2, sometimes 0-4, while 2 were observed in the hybrid.

This pollination was made at the Institute in 1955. One hybrid plant from seed sown in 1957 was outplanted in 1959 and was about 4 feet high in 1962.

Pinus attenuata* × *radiata
Knobcone pine × Monterey pine (fig. 8)

Artificial and natural hybrid between *Pinus attenuata* Lemm. (Mining and Sci. Press 64: 45. 1892) of California, adjacent Oregon, and Baja California, Mexico, and *Pinus radiata* D. Don (Linn. Soc. London Trans. 17: 442. 1836), native locally on the coast of central California and Guadalupe Island of Mexico. (*P. × attenuata* Stockwell & Righter, Madroño 8: 160. 1946.) Tree of rapid growth, with tall straight axis, many ascending to spreading branches, and broad crown. Bark gray, smoothish and slightly scaly, on lower part of large trunks becoming rough and shallowly furrowed into longitudinal scaly ridges. Spring shoots multinodal. Twigs glabrous, light brown. Buds cylindrical, acute, reddish brown, not or slightly resinous.

Leaves 3 in a fascicle, slender, spreading and becoming slightly drooping, 8-12 (18) cm. long, 1.1-1.2 (1.5) mm. wide, acuminate, serrulate, dull dark green; stomatal rows 7-10 dorsal and 3-5 on each ventral surface; membranous sheath about 10-15 mm. long, light brown, persistent but in age only about 5 mm. long. Needle anatomy in cross section: Stomata usually deeply sunken in an urn-shaped depression with walls of modified epidermal cells arched over stomatal court; hypodermis biform, of 2-3, sometimes 4, layers of cells, the inner border straight or nearly so; resin canals 2 medial at dorsal angles, sometimes only 1 or none, small, about 0.02-0.04 mm. in diameter; endodermis of thin-walled cells; thick-walled cells in transfusion tissue forming line outside phloem or absent.

Male strobili clustered, cylindrical, about 15 mm. long and 3 mm. in diameter, pink red, with brown scales at base. Year-old conelets 1, 2, 3, or more clustered together, often 2 whorls produced in a year, slightly reflexed on stout scaly peduncles nearly 1 cm. long, slightly oblique, about 18 mm. long and 11 mm. broad, the keeled umbos with sharp prickle about 1 mm. long, nearly straight and pointing slightly toward apex. Cones sessile, reflexed against twig, oblique conic, about 9-13 cm. long and 4.5-5.5 cm. in diameter when closed, brownish, long persistent, serotinous; apophyses 4-sided, with faint horizontal keel, those in lower part of outer side with prominent tubercle or pyramid 3-10 mm. high; umbos ending in sharp, nearly straight, persistent prickle 1-2 mm. long. Specimen: 17223 (Tree AtR 45, 191/41).

This hybrid is like *Pinus radiata* in its rapid growth and tall straight axis but is intermediate in branching. It approaches *P. attenuata* in its late bark formation, with smoothish bark except on lower parts of large trunks. The needles are dark green as in the former, intermediate in thickness, and spreading to slightly drooping as in the latter. In needle anatomy the hybrid is more like *P. radiata* in the modified epidermal cell walls usually arching over the stomatal court,

the smaller number of resin canals, and thick-walled cells outside phloem in transfusion tissue.

Stockwell and Righter (46) described and named this hybrid and compared it with the parent species in a table. This cross was made at the Institute in 1927 as its first pine hybrid and was repeated in 1947. About 80 progeny trees were grown from seeds planted in 1929 and 1949. Twenty trees measured at the age of 30 years averaged 73.2 feet high and 17.4 inches d.b.h.

At the Institute this hybrid has grown more rapidly than the other hybrids, even greatly exceeding native ponderosa pine. Though intermediate, this promising hybrid exhibits great vigor and combines the rapid growth of *Pinus radiata* and the cold and drought resistance of *P. attenuata*. It is being mass produced by the U.S. Forest Service for field trials in several places in California. Through treatment of seeds and buds with colchicine, Hyun (21) obtained mixoploid plants of this hybrid.

Bannister (4), using seven characters of seedlings, found the F_1 hybrids to be intermediate between the parents in most characters. Bannister, Brewerton, and McDonald (5) used vapor-phase chromatography in a study of the chemical composition of the turpentine of hybrids and parents. They included five F_1 's from Placerville. They found those F_1 's to be intermediate in the A-pinene/B-pinene ratios and an almost perfect relationship between this chemical ranking and a subjective taxonomic ranking based on morphological characters and evidence from progeny tests.

Pinus attenuata* × *muricata
Knobcone pine × bishop pine (fig. 8)

Artificial hybrid between *Pinus attenuata* Lemm. (Mining and Sci. Press 64: 45. 1892), of California, adjacent Oregon, and Baja California, Mexico, and *Pinus muricata* D. Don (Linn. Soc. London Trans. 17: 441. 1836), of the coast of California and adjacent Baja California. The pollen parent is the variation of the latter species described also as *P. remorata* Mason (Madroño 2: 9. 1930). Tree with straight axis, ascending branches, and broad conical, pointed crown. Bark on trunks and large branches smoothish, slightly fissured, light brownish gray. Spring shoots multinodal. Twigs glabrous, orange brown, older twigs tan or light brown. Buds cylindric, acute to acuminate, pink red, slightly resinous, the scales slightly white fringed.

Leaves 3 and 2 in a fascicle (on some shoots or plants either number may be commoner), stout, stiff, mostly erect to slightly spreading, 10-16 (18) cm. long, acute-acuminate, serrulate, dull light green: stomatal rows of leaves in 3's 11-18 dorsal and 6-10 on each ventral surface, of leaves in 2's 15-24 dorsal and 11-18 ventral: membranous sheath about 20 mm. long, light brown, persistent but in age only about 5 mm. long. Needle anatomy in cross section: Stomata deeply sunken in an urn-shaped cavity; hypodermis bifurcated, of 2 or 3 layers of cells, the inner border straight; resin canals medial, or medial and internal (or subinternal). 3-7, 3 medial at angles, sometimes 1-4 additional smaller dorsal and ventral, from less than 0.02 mm. to 0.04 mm. in diameter; endodermis of thin-walled cells; thick-walled cells absent from transfusion tissue or sometimes forming line outside phloem.

Male strobili clustered, cylindric, about 18-20 mm. long and 4 mm. broad, pink red, with brown scales at base. Year-old conelets 3-6 (sometimes only 1 or 2) together, often 2 whorls produced in a year, spreading to slightly pendent on stout scaly peduncles about 1 cm. long, ovoid, slightly oblique, about 20 mm. long and 17 mm. broad, the umbos with prominent unequal incurved spines 2-5 mm. long, fulvous brown. Cones sessile, reflexed against twig, oblique, ovoid to conic, 7-12 cm. long, 4.5-5.5 cm. broad closed, long persistent, serotinous, remaining closed indefinitely; apophyses mostly 4-sided, pyramidal with horizontal keel, 2-15 mm. high including umbo ending in stout, sharp, slightly incurved spine 2-5 mm. long, the apophyses, umbos, and spines very short on side next to twig and longest on opposite side. Specimen: 17222 (Tree At Mc (Rem) 11, 175/58).

This hybrid is like *Pinus muricata* (*P. remorata*) in the stiff, erect to slightly spreading dull green leaves, while *P. attenuata* has slender, often slightly longer yellow green leaves that spread widely and droop the second year. The hybrid combines the 2 leaves per fascicle of *P. muricata* with the 3 of *P. attenuata* and retains the latter's long needles. The acute-acuminate needle apex is between the acute to obtuse apex of the former and the acuminate of the latter. Needle anatomy of parents and hybrid is similar in most characters.

Combining characters of both parents, the cone is intermediate in size and shape, often larger than in *Pinus muricata* and as large as some cones of *P. attenuata*, varying from the ovoid shape of the former to the elongated conic shape of the latter. The stout spines are intermediate in length and nearly straight or slightly incurved, but in *P. muricata* longer and recurved (or incurved in *P. remorata*) and in *P. attenuata* shorter and slightly incurved.

This cross was made at the Institute in 1946 with *Pinus attenuata* as seed parent and the pollen parent the variation of *P. muricata* known also as *P. remorata*. Twelve progeny trees were grown from seed planted in 1949. At 8 years of age they were about 16-18 feet high and 4-5 inches d.b.h. At 13 years they were about 25 feet high and 8 inches d.b.h.

DISCUSSION

Notes on the identification of many of these hybrids by needle characters and on the inheritance of needle characters have been reported by Keng and Little (25). In *Pinus*, cone features are more definitive, and hence more useful, than vegetative characters in identifying species and hybrids. As many young hybrids lack cones, the needle, bud, twig, and bark characters can be used. These descriptions should be helpful in identifying many putative natural and artificial hybrids.

Many characters of hybrids are intermediate: others are like or more closely resemble those of one or the other parent. The first-generation (F_1) interspecific hybrids are intermediate in nearly half of the needle characters and resemble each parent in roughly a fourth of the characters, though many differences are slight (25). Reciprocal crosses were all identical.

SUMMARY

Botanical descriptions are presented of 40 artificial pine hybrids made at the Institute of Forest Genetics, Placerville, Calif., 11 of soft pines and 29 of hard pines. These include 34 first-generation (F_1) interspecific hybrids from 32 species, 5 additional crosses involving another variety of 1 parent species, and 1 intervarietal hybrid. One interspecific hybrid grown but not produced at the Institute is included. These hybrids are designated by formulas. Of the 36 species of pines native in the United States, 26, including 5 of soft pines and 21 of hard pines, are represented in these crosses.

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