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AUSTRIAN X JAPANESE RED PINE HYBRIDS:
MORPHOLOGICAL FEATURES, NATURAL
DISTRIBUTION, AND YIELD FROM
OPEN-POLLINATED AUSTRIAN PINE

Thesis for the Degree of M. S.
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THESIS



ABSTRACT

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by David S. Canavera

Thirty-five natural Austrian pine (P. nigra Arn. var. austriaca) X Japanese red pine (P. densiflora) hybrids were observed growing within 20 feet of a 30-year-old Austrian pine stand located 200 feet east of a similar-aged Japanese red pine stand at the W. K. Kellogg Forest near Augusta, Michigan. Only seven pure Austrian pines were growing next to the same Austrian pine stand. Probable hybrids were identified by red-brown buds and moderately stiff needles, in contrast to Austrian pine which had white buds and very stiff needles. Probable hybrids, six to eight years old, were significantly different from and intermediate between similar-aged Austrian and Japanese red pines in number of rows of stomata, number of stomata per millimeter, bud size and color. The probable hybrids have straight trunks, fine branches, and are growing up to three feet per year.

Seeds from the open-pollinated Austrian pine, possibly pollinated by Japanese red pine, were grown along with seeds of pure Austrian and Japanese red pines to determine the percent of hybrids in the open-pollinated Austrian pine. A hybrid yield as high as 85 percent was found when two-year-old hybrids were compared to three-year-old pure Austrian pines. The hybrids had a significantly lower value than the comparison Austrian pine in needle length and width, total number of

stomata per millimeter, bud length and width, and bud color. The hybrids averaged 45.9 centimeters tall, which was significant from Austrian pine only 16.2 centimeters tall.

At the end of the first growing season, possible hybrids that were germinated in the greenhouse and later transplanted to the nursery were identified in the open-pollinated Austrian pine collected at the Kellogg Forest. These seedlings had red-brown buds, secondary needles and averaged 15.1 centimeters tall which was significantly different from similarly treated seedlings of pure Austrian pine, with white buds, 11.8 centimeters tall and Japanese red pine, with red buds, 10.5 centimeters tall.

Color differences of one-year-old open-pollinated seedlots, sown directly in the nursery, show the hybrid yield to be 54 percent. A seedlot of pure Japanese red pine was purple; a similarly treated seedlot of pure Austrian pine was green; at the same time two seedlots of Austrian pine, possibly pollinated by Japanese red pine, had both purple and green seedlings.

This unusually high yield of natural hybrids may result from the suppression of archegonia fertilized with Austrian pine by superior archegonia fertilized with Japanese red pine; equal amounts of Austrian and Japanese red pine pollen in the Austrian pine stand; or identification of the hybrids at ages one and two may be wrong.

Mass-production of the Austrian X Japanese red pine hybrids is best accomplished by planting Japanese red pine around existing Austrian pine stands. The wind will carry quantities of Japanese red pine pollen into the Austrian pine, so that harvest of the hybrids will be possible ten years after planting of the Japanese red pine.

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INTRODUCTION

Hybrids play an important role in the production of food. Many are important because they exhibit heterosis or hybrid vigor in the first generation. Tomatoes, corn, onions, and sorghum are among the crops in which first-generation hybrids are planted extensively.

Corn is the classical example of a useful hybrid exhibiting heterosis. Beginning with the work of W. J. Beal at Michigan Agricultural College in the late 1870's, hybrid corn was shown to have more vigor than the open-pollinated varieties then in use. Although Beal did not give detailed data, he stated that hybrids produced 25 percent higher yields than their parents (Wallace and Brown, 1956). Actual development of hybrid varieties began much later and large scale planting started three decades ago. Of the total corn acreage in the United States, very little was planted to hybrids in 1929; 23 percent in 1939; and at present the figure has climbed to 99 percent. The acreage of corn in the United States decreased from slightly over 100 million acres in 1929 to less than 80 million acres in 1963, but yield increased by one third (Gardner, 1963). The use of hybrids accounted for about one-third of this increase. Improved agricultural practices, such as efficient weed and disease control along with the application of proper fertilizers accounts for the remaining increase in production.

A potential tree that shows hybrid vigor is the eastern white

pine (P. strobus L.) X Himalayan white pine (P. griffithii McClel.) hybrid. In a four-year test at Philadelphia, the hybrids grew 31 percent faster than eastern white pine and 44 percent faster than Himalayan white pine (Wright 1962).

In South Korea, pitch pine (P. rigida Mill.) X loblolly pine (P. taeda L.) hybrids are very important. Impressed with the heterotic performance of this combination in California, S. K. Hyun started a large scale hybridization program at Suwon, South Korea in 1953. These hybrids are valuable because they are more productive than pitch pine and hardier than loblolly pine (Hyun, 1956).

Hybrids often exhibit hybrid vigor, that is grow faster than either parent. This can be regarded as the reverse of inbreeding depression. Three hypotheses help explain the phenomenon. According to the dominance theory, hybrid vigor results from the action of dominant growth factors and the consequent suppression of deleterious recessive genes. The overdominance theory states that heterozygosity per se is necessary, i.e. that two different genes at a locus can accomplish more than two of any one gene. Thirdly, Edgar Anderson postulated that the excellent growth of many hybrids was due to the fact that they were grown in hybrid (intermediate) habitats.

Recently, several probable natural Austrian pine X Japanese red pine hybrids were observed growing on the W. K. Kellogg Forest near Augusta, Michigan. Their exceptional vigor made it desirable to learn more of their characteristics and means by which they might be mass-produced. My study was undertaken to confirm their hybridity and growth potential, and to learn whether hybrids of this combination

could be mass-produced.

MATERIALS AND METHODS

Parental stands.--Austrian pine (P. nigra Arn. var. austriaca (Hoess) Aschers & Graebn.) is an introduction from southern Europe that has been planted extensively in the eastern half of the United States. This variety has straight trunks, coarse branches, and 4- inch needles that are dark-green and very sharp. It attains a height of 70 feet and grows one to two feet per year.

An Austrian pine plantation was established at the W. K. Kellogg Forest, 2 miles west of Augusta, Michigan on October 24, 1936. The 1000 seedlings of 2-0 stock were row planted by hand on a 7 X 7-foot spacing, and occupied 1.1 acres. The first treatment given to the stand was in 1947, when a few trees were removed for use as Christmas trees. In 1955, one-quarter of the remaining trees were removed with a crown cut. Only potential crop trees were left. In September 1966 the dominant trees averaged 47 feet in height.

Japanese red pine occurs naturally between 300 and 3000 feet elevation on the Japanese island of Honshu. It has fine brittle branches, fine needles and is sometimes very crooked. In its natural range this tree grows as much as two and one-half feet per year and reaches a height of 105 feet.

A Japanese red pine plantation was established at the Kellogg Forest on May 2 and May 9, 1936. The 2-2 stock came from the Michigan State College nursery. The 2700 seedlings were row planted by hand with a 6 X 6-foot or 6 X 8-foot spacing, and occupied 2.5 acres. The

only treatment given the stand was in 1952 when 10 percent of the trees were cut and used as fence posts. The dominant trees averaged 45 feet in height in September 1966.

These stands of Austrian pine and Japanese red pine are very close together. They join on the south edge and radiate outward in an east-west direction. The northern boundary marks their point of greatest separation, here the Austrian pine is 200 feet east of the Japanese red pine. The Austrian pine is growing on a level site and the Japanese red pine is on a hill. Wind direction is from the south and southwest in the spring of the year, therefore, as it passes through the Japanese red pine it could easily pick up pollen and carry it east to the Austrian pine stand.

Natural reproduction near the parental stands.--The probable Austrian X Japanese red pine hybrids are seeding in naturally along the north and west edges of the Austrian pine stand. The area is open but the seedlings face competition from existing vegetation for nutrients and water.

Austrian pine, Japanese red pine, jack pine (P. banksiana Lamb.), red pine (P. resinosa Ait.), pitch pine and Virginia pine (P. virginiana Mill.) are also seeding into the open area between the Austrian and Japanese red pine plantations. All of these species are growing north or west of the Austrian pine and no more than 200 feet from it. Natural reproduction for each has a limited distribution. Most seedlings are found within 30 feet of their parental stands. The probable hybrids extend 500 feet in a linear north-south direction, but all are found within 20 feet of the Austrian pine stand. Natural reproduction of

Japanese red pine was abundant near the original Japanese red pine stand, but no hybrids were found near this stand.

TABLE 1--Seedlings at least two years old seeding into the open
area between the Austrian and Japanese red pine stands

Species	No. trees	Percent of total
<u>P. banksiana</u> Lamb.	5	5
<u>P. densiflora</u>	32	34
<u>P. nigra</u>	7	8
<u>P. nigra</u> X <u>densiflora</u>	35	37
<u>P. resinosa</u>	4	4
<u>P. rigida</u> Mill.	6	6
<u>P. virginiana</u>	6	6

Test of open-pollinated progeny.--Cones from at least 10 Austrian pine trees, subject to pollination by Japanese red pine, were collected in each of three different years at the Kellogg Forest. The cone and seed yields are given in Table 2. For comparison purposes, seeds of supposedly non-hybrid Austrian pine were collected from two sources and seed of non-hybrid Japanese red pine were obtained from three sources in Japan.

Seedlings measured in the nursery resulted from seedlots sown directly in nursery seedbeds or from seedlots sown in the greenhouse and later transplanted to the nursery. Comparisons of the probable hybrids with Austrian and Japanese red pine were made on seedlings one to three years old (Table 3).

TABLE 2--Cone and seed harvest from Kellogg Forest Pinus nigra
trees subject to pollination by Pinus densiflora

Year of collection	Seedlot numbers	Cones collected	Filled seeds	
			(Total)	(Per cone)
		<u>Number</u>	<u>Number</u>	<u>Number</u>
1962	3371	353	7300	21
1963	3372	100	2100	20
1964	3955 to 3959	1716	47000	27

TABLE 3--Seedlings available for study at the Tree Research Center,
Michigan State University

Species and seedlot	Source	Year sown	Seedlings measured	Seedling density
<u>MSFG number</u>			<u>Number</u>	<u>Number per square foot</u>
<u>Sown directly in nursery seedbeds.</u>				
<u>P. densiflora</u>				
3945 to 3947	Japan	1966	600	30
<u>P. nigra(a)</u>				
3371 3372	Kellogg	1964	50	30
3955 to 3958	Kellogg	1966	200	30
<u>P. nigra</u>				
3955	Yugoslavia	1965(b)	25	0.5
3951, 3952	MSU Campus	1966	200	30
<u>Sown in greenhouse 1/12/66 and transplanted to nursery seedbeds 4/25/66.</u>				
<u>P. densiflora</u>				
3955	Kellogg	1966	25	14
<u>P. nigra(a)</u>				
	Kellogg	1966	25	14
<u>P. nigra</u>				
3951, 3952	Yugoslavia	1966	25	14

(a) Possibly pollinated by Pinus densiflora.

(b) Transplanted as 1-0 stock in 1965.

Kellogg Forest measurements.--Needle collections were made in September 1966 from probable hybrids six to eight years old, from comparison Austrian pine trees (Seedlot MSFG 423) in an eight-year-old plantation (No. MSFG 5-61) about 1 mile distant, and from Japanese red pine natural reproduction near the 30-year-old Japanese red pine parent stand. Four needles, each from a different fascicle, were measured from each tree. All measurements were made in the laboratory with a dissecting microscope. Lengths were measured to the nearest millimeter and widths to the nearest tenth of a millimeter. Ventral stomata in the complete rows of a 1-centimeter section were counted for each needle. Each section used was 3-centimeters from the tip of the needle.

Bud measurements were made on terminal buds collected from the largest branch in the 1965 whorl. All measurements were made in the field except for color, which was made in the laboratory under fluorescent light. Color was scored on a scale of 1 to 9. Using the Munsell Color Charts For Plant Tissues (1963), grade 1 corresponded to Hue 7.5 YR (Value 8/Chroma 2), and grade 9 corresponded to Hue 10 R (Value 4/Chroma 4).

Four mature cones were collected from the one 12-year-old probable hybrid which fruited in 1966. Four cones were also collected from ten trees each of the 30-year-old Austrian and Japanese red pines. Cone length and width were measured to the nearest millimeter. The cones were then air dried at room temperature. Time of cone opening and duration of opening were recorded to the nearest day. Width of the five largest scales per cone was measured to the nearest millimeter.

The total number of scales per cone were also counted.

Seed and seed-wing measurements were made on 25 seeds each of the probable hybrid, Austrian and Japanese red pines.

Nursery measurements.--Probable hybrids were identified in the open-pollinated seedlots of Austrian pine collected at the Kellogg Forest. The seedlings labeled as probable hybrids all had brown buds, grew rapidly, had three needle fascicles, and moderately stiff needles. By contrast, Austrian pine seedlings had white buds, very stiff needles and were only about one-third as tall as the suspected hybrids.

Needles and buds were measured in the same manner used for material collected from the Kellogg Forest. In addition to these measurements, height of the various-aged seedlings was measured to the nearest centimeter.

RESULTS

Authenticity of the Kellogg Hybrids.---Austrian X Japanese red pine hybrids have been reported previously by Blakeslee (Austin, 1927), Wright and Gabriel (1958), Mergen (1959), and Vidakovic (1966). Austin gives only a brief mention of the pioneer work done by Dr. A. F. Blakeslee at Cold Springs Harbor, New York in 1914.

Wright and Gabriel successfully made controlled pollinations at Philadelphia from 1948 to 1956. They pollinated 385 Austrian pine strobili; had 40 percent cone set; 5.0 empty seeds per cone and 5.9 full seeds per cone. One-year-old seedlings showed heterosis. Also, probable natural hybrids were identified in four open-pollinated progenies of isolated Austrian pine trees growing close to Japanese red pine.

Mergen verified the hybrids made by Wright and Gabriel by counting the number of rows of stomata and the total number of stomata per millimeter. By this method, he was able to show that the hybrids were intermediate between Austrian and Japanese red pine.

The cross was most recently made by Vidakovic in Yugoslavia. He found the needle structure of the hybrid to be intermediate in the position of the resin ducts and the width of the cross section. More interesting, the rate of growth of two-year-old hybrids was dependent on the female parent used. The hybrids did not always display a greater height growth than pure P. nigra.

Needle measurements made from collections at the Kellogg Forest showed that the probable hybrids were significantly different from and

intermediate between Austrian and Japanese red pine in rows of stomata and number of stomata per millimeter. These results agree with Mergen's and give a sound basis for saying that the probable hybrids are indeed Austrian X Japanese red pine hybrids (Table 4).

The buds, cones, and seeds help confirm hybridity. Buds of the probable hybrids were nearly as long as those of Austrian pine, but intermediate in thickness and color. Austrian pine buds were longer, thicker, and lighter in color than Japanese red pine. Width and color of the probable hybrids were significantly different from both Austrian and Japanese red pine.

Trees initially identified as probable hybrids had needles intermediate in stiffness between the fine needles of Japanese red pine and the stiff needles of Austrian pine, and also had red-brown buds. Their buds closely resembled the red buds of Japanese red pine, but were distinctly different from the white buds of Austrian pine. All of these trees were growing within 30 feet of the parental Austrian pine stand. The most questionable hybrid had needles almost as stiff as the finest needles found on the Austrian pine trees, but it also had red-brown buds, which were easily distinguishable from the white buds of Austrian pine. Therefore, all of the trees designated as probable hybrids differed from Austrian pine in at least one readily observable character.

TABLE 4--Needle and bud characters of P. nigra, P. densiflora, and their probable hybrids (a)

Character and unit of measurement	Probable		
	<u>P. nigra</u>	hybrids	<u>P. densiflora</u>
NEEDLE			
Length(mm.)	106*	90	98*
Width(mm.)	1.44	1.20	0.97
Rows of stomata(no.)	8.0*	6.5	5.5*
Stomata per mm.(no.)	94*	79	65*
BUD			
Length(mm.)	15.9*	12.2	11.8
Width(mm.)	5.3*	4.4	3.0*
Color	Tan*	Brown	Red-brown*

* Differs significantly (5 percent level) from the probable hybrids.

(a) The measurements were made on 25 trees varying in age from 6 to 12 years. The measurements of the parents were made on twenty-five similar-aged trees of each species.

The four cones collected from the one 12-year-old probable hybrid were also significantly different from and intermediate between Austrian and Japanese red pine in length, width, and width of the scales. In addition, their opening date was intermediate between those of Austrian and Japanese red pines.

The medium-brown seeds of the probable hybrids resembled the dark-brown seeds of Austrian pine more than the red-brown seeds of Japanese red pine. Seeds of the probable hybrids were significantly different from and intermediate between both Austrian and Japanese red pine in color (Table 5).

TABLE 5--Cone and seed characters of Pinus nigra, Pinus densiflora,
and a probable hybrid

Character and unit of measurement	Probable		
	<u>P. nigra</u>	hybrid	<u>P. densiflora</u>
CONE			
Length(mm.)	72*	55	42*
Width(mm.)	32*	25	21*
Scale width(mm.)	13*	11	9*
Scales per cone(no.)	93*	76	80*
Date opening started	Oct. 20	Oct. 17	Oct. 9
Days needed to open	4	2	12
SEED			
Length(mm.)	22.3	21.6	16.8*
Color	Dark-brown*	Brown	Red-brown*
BASIS			
Number of trees	10	1	10
Age of trees	30	12	30

* Differs significantly (5 percent level) from the hybrid cones or seeds.

The possibility of Austrian pine successfully crossing with any of the other hard pines near the Austrian pine plantation was considered. The only successful combination of Austrian pine with any of these hard pines is P. nigra X resinosa. Six of these hybrids were obtained at Placerville in 1957 (Critchfield, 1963). Three hundred and twenty-six P. nigra strobili were pollinated with P. resinosa before the six hybrids were obtained. Many other attempts to make this cross were unsuccessful (Johnson and Heimbürger, 1946; Duffield 1952; Holst and Heimbürger, 1955; Wright and Gabriel 1958).

The extreme difficulty of obtaining inter-series crosses in the pines eliminates the possibility of P. nigra combining with P. banksiana, rigida or virginiana. Natural P. nigra X sylvestris (Scotch pine) hybrids have been reported by Vidakovic in Denmark (Vidakovic, 1958). No Scotch pine is growing less than one-quarter mile from the parent Austrian pine stand at Kellogg, so possibility of this cross was slight. Considering the distribution of natural reproduction, with respect to parental stands, in the open area between the Austrian and Japanese red pine stands; plus the convincing results obtained from the comparison of Austrian and Japanese red pine with the probable hybrids in needle, bud, cone and seed characters would all combine to verify the Austrian X Japanese red pine hybrids.

The Austrian X Japanese red pine hybrids appear to combine the favorable growth characteristics of both Austrian and Japanese red pine. They have the characteristic straight stems of Austrian pine and fine branches of Japanese red pine. The hybrids are also very fast growing. The present growth rate is two and one-half to three feet per year. One 22-year-old hybrid will soon surpass 30-year-old Austrian pine trees

located just 10 feet from it.

Two-year-old nursery measurements.--A comparison was made between two-year-old probable hybrids, grown from open-pollinated Austrian pine possibly pollinated by Japanese red pine (Seedlots 3371, 3372, 3955 to 3958), and three-year-old Austrian pine (Seedlot 3955). The probable hybrids were identified by needle stiffness, bud color, three needle fascicles and rapid growth. They were significantly different from and had a lower mean value than Austrian pine in needle length and width, total number of stomata per millimeter, bud length and width and bud color.

Forty-seven percent of the seedlings in the open-pollinated Austrian pine seedlots were identified as probable hybrids because they were tall, had needles less stiff than the comparison Austrian pine, and also had red-brown buds. The actual hybrid yield may be as high as eighty-five percent. The additional seedlings had red-brown buds, but were not taller and did not have less stiff needles than the comparison Austrian pines.

The probable hybrids identified by three characters outgrew the Austrian pine. Twenty-five of the two-year-old probable hybrids were 45.9 centimeters tall, which was significantly different from the same number of three-year-old Austrian pine seedlings only 16.2 centimeters tall (Table 6).

Eighty-eight percent of the probable hybrids had some fascicles with three needles in them. In contrast, pure Austrian pine had a significantly lower value with only 15 percent of the seedlings possessing some fascicles with three needles.

TABLE 6--Comparison of Austrian pine and probable Austrian X Japanese red pine seedlings(a)

Character and unit of measurement	<u>P. nigra</u> (b)	Probable hybrids(c)
NEEDLE		
Length(mm.)	109	93*
Width(mm.)	1.31	1.40*
Rows of stomata(no.)	7.9	7.8
Stomata per mm.(no.)	93	84*
BUD		
Length(mm.)	21.4	16.5*
Width(mm.)	5.6	4.8*
Color	Tan	Brown*
Height in cm.	16.2	45.9*

* Differs significantly (5 percent level) from Austrian pine.

(a) Twenty-five trees of each kind were measured.

(b) 3-year-old seedlings grown from seed collected in Yugoslavia.

(c) 2-year-old seedlings from seed collected at Kellogg Forest.

One-year-old nursery measurements.--Seedlots of Japanese red pine, pure Austrian pine and open-pollinated Austrian pine, possibly pollinated by Japanese red pine, were germinated in the greenhouse and later transplanted to the nursery. Possible Austrian X Japanese red pine hybrids were identified in the open-pollinated Austrian pine by their red-brown buds and secondary needles. At the end of the first growing season the suspected hybrids were significantly taller than similarly treated Austrian or Japanese red pine seedlings, as shown in the following tabulation which is based upon 25 trees of each kind.

Species	1-year
	height
	<u>Centimeters</u>
<u>P. nigra</u>	11.8
Probable hybrids	15.1
<u>P. densiflora</u>	10.5

In October 1966, seedlings in a broadcast-sown seedbed of pure Austrian pine (Seedlots 3951, 3952) were green, while at the same time a broadcast-sown seedbed of Japanese red pine had purple seedlings (Seedlot 3955). A similarly treated seedbed of Austrian pine, possibly pollinated by Japanese red pine (Seedlots 3955 to 3958), had both green and purple seedlings. No other differences were evident between seedlings in the three seedbeds. Based on color, the probable hybrid yield is 54 percent.

POSSIBLE EXPLANATIONS OF THE HIGH YIELD OF HYBRIDS

The high yield of Austrian X Japanese red pine hybrids in the open-pollinated Austrian pine is unusual. There may be several reasons for it. Flowering dates for both Austrian and Japanese red pine have been studied for the last five years at Michigan State University and an overlap of two to four days was recorded. As the spring winds from the south and southwest pass through the Japanese red pine they could pick up pollen and transport it east to the receptive female flowers on the Austrian pine trees.

One reason why the hybrid yield seems so high is that identification of the hybrids at age two may be wrong. Individual trees have been labeled as probable hybrids and their performance will be watched to verify their hybridity.

Another possibility is that the hybrid yield actually represents the percent of pollen of both Austrian and Japanese red pine present. The name P. densiflora means many flowers. It may be, that there is as much or more Japanese red pine pollen available in the Austrian pine stand as there is pollen from the Austrian pine itself.

Polyembryony has been observed in the pines and very likely could be the reason for the high yield of hybrids. Fertilization of the archegonia in pines takes place about 13 months after pollination. Two to five archegonia may be present at the micropylar end of the female

gametophyte at this time, and all archegonia can be fertilized. After fertilization, each archegonium differentiates suspensor cells, which thrust each proembryo deep into the female gametophyte where the proembryo develops into the embryo.

Competition between the different archegonia, one of which ultimately develops into the embryo, may occur at any stage of development. Some likely places are in the development of the suspensor cells or the proembryo. In the Austrian pine at the Kellogg Forest, perhaps only one archegonium is fertilized by Japanese red pine, but somehow it has an advantage over the other archegonia fertilized by Austrian pine in developing into the embryo. This ability of the archegonium fertilized by Japanese red pine to suppress those fertilized by Austrian pine may be an early expression of heterosis.

A POSSIBLE SEED ORCHARD SCHEME

Various approaches may be used in developing a productive seed orchard that will yield high quantities of Austrian X Japanese red pine hybrids. Because the percent of hybrids in the open-pollinated Austrian pine is high, controlled pollinations will not be necessary. The most promising method of mass-pollination is the one used by nature at the Kellogg Forest, pollination by wind. Present evidence indicates that the wind will carry quantities of Japanese red pine pollen into nearby Austrian pine stands. A hybrid yield of at least 50 percent can be expected with this type of pollination.

One long-range approach of supplying the Japanese red pine pollen source is to grow both Austrian and Japanese red pine from seed and mix the two in outplantings. The main advantage of using this approach is that a choice can be made as to which variety of P. nigra to use. The main disadvantage is the long time needed for the Austrian pine to flower. Even using flower producing stimulants, the minimum time needed for the Austrian pine to flower would be around 20 years.

A more realistic approach to mass-producing the hybrids would be to locate already flowering Austrian pine stands and plant Japanese red pine around them. Japanese red pine flowers prolifically at 10 years of age, so production of the hybrids would begin in one-half the time needed with the other scheme. The main disadvantage, here, however is the source of P. nigra used may not be the most desirable. Consequently, the hybrids produced may be slower growing and have coarser

branches than the best hybrids which could be produced.

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