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THE HYBRID WHITE SPRUCE X HIMALAYAN SPRUCE

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ABSTRACT.—*Picea glauca* and *P. smithiana* were successfully crossed. Crossability ranged from 2 to 30 percent depending on the female *P. glauca* parent tree. Early characteristics and growth in Wisconsin and in New Brunswick are described. *P. smithiana* relatedness in the genus is discussed.

KEY WORDS: Crossability, seedling characteristics, hybridity, phylogeny.

Species hybridization creates new genotypes that may be superior to the parental species; it can also be used to help determine intrageneric relations among species (Wright 1955).

Himalayan spruce, *Picea smithiana* (Wall.) Boise., is a high elevation (2,000-4,000 m), commercially important species. It extends from eastern Afghanistan southeastward to central Nepal, a distance of approximately 2,000 km. Himalayan spruce is one of the largest spruce species with heights of up to 50 m (Schmidt-Vogt 1977). The species has been planted on a small scale as an ornamental in Great Britain (Streets 1962) and in eastern North America (Wright 1956).

White spruce, *Picea glauca* (Moench) Voss, is the most widely distributed conifer in North America. The species has been extensively planted throughout the north-central and northeastern United States and adjacent Canada during the last 40 years. White spruce is known to be highly variable with a great potential for genetic improvement (Nienstaedt and Teich 1971).

Mergen *et al.* (1965) were the first to attempt to cross white spruce and Himalayan spruce. They obtained 852 seeds from 32 cones but provided no information on proportions of full seed or on germinations. At least 40 seeds germinated and survived for 4 years in a nursery. At the end of the first growing season, the hybrids were not significantly different from white spruce. At the end of the fourth growing season in the nursery, their heights were intermediate between white spruce seedlings obtained from self- and from wind-pollinations.

Fowler *et al.* (1973) reported obtaining 144 full seeds from 443 cones from crosses of three white spruce with pollen of Himalayan spruce. Later Fowler *et al.* (1975) obtained 14 full seeds from 310 cones from this same cross on nine additional white spruce at the Acadia Forest Experiment Station (AFES) near Fredericton, New Brunswick. The same cross using 42 female strobili on three trees was reported as successful by Hoffman and Kleinschmit (1979).

We present additional information on some crosses reported by Fowler *et al.* (1975) and on crosses made at the Forestry Sciences Laboratory (FSL) in Rhinelander, Wisconsin.

MATERIALS AND METHODS

In the spring of 1971, an attempt was made to cross three white spruce trees growing at the AFES

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with pollen from a single Himalayan spruce growing in the Yale Brett Arboretum in Fairfield, Connecticut. This same combination, as well as intraspecific white spruce crosses, was attempted again in 1973 using nine other white spruces at the AFES, one at Taymouth, N.B., and four white spruces at the FSL.

The pollination techniques used were essentially the same as those described for white spruce by Nienstaedt and Teich (1971). The general procedures used for seed cleaning and germination and for raising and testing seedlings at the AFES and the FSL are described by Fowler (1980) and Nienstaedt (1979) respectively. One deviation, however, should be mentioned: At the FSL seedlings in the greenhouses were transplanted progressively to larger containers; at no time were they rootbound.

RESULTS

Ten of the 17 attempts to cross white spruce and Himalayan spruce produced at least a few full seeds. The seven unsuccessful crosses occurred at the AFES in 1973 when Himalayan spruce pollen known to have low *in vitro* germination was used. Seed yields from both hybrid and control crosses were considerably higher at the FSL than at the AFES (table 1).

Germination of hybrid seeds was variable. Two AFES crosses failed to germinate; otherwise, the germination of hybrid seed was similar to that of comparable white spruce. The frequency of abnormal germination, e.g., seeds with reverse embryos, was higher among the hybrids than among the parental species. It was especially high for one cross (#7583) in which 15 of 38 germinants had reverse embryos.

Estimates of crossability, based on the yield of sound, germinable seed from crosses between two species, expressed as a percentage of the seed yield from within species crosses, provide a measure of relation between species (Critchfield 1973). However, for such estimates to be meaningful, comparable information should be available from intra- and interspecific crosses made on the same mother trees. Only six of the attempted crosses reported here meet this requirement. Crossability estimates based on these crosses range from 1.7 to 30 percent and average 9.1 percent (table 1).

The hybrid families can be distinguished from parental species on the basis of needle length and stem form and in some cases on the basis of number of cotyledons and needle serrulations. Variation in respect to hypocotyl color and foliage color is too great to be of diagnostic value, at least for young seedlings.

Table 1.--Crossability estimates for the cross Picea glauca x P. smithiana--full seeds and germination percentages[1/]

Identification Number	Parentage ♀	Parentage ♂	Cones No.	Full Seed No.	Germination Percent	Crossability[2/] Percent
1971 CONTROLLED POLLINATIONS (NEW BRUNSWICK)						
2220	glauca #556	smith	166	20	20.0	
--	glauca #561	smith	234	3	0	No
2224	glauca #558	smith	43	119	53.8	estimates
2226	glauca AFES	open[3/]	--	250	88.0	possible
2227	smith India	open	--	200	37.0	
2228	smith India	open		200	80.0	
1973 CONTROLLED POLLINATIONS (NEW BRUNSWICK)						
2860	glauca 73-6	smith	48	13	61.5	6.08
2863	glauca 73-6	glauca	54	266	55.6	
--	glauca T-3	smith	27	12	[4/]	7.56
--	glauca T-3	glauca	32	188	[4/]	
2867	glauca 73-2	smith	16	1	0	
2892	smith India	open		100	19.0	
1972 CONTROLLED POLLINATIONS (WISCONSIN)						
7579	glauca 1885	smith	165	902	21.8	30.42
7123	glauca 1885	glauca 1887	52	1,164	17.5	
7584	glauca 1888	glauca 1889	43	1,931	41.5	2.42
7583	glauca 1888	smith	51	63	36.5	6.52
7585	glauca 1888	glauca 1887	52	1,285	28.0	
7586	glauca 1889	smith	28	29	48.3	1.67
7127	glauca 1889	glauca 1885	36	2,182	48.0	
7582	glauca 1887	smith	49	120	58.5	

[1/] Only the 10 hybrid combinations that yielded full seeds are included.

[2/] $\frac{\text{Germinated hybrid seed/cone}}{\text{Germinated control-cross seed/cone}} \times 100.$

[3/] "Open" indicates open pollinated seed collected in native stands.

[4/] Seeds not germinated.

The hybrid seedlings are clearly distinguishable from white spruce (table 2).

The performance of hybrid families in respect to that of both parents or to white spruce alone was highly variable (table 2, 3). Seedlings from the two hybrid families from the 1971 pollinations at the AFES were smaller than seedlings of either parent species after 5 months in the greenhouse (table 2). After 2 years in the nursery, the hybrids and Himalayan spruce seedlings were somewhat taller than white spruce. However, the Himalayan spruce seedlings had lower survival (80 percent) than the hybrid and white spruces (100 percent) and showed winter damage, i.e., shoot tips killed back and desiccated needles. After 5 growing seasons in the field, all the Himalayan spruce seedlings had died and the hybrids had poorer survival (71 percent) than white spruce (94 percent). The hybrids showed winter damage and were shorter than white spruce.

After two growth cycles in the greenhouse, 15-month-old seedlings of hybrid family 2860 (1973 pollination, AFES) were intermediate in height between Himalayan (44 cm) and white spruce (34 cm). After 2 years in the nursery, the hybrids were shorter than either parent species. Six of the ten Himalayan spruce seedlings and one of the four hybrid seedlings suffered some winter damage. White spruce seedlings were undamaged.

The hybrids produced at the FSL generally performed better in terms of height growth than those produced at the AFES. Two of the three hybrid families were as tall or taller than the best white spruce after 5, 10, and 19 months. The other hybrid family was shorter than the shortest white spruce family at 10 and 19 months. However, after one winter's exposure, all hybrids showed much winter damage.

DISCUSSION

Our estimates of crossability for white x Himalayan spruce are tentative. Although the cross has been attempted on more than 17 different white spruces, all the Himalayan pollen came from a single non-native source (Brett Arboretum) and possibly from a single tree. It is highly probable that different Himalayan spruces used as either male or female parents would have yielded somewhat different estimates of crossability.

Attempts have been made to cross Himalayan spruce with eight other spruce species (and one hybrid), but apparently the species has never been used as female parent in any attempted crosses. In table 4, we have listed all recorded attempts to cross Himalayan and other spruce species as well as unpublished information on crosses made at the FSL. More detailed information is needed on the Hoffman-Kleinschmit crosses, some of which were made using mentor pollen. It appears that Himalayan spruce is closely related to white spruce, distantly related to *P. mariana* (Mill.) Brit., and only very distantly related to *P. abies* (L.) Karst. and *P. asperata* Mast. It is also probable that Himalayan spruce can be crossed with reasonable ease with other white spruce-related species, i.e., *P. engelmannii* (Parry) Engelm., *P. sitchensis* (Bong.) Carr., *P. jezoensis* (Sieb. et Zucc.) Carr.

Table 2.--Seedling characteristics of the cross Picea glauca x P. smithiana and of the parent species to age 5 months

(In percent)[1/]

Identification Number	Parentage ♀	Parentage ♂	Cotyledon No.	Needle length mm	Needle Percent with serration	Stem[2/] form	Height 5 mon. cm	Seedlings No.
1971 CONTROLLED POLLINATIONS (NEW BRUNSWICK)								
2226	Glauca means		7.40	13.2	100	1.08	6.2	
2220	glauca #556	smith	105	131	100	185	85	3
2224	glauca #558	smith	105	120	96	168	74	24
2226	glauca AFES	open[3/]	100	100	100	100	100	24
2227	smith, India	open	131	202	79	269	90	24
2228	smith, India	open	123	180	79	267	97	24
1973 CONTROLLED POLLINATIONS (WISCONSIN)								
	Glauca means		5.81	13.1	99	1.00	5.1	
7123	glauca 1885	glauca 1887	97	97	101	100	92	40
7583	glauca 1888	smith	107	117	80	189	106	18
7585	glauca 1888	glauca 1887	103	103	99	100	108	40
7586	glauca 1889	smith	90	136	101	225	106	5
7582	glauca 1887	smith	103	111	79	175	96	40

[1/] Expressed as percent of P. glauca mean values.

[2/] Numerical rating: 1 = orthotropic; 2 = intermediate; 3 = plagiotropic.

[3/] "Open" indicates open pollinated seed collected in native stands.

Table 3.--Growth beyond 5 months, winter damage, and survival of the cross *Picea glauca* x *P. smithiana* and of the parent species

(In percent)[1/]

Identification Number	Parentage ♀	♂	Seedlings	Heights Months 10	15	19	Nursery	Plantation	Survival[2/] Nursery	Plantation	Winter damage[2/] Nursery	Plantation
			No.	cm	cm	cm	cm	cm				
1971 CONTROLLED POLLINATIONS (NEW BRUNSWICK)												
2226	Glauca means						23.9	88.7	100	93.8	0	0
2220	glauca #556	smith	3				142	98	100	67	0	0
2224	glauca #558	smith	32				105	63	100	72	0	0
2226	glauca AFES	open[3/]	32				100	100	100	94	0	0
2228	smith, India	open	16				114	--	80	0	100	(100)
1973 CONTROLLED POLLINATIONS (NEW BRUNSWICK)												
2863	Glauca means				33.8		48.4		100		0	
2860	glauca 73-6	smith	5		113		97		80		25	
2863	glauca 73-6	glauca	10		100		100		100		0	
2892	smith, India	open	10		129		113		60		67	
1973 CONTROLLED POLLINATIONS (WISCONSIN)												
	Glauca means			15.5		66.7			100		10.7	
7579[4/]	glauca 1885	smith	40			84						
7173	glauca 1885	glauca 1887	40	180		104			100		15	
7583	glauca 1888	smith	18	88		70			100		49	
7584	glauca 1888	glauca 1889	40	88		96			100		7	
7585	glauca 1888	glauca 1887	40	102		87			100		9	
7586	glauca 1889	smith	5	122		118			100		75	
7127	glauca 1889	glauca 1885	40	102		113			100		12	
7582	glauca 1887	smith	40	107		106			100		69	

[1/] Expressed as percent of *P. glauca* mean values.

[2/] Data recorded as percentages - therefore not converted.

[3/] "Open" indicates open pollinated seed collected in native stands.

[4/] This hybrid was not grown with other hybrids and white spruce. The value is computed using other *P. glauca* mean values.

At this time, the value of the hybrid, white x Himalayan, for direct use in reforestation is questionable. In eastern Canada, the hybrids have not performed as well as native white spruce. In Wisconsin, early growth of some hybrid families exceeds that of white spruce, but the hybrids are not adapted to the severe continental climate. However, they are promising enough to warrant further testing. Available hybrids should be vegetatively propagated and small tests outplanted in less extreme north temperate climates. At the same time, if possible, the cross should be repeated on a larger scale with pollen representing a wide array of Himalayan spruce provenances.

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Table 4.--Summary of interspecific hybridization attempted with *Picea smithiana* as pollen parent

Female Parent	Reference[1/]	Results	
P. abies	1	1 Attempt, 0 full seeds.	Fail
"	2	1 Attempt, 0 full seeds.	Fail
"	3	3 Attempts, No other information.	Hybrid
P. asperata	4	1 Attempt, 0 full seeds.	Fail
"	3	No information.	Hybrid?
P. glauca	4	?, full seeds.	Hybrid
"	3	3 Attempts, No other information.	Hybrid
"	This study	17 Attempts, 1.7 - 30.4% crossability.	Hybrid
P. glehnii	3	3 Attempts, 0 full seeds.	Fail
P. mariana	5	7 Attempts, 1 yielded 34 full seeds.	Probable hybrid.
"	1	14 Attempts, 1 yielded 3 full seeds, 0.1% crossability.	Hybrid
"	3	3 Attempts, No other information.	Hybrid
P. omorika	3	3 Attempts, 0 full seeds.	Fail
(*P. mariana* x *P. omorika*)	2	4 Attempts, 20 full seeds, no germination.	Fail
P. orientalis	3	3 Attempts, No other information.	Hybrid
P. sitchensis	3	3 Attempts, No other information.	Hybrid

[1/] 1. Fowler, *et al.*, 1975.
2. Nienstaedt, unpublished data on file, FSL, Rhinelander, WI.
3. Hoffman and Kleinschmit, 1979.
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