INTRASPECIFIC VARIATION IN HIMALAYAN WHITE PINE, PINUS GRIFFITHII [1]

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ABSTRACT.--Twenty-one seed sources of Himalayan white pine (Pinus griffithii McClel.) (11 from native stands and 10 from planted trees) were studied in Maryland's State Forest Tree Nursery and in 11 plantations in Maine, Maryland, Michigan, Illinois and North Carolina. In the nursery, intraspecific variations were observed in leaf lengths, time of bud-set, tendency for secondary growth, and 2-year heights and diameters. Survival rates in Maryland's Piedmont Plateau and coastal plain, and in North Carolina were satisfactory. In Maine, New York, Michigan, Illinois and Maryland's Allegheny Mountains, P. griffithii either completely failed or showed very poor survival. Some strains from Pakistan were more winter-hardy than those from India or Bhutan. In two Maryland plantations best growth rates were attained by populations from Uttar Pradish in India, Shorgan in Pakistan, and from three locations of planted trees. In New York and North Carolina plantations, Himalayan white pine was attacked by white pine weevil (Pissodes strobi Peck).

Himalayan white pine (Pinus griffithii McClelland) was named and described in 1854. Some synonyms are P. excelsa Wallich ex. D. Don, P. wallichiana A. B. Jackson, and P. nepalensis De Chambey. In India, common names are blue pine, kail or biar. Some writers have called it Bhutan pine, Bohtan pine, Nepal pine, or because of white granules on its leaves -- "pine of tears" (Tränenkiefer).

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Morphologically, Himalayan white pine is a close relative to other white pines of subsection Strobi (Konar 1960). In comparison to eastern white pine (P. strobus L.), this species has longer, drooping, more bluish green leaves, larger cones (15 to 30 cm long), and larger seeds. In its native range, it reaches heights of 100 to over 160 feet. P. griffithii includes several known horticultural forms: P.g. form monophylla Carr. (needles in a single bundle), P.g. form zebrina Croux (needles golden-yellowish with white cross-stripes), and P. g. form nana R. Smith (dwarf-like). However, there are no described botanical varieties.

The natural range of Himalayan white pine extends along the southern slopes of the western and central Himalayan Mountains from eastern Afghanistan, through northern West Pakistan, southern Kashmir, Jammu and Punjab provinces of India, Nepal, Sikkim and Bhutan, to isolated populations in Assam, eastern Tibet and northern Burma. It is most common at elevations from 6,000 to 10,000 feet, but occurs as low as 4,000 feet and as high as 12,500 feet. Within this range, P. griffithii is the only pine of subsection Strobi; therefore, it does not cross naturally with other pines in its native habitats. It has been crossed artifically with other white pines, and the hybrid of P. griffithii x P. strobus grows rapidly (Meyer 1954).

Himalayan white pine has been planted in all continents outside its range. In the United States, individual specimens are found in all northeastern states, but they are most common in the area near Philadelphia, Pennsylvania (Wright 1958). In comparison to P. strobus, the growth of Himalayan white pine is faster at Rochester, N.Y., but slower at the Pack Forest in New York.

A report by Lemmien and Wright (1963) indicates that Himalayan white pine can grow as far north as southern Michigan. A few 32-year-old trees were 52 feet tall and had 12-inch diameters breast high. In comparison to P. strobus, they had smaller heights, but slightly larger diameters.

In Maryland, the author has registered small plantings of P. griffithii at about 20 locations. The three largest Himalayan white pines in the U.S.A. grow near Catonsville, Maryland. At age 38 they were about 75 feet tall, had straight stems, and were healthy in all respects. Natural reproduction at this location indicate that Himalayan white pine is able to reproduce when planted outside its natural range.

Wright and Gabriel (1959) reported that some trees were injured and killed in Philadelphia during a severe winter of 1933-34; at the George Landis Arboretum in New York, it is classified as "not successful" because young seedlings are killed by early frost (personal communication with Fred Lape, Director); while in Highland Park of

Rochester, New York, two specimens of Himalayan white pine grew very well. Himalayan pine suffers from attacks by the white pine weevil (Pissodes strobi Peck) in southern Connecticut (Bailey 1955), and Genys (1977) reported from Maryland that P. griffithii can be attacked by Nantucket pine tip moth (Rhyacionia frustrana Comstock). One of the best traits of this species is its high degree of resistance to white pine blister rust (Cronartium ribicola Fischer) (Heimburger 1956, Wright and Gabriel 1959).

In the present study, Himalayan white pine was represented by 11 seed sources from native stands and 10 from trees planted in the United States and Italy. The major objectives were:

(1) To determine the nature and extend of genetic variation in Himalayan white pine, and

(2) to determine the potential for selection of frost-hardy Himalayan white pine for planting in northern regions of the eastern United States.

MATERIALS AND METHODS OF STUDY

Twenty-one seedlots for this experiment were acquired in 1961 and 1962 from 11 native stands in Pakistan, India and Bhutan, and 10 trees planted in the United States and Italy. A random sample of 50 filled seeds from each lot was used for determination of 1000-seed weights (data code No. 6 in table 1).

Two experiments were conducted at the State Forest Tree Nursery in Harmans, Maryland (latitude 39°07'N, longitude 76°45'W). This site is in plant hardiness zone 7 with average annual minimum temperatures ranging from 0° to 10°F, a frost-free period lasting from 180 to 210 days, and the first fall frost occurring between October 30th and November 10th.

The first experiment in the nursery was started on November 19, 1962. Twenty seed lots were used to establish a 4-times replicated, randomized block experiment using 2-foot rows as plots. Seedlings were spaced 2 inches apart within rows and 6 inches between rows. Bulk plots of seedlings were also grown for field plantings. The replicated plots were used for studies of coded characteristics as follows:

(8) Needle length

(9) The day of the year when 50 percent of 1-year-old seedlings set terminal buds,

(11) The percent of 1-year-old trees exhibiting secondary growth (resuming growth after terminal buds were once formed),

(12) The 2-year height based on the plot averages of the four largest seedlings representing four quarters of row-plots, and,

(13) The 2-year diameter above groundline on the three largest sample trees, dug from each plot before planting.

A second similar experiment in the nursery was established in spring 1967, using seed-lots of 15 sources. This time, two characteristics were studied:

(10) The percent of 2-year-old trees with terminal buds on October 24, 1968, and,

(14) The 2-year heights.

During the springs 1965, 1966 and 1967, the trees seeded in November 1962 were planted in Maryland (on 3 sites), Michigan (on 3 sites), Illinois (on 2 sites), Maine (1), New York (1), and North Carolina (1). Site descriptions, the age of stock and experimental designs of these plantations are given in the accompanying list.

Survival and heights were studied at various ages. Data in this report were based on 10- and 12-year-old trees. Heights are included for the two plantations in Maryland which had sufficient numbers of trees. White pine weevil (Pissodes strobi) was studied in the New York and North Carolina plantations.

Analysis of variance was based on the randomized block design. The least significant differences (L.S.D.) were determined by the Duncan's multiple range test. Character correlation and the correlations between measured characteristics and geographic data were also determined; only significant correlations will be discussed in the text.

RESULTS

Characteristics of Seedlings in the Nursery

Seed weights

Weights of 1000 filled seeds of P. griffithii from 9 stands and 10 individual tree collections varied from 36 grams (collected from a planted tree in Catonsville, Md.) to 77 grams (collected in Oxford, Md.). There was less variation among the seed lots from the native stands (table 1). For the stand collections, the correlation between the seed weights and eastern longitude was r = .-73* (d.f. = 6). Seeds from West Pakistan tended to be heavier than those from India and Bhutan.

List of research sites, experimental design, dates of planting, and age of stock

Maryland, Carroll Co., Piedmont Plateau, near Liberty Lake; 39°23'n; 76°54'W; elev. 490 ft; property of City of Baltimore; a former farm field; fertile, good drainage.	March, 1965; 2-0 stock; 4-tree square plots; spacing 7 ft x 7 ft; 21 populations; replicated in 4 blocks; measured at age 10.
Maryland, Anne Arundel Co., coastal plain, near Annapolis; 39°02'N; 76°24'W; elev. 15 ft; property of State of Md.; poor drainage; fertile soil.	April, 1965; 2-0 stock; 4-tree square plots; spacing 7 ft x 7 ft; 21 populations, replicated in 4 blocks; measured at age 10.
Maryland, Garrett Co., mid-Appalachian Mtns., Pleasant Valley Research Center; 39°3'N, 79°14'W; elev. 2600 ft; rocky and shallow soil; growing season about 130 days, cold winters.	April, 1965; 2-0 stock, spaced at 7 ft x 7 ft; 4-tree plots; 21 populations; replicated in 4 blocks. Last measurements made in Fall 1974.
Michigan, Kalamazoo Co., Kellogg Farm, near Hickory Corners; elev. 700 ft, slopes 3 to 30%; brush killed by 2,4,5-T; soil sandy loam to loamy sand.	April 9, 1966; 2-1 stock; spaced 8 ft x 6 ft; 4-tree row plot, 11 strains, replicated in 4 blocks. Last measurements made on July 17, 1974.
Michigan, Cass Co., Fred Russ Forest; elev. 700 ft; previous corn field, moved, and 3-foot strips sprayed with aminotriazole.	March 3, 1966; 2-1 stock; 4-tree plots; 10 strains replicated in 4 blocks. Last measurements on July 17, 1974.
Michigan, Ingham Co., Tree Research Center; elev. 700 ft; moist site, moderately well drained silt soil.	April 9, 1966; 2-1 stock; spaced 8 ft x 6 ft; 4-tree row plots; 12 populations; 2 blocks. Last measurements: early summer 1974.
Maine, Penobscot Co., near Olamon; state-owned land; 45°8'N, 68°35'W; elev. 200 ft; moderately well drained, 2 ft deep, sandy loam soil.	May 1967; 2-2 stock; originally 16 populations; 8 blocks; only 4 blocks were complete.

List of research sites, experimental design, dates of planting, and age of stock. cont.

New York, Warren Co., Heiberg Memorial Forest, north of Warrensburg.	April 1965; 2-0 stock; 15 populations; 4-tree square plots in 4 blocks.
Illinois, Henderson Co., Oquawka; level, loamy sand soil, dry in summe·.	April 16, 1965; 2-0 stock; 6 populations in 4 blocks, represented by 4-tree plots; trees spaced at 7 ft x 7 ft. in 1974 only 3 blocks available for analysis.
Illinois, Edwards Co., West Salem; level, silty loam site. Simazine was applied after planting.	April 16, 1965; 2-0 stock; 6 populations in 5 blocks represented by 4-tree plots; trees spaced at 7 ft x 7 ft.
North Carolina, Madison Co., near Mars Hill, north of Asheville, southern slopes of south Appalachian Mtns.; shallow, rocky soil.	April, 1965; 2-0 stock; 15 populations, replicated in 4 blocks; 4-tree square plots; spacing 6 ft x 8 ft; some trees were currently injured by fire when measured in Spring 1975.

Leaf lengths

Leaf lengths in 6 of the provenance collections and 6 families ranged from 8.9 cm (No. 589 from a tree planted in Oxford, Md.) to 12.3 cm (No. 282 from Pakistan). Five out of six populations from the native range had longer needles than those from the planted trees.

Setting of terminal buds

Setting of terminal buds in the fall was studied twice in the nursery. Twelve populations (6 representing provenances and 6 single tree families) studied in fall 1964 set their terminal buds during the period from October 23 to November 7. Populations with the latest budset originated from planted trees (Nos. 589, 588, and 596). Populations from native stands showed only a 5-day variation in bud set date. Date of bud set was negatively correlated with the leaf length ($r = -.72^{**}$ d.f. = 10) suggesting that populations with short leaves set their buds earlier.

On October 24, 1968, twelve populations (10 representing provenances and 2 single tree families) of 2-year-old trees had different numbers of trees with terminal buds, ranging from only 2 percent (No. 721 from Bhutan) to 32 percent (No. 762 from Rochester, N. Y.). These two populations, showing extreme values in bud set, also showed extreme values in their survival rates in cold regions. All trees of population No. 721 set buds late and all died; trees from Rochester set their buds early and showed the best survival. The percent of trees with buds was negatively correlated with eastern longitude ($r = -.85^{**}$ d.f. = 7).

Secondary growth

In the six provenances and 6 families studied, the tendency for secondary growth (starting growth after primary terminal bud was formed) varied significantly (table 1). Some populations had as few as 23 percent of trees with secondary growth (No. 282 from Pakistan), while others had 74 percent (No. 592 from Annapolis, Md.). This characteristic showed no significant correlation to geographic data, and, contrary to expectation, it was not related to the survival rates in the northern regions.

Two-year height growth

In 1964 the 2-year-old Himalayan white pines (9 provenances, 6 families) averaged 12.2 cm in height. Variation among populations ranged from 84 percent (Nos. 588 and 596 from planted trees in Maryland) to 119 percent (No. 589 from trees planted in Maryland) of the mean for all populations. In 1968 (10 provenances, 2 families), 2-year heights averaged 8.5 cm, and differences among populations

Table 1.--Origin and growth data of different populations of Himalayan white pine (*Pinus griffithii*) studied in Maryland (at the State Forest Tree Nursery) in 1963-64, and 1967-68 (2-year heights)

Code:	(2)	(3)	(4)	(6)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Seed lot no.	Seed origin-country: Longitude	Latitude	Altitude	1000 seed weight	Needle length	Bud set: Day of year	10/24 trees	Trees w/2nd growth	Two-year data: 1964 Height	1964 Diam.	1968 Height
Mean height or diameter in cm:									12.2	.42	8.5
			Feet	Grams	Cm		Percent	Percent	---- Percent of mean ----		
Pakistan											
719	67°30'	29°00'	7500	65	--	--	26	--	107	--	107
756	72°22'	34°04'	7500	--	--	--	--	--	--	--	--
720	73°12'	33°30'	7000	51	--	--	13	--	92	--	100
103	73°15'	35°38'	6500	53	11.6	302	17	37	99	98	104
282	73°20'	34°10'	7900	56	12.3	304	9	23	111	95	102
280	73°20'	34°10'	7600	59	11.2	302	14	51	117	117	107
281	73°30'	34°	7500	66	11.6	303	12	54	110	110	119
India											
296	77°14'	32°15'	6200	51	10.5	304	10	35	102	100	95
771	78°	31°	7200	--	--	--	5	--	102	--	123
297	--	--	7000	46	11.7	307	17	65	111	107	110
Bhutan											
721	86°06'	27°42'	7500	46	--	--	2	--	--	--	94
Planted trees											
106	Italy			55	10.2	307	--	37	102	100	--
586	Catonsville,Md.(No.1)			62	--	--	--	--	--	--	--
587	Catonsville,Md.(No.2)			63	10.8	305	--	36	88	--	--
588	Catonsville,Md.(No.3)			36	10.8	308	--	39	84	86	--
589	Oxford,Md.(No.1)			77	8.9	311	--	45	119	102	--
592	Annapolis,Md.(No.2)			71	10.0	306	--	74	101	95	--
596	Solomons,Md.			58	9.6	308	6	38	84	88	80
598	Washington,D.C.(No.1)			74	--	--	--	--	--	--	--
641	Easton,Md.			72	--	--	--	--	--	--	--
762	Rochester, NY			49	--	--	32	--	--	--	83
The least significant difference at 0.05 level				--	2.7	ns	16	38	30	27	19

varied from 80 percent (No. 596 from Solomons, Md.) to 123 percent (No. 771 from India) of the mean. Two-year heights of the same populations, studied in 1964 and 1968, showed a significant positive correlation ($r = .63^{*}$ d.f. = 8).

In 1964 (6 provenances, 5 families), basal diameters averaged 0.42 cm and differences among populations ranged from 86 percent (No. 588 from Catonsville, Md.) to 117 percent (No. 280 from Pakistan). Diameters were significantly correlated with the 2-year heights measured in 1964 and 1968 ($r = .81^{**}$ d.f. = 9 and $.78^{*}$ d.f. = 5, respectively).

Characteristics after Planting

Data on survival in three plantations, heights in two plantations, and white pine weevil attack in two plantations are summarized in table 2.

Survival

Survival rates of Himalayan white pine varied in different climatic regions, and were related to the origin of seed source.

Survival in Maine, New York, Michigan, Illinois and Garrett County, Maryland, of Himalayan white pine was very poor at all sites located in plant-hardiness zones 3, 4 and 5, where the average annual minimum temperatures are -5°F or lower. In all this region, more than half of the populations had 0 percent survival, and none of the populations had more than 31 percent of trees living. Among the provenances showing best survival (13 percent) were Nos. 280, 282 and 719 from West Pakistan. Of the single tree families, Nos. 106, 586 and 762 were among the best. Trees from higher elevations showed somewhat better survival than those from lower elevations. In the Garrett County, Md. plantation, trees with early budset tended to have higher survival rates.

In Maryland plantations located in the Piedmont Plateau (Carroll County) and Atlantic Coastal Plain (Anne Arundel County) within plant hardiness zone 6, Himalayan white pine survived as well as eastern white pine. In Carroll County, survival rates among the 11 provenance collections and 10 families ranged from 0 percent (No. 721 from Bhutan) to 100 percent (No. 592 from Annapolis, Md.) and about two-thirds of the populations had survival rates exceeding 50 percent). Survival rates in this plantation were positively correlated with survival rates in the Anne Arundel County, Md. ($r = .72^{**}$ d.f. = 19) plantation, and negatively correlated with longitude ($r = -.69^{*}$ d.f. = 9). In Anne Arundel County, survival rates among populations ranged from 13 percent (No. 721 from Bhutan) to 100 percent (No. 587 from Catonsville, Md.), and 19 of 21 populations had survival rates greater than 50 percent. In this plantation, survival rates were also negatively correlated with longitude of seed source ($r = -.85^{**}$ d.f.-9) (table 2).

Table 2.--Survival and growth rates of different populations of Himalayan white pine, *Pinus griffithii*, in eastern United States (some data on attack by white pine weevil, *Pissodes strobi*, are also included)

Code	(2)	(3)	(4)	(20)	(21)	(22)	(23)	(24)	(26)	(27)
				Survival			Height		Weevil attack*	
Seed lot no.	Seed origin-country: Longitude	Latitude	Altitude	Carroll County Md.	Anne Arun. County Md.	North Carolina	Carroll County Md.	Anne Arun. County Md.	New York	North Carolina
Age of studied trees (yrs)				10	10	12	10	10	-	-
Mean height $\bar{x}$ (feet):				-	-	-	5.8	5.1	-	-
			Feet	Percent			Percent of mean		Number	
Pakistan										
719	67°30'	29°00'	7500	50	81	25	115	114	0/1	1/4
756	72°22'	34°04'	7500	94	88	--	89	103	--	--
720	73°12'	33°12'	7000	44	81	--	--	77	--	--
103	73°15'	35°38'	6500	63	63	19	89	91	--	3/3
282	73°20'	34°10'	7900	38	67	6	--	112	0/2	0/1
280	73°20'	34°10'	7600	75	75	31	124	97	0/2	2/5
281	73°30'	34°	7500	63	88	31	104	105	0/1	3/3
India										
296	77°14'	32°15'	6200	44	44	6	--	--	--	1/1
771	78°	31°	7200	56	75	6	123	138	--	1/1
297	--	--	7000	44	56	19	82	105	0/1	3/3
Bhutan										
721	89°06'	27°42'	7500	0	13	0	--	--	--	--
Planted trees										
106	Italy			56	67	25	91	125	1/3	3/4
586	Catonsville, Md. (No. 1)			67	94	--	70	97	1/3	--
587	Catonsville, Md. (No. 2)			88	100	13	107	108	--	1/3
588	Catonsville, Md. (No. 3)			67	75	13	--	84	--	0/2
589	Oxford, Md. (No. 1)			50	81	25	--	77	--	2/4
592	Annapolis, Md. (No. 2)			100	75	31	84	76	--	2/5
596	Solomons, Md.			63	88	0	--	94	0/1	--
598	Washington, D.C. (No. 1)			56	81	--	130	119	--	--
641	Easton, Md.			44	75	--	130	138	--	--
762	Rochester, N.Y.			75	88	--	91	68	0/3	--
The least significant difference at 0.05 level				68	56	ns	70	61	--	--

* trees attacked by *Pissodes strobi* (left): trees studied (right).

The North Carolina plantation is located in the transition region of plant hardiness zones 6 and 7. On this site, Himalayan white pine (9 provenances, 6 families) showed a better survival than in the northern regions, but worse than in Maryland's hardiness zone 6. Survival rates ranged from 0 percent (Nos. 721 from Bhutan, and 596 from Solomons, Md.) to 31 percent (Nos. 280 and 281 from Pakistan and No. 592 from Annapolis, Md.). Survival in North Carolina was correlated with survival in Carroll County, Md. ($r = 0.52^*$ d.f. = 13) and was correlated with diameters of 2-year-old trees ($r = .64^*$ d.f. = 9).

Height growth in plantations

Heights are only reported for the two plantations in Maryland (Carroll and Anne Arundel Counties) with good survival.

In Carroll County, heights of 10-year-old trees averaged 5.8 feet. Heights of different populations and families ranged from 70 percent to 130 percent of the plantation mean. The slowest growing family was from planted tree No. 1 in Catonsville, Maryland (No. 586). The fastest growing families originated from planted trees in Washington, D.C. (No. 598) and Easton, Md. (No. 641), followed by populations from Pakistan (No. 280) and India (No. 771). Heights in this plantation were significantly correlated with diameters of 2-year-old trees ($r = .82^*$ d.f. = 4) and with heights of 10-year-old trees in Anne Arundel County, Md. ($r = .60^*$ d.f. = 12).

In Anne Arundel County, 10-year-old trees had an average height of 5.1 feet. Heights of different populations and families ranged from 68 percent to 138 percent of the plantation mean. Slowest growing were the families from Rochester, N.Y. (No. 762), Annapolis, Md. (No. 592), Oxford, Md. (No. 589), and the population from Pakistan (No.720). The fastest growing were again the family from Easton, Md. (No. 641), and the populations from India (No. 771), and Italy (No. 106). Heights in this plantation were significantly correlated with latitude ($r = .75^*$ d.f. = 6).

In summary, the best families were from planted trees No. 641 in Easton, Maryland, and No. 598 in Washington, D.C., and from native stands No. 771 in Pradish, India, and No. 719 in Shogran, West Pakistan. With the exception of the populations No. 280 from West Pakistan and family No. 106 from Italy, rankings were rather similar at the two sites.

Reliability of early growth data

If trees were selected for rapid growth on the basis of 2-year heights in 1964, populations No. 589, 280, 282 and 297 would be included. However, none of these populations were among the four best at age 10. In fact, 2-year heights of the first experiment

(1963-1964) showed no relationship to 10-year heights in the Maryland plantations (r = .20 and .14). Much more reliable for prediction of 10-year heights were the 2-year diameters (r = .82* d.f. = 4 and r = .26 d.f. = 8) and 2-year heights of seedlings studied in 1967-1968 (r = .57 d.f. = 5, and r = .45 d.f. = 8).

Attack by white pine weevil

White pine weevil (Pissodes strobi) was studied in New York and North Carolina (table 2). In New York, out of 17 surviving trees, two (12 percent) were attacked by white pine weevil. In North Carolina, weevil attack was more extensive, and out of 39 trees, 22 (56 percent) were injured. In this plantation, populations from low elevations (like No. 103) included more trees attacked by white pine weevil than those from higher elevations (like No. 282), and the correlation of the numbers of attacked trees with the elevation of the seed-source was r = -.84** d.f. = 6

Cone production

In North Carolina, at age 12, about 10 percent of Himalayan white pine had cones. The most pronounced cone producer was population No. 280 from Pakistan. Out of 4 trees studied, 3 had cones. In general, at this early age, P. griffithii had fewer cones than P. strobus (20 percent of trees with cones).

Comparison of Himalayan White Pine with Eastern White Pine

In comparison to P. strobus, Himalayan white pine had heavier seeds, and when growing on the same sites longer leaves, smaller 2-year heights, larger 2-year diameters, more trees with secondary growth, and set terminal buds later in the fall. When planted in the field and studied for 8 or 10 years, Himalayan white pine had significantly greater mortality than P. strobus in Maine, New York, Michigan, Illinois, Garrett County, Md., and North Carolina. It survived nearly as well as P. strobus in Carroll County, Md., and showed a similar survival rate in Anne Arundel County. In Maryland's Piedmont Plateau and Coastal Plain, Himalayan white pine had smaller 10-year heights than eastern white pine. In North Carolina, both species had similar percentages of trees attacked by Pissodes strobi, Himalayan white pine had fewer trees with cones. While the characteristics listed above were distinctly different, in other measurements one species were within the range of the other species. Such overlapping ranges at variation were in numbers of cotyledons, time of bud-set, and growth rates of different populations.

DISCUSSION

Results on seed weight, date of bud-set, percent of trees with secondary growth, and growth rate of 2-year-old trees are mainly of basic interest, while the survival rates of different populations planted in the northern regions of eastern United States are of more practical importance. Also important are the data on variation in growth rates of 10-year-old trees.

Studies on survival rates in various hardiness zones lead to identification of several general trends. In the northern plantations, except in Illinois, populations Nos. 280, 281 and 719 from Pakistan were most promising. In all plantations, population No. 721 from Bhutan failed completely, and population No. 762 from a planted tree in Rochester, N.Y. showed the best or the second best survival. Correlation analysis suggests that survival rates were negatively correlated with the eastern longitude and the date of bud-set, and positively correlated with the elevation of seed source. Apparently, best survival rates can be expected from the seed sources from western longitudes, higher altitudes, and populations setting terminal buds early in the fall. Also, good survival can be expected from some progenies originating from planted trees in northern regions (like Rochester, New York).

Contrary to many instances in other pines, the growth rates of *P. griffithii* showed a positive relationship with northern latitude and elevation of the seed source. Also, heights showed positive relationships with needle lengths and diameters of 2-year-old seedlings, and a negative correlation with day of budset and the percent of trees with secondary growth.

If selection of seed sources for rapid growth are based on these current results, most likely trees planted in Easton, Maryland (No. 641) and Washington, D.C. (No. 598), would be recommended for use as seed sources. Among the populations from the native region, most promising were No. 771 from India for warmer regions and Nos. 719, 282 and 280 from Pakistan for colder regions.

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