Root growth potential of scotch pine seed sources and its relationship to field performance

James E. JOHNSON, Richard E. KREH, John L. TORBERT, and Peter P. FERET
School of Forestry Wildlife Resources
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061, USA

Paper read at the Northeastern State, Federal and Provincial Nurserymen's Conference, Montreal, Quebec, July 24 to July 27, 1990.

Abstract

Commercially available Scotch pine seed sources were studied to determine root growth potential (RGP), field performance, and the relationship between RGP and field performance in the Mountain, Piedmont, and Coastal Plain physiographic regions of Virginia. RGP's ranged from 41 new roots for the Lower Austria seed source to 7 new roots for the Burgos seed source. Seed sources varied in field performance across the state. Overall, second year survival was greatest in the Mountains (79%), and significantly lower in the Piedmont and Coastal Plain (64% each). The seed sources with the highest and lowest RGP's also exhibited the highest and lowest field survivals and field performance as measured by volume increase.

Key words: root growth, containerized seedlings, tree planting, Christmas trees.

Résumé

Le *potentiel de croissance racinaire des provenances de graines de pin sylvestre et ses rapports avec leur rendement sur le terrain.*

On a etudie les diverses provenances de graines de pin sylvestre disponibles dans le commerce afin d'evaluer leur rythme de croissance racinaire (RCR), leur rendement sur le terrain ainsi quo la relation entre celui-ci et le RCR, dans les trois regions physiographiques de la Virginie : montagneuse, de piedmont et de la plaine cOtiere. Le RCR a varie de 41 racines nouvelles pour la provenance de Basso Autriche a 7 racines nouvelles pour la provenance n Burgos A travers tout l'Etat, les rendements sur le terrain ont varie selon les provenances. Dans /'ensemble, le faux de survie pour la deuxieme annee a ete superieur dans la region montagneuse (79 %) mais significativement plus faible dans le piedmont et la plaine c6tiere (64 % chacune). Les provenances montrant les RCR les plus hauts et les plus bas presentaient aussi les faux de survie les plus forts et les plus faibles.

Mots-cles : croissance racinaire, recipients, plantation, arbres de Noel

Introduction

Production of seedlings for Christmas trees in the U.S. is increasing each year. The National Christmas Tree Association estimated the 1988 planting at over 73.5 million seedlings, an increase of nearly 12% since 1984. With Scotch pine (Pinus sylvestris L.) as the major Christmas tree species, nursery producers are interested in seedling characteristics and quality differences among the major seed sources and varieties. Variability in growth, morphological features, and pest resistance of numerous Scotch pine varieties have been studied in the north central U.S. (WRIGHT *et al.* 1966); and currently many varieties are available from commercial seed dealers and nurseries throughout the country (Noecker 1988).

The concept of root growth potential (RGP), introduced by Stone (1955), has emerged as a useful method of estimating the physiological status of seedlings. Root growth potential is defined as the ability of a tree seedling to initiate and elongate roots when placed into an environment favorable for root growth (Ritchie 1985).

This study was established to compare the growth and phenotypic characteristics of 15 commercially available seed sources of Scotch pine, with particular reference to suitability for Christmas tree production in Virginia. This paper deals with the establishment phase of the Scotch pine plantations, and reports potential (RGP), field performance and discusses the overall relationship between RGP and field performance.

Methods

Stock Production

Seed was obtained from commercial sources for 15 Scotch pine seed sources, stratified at 4°C for 45 days, then sown, three seeds per container, in April, 1986. Following germination seedlings were thinned to one per container. Seedlings were grown in 65 cm^3 container cells in a 50:50 *Promix* BX/sand mix in the greenhouse under natural light supplemented with artificial lighting to 11:00 p.m. Seedlings were periodically irrigated, fertilized with a complete liquid fertilizer, and treated with a commercial fungicide. During November, 1986, the seedlings were placed under natural light to induce dormancy and then placed in an outdoor slat house in January, 1987.

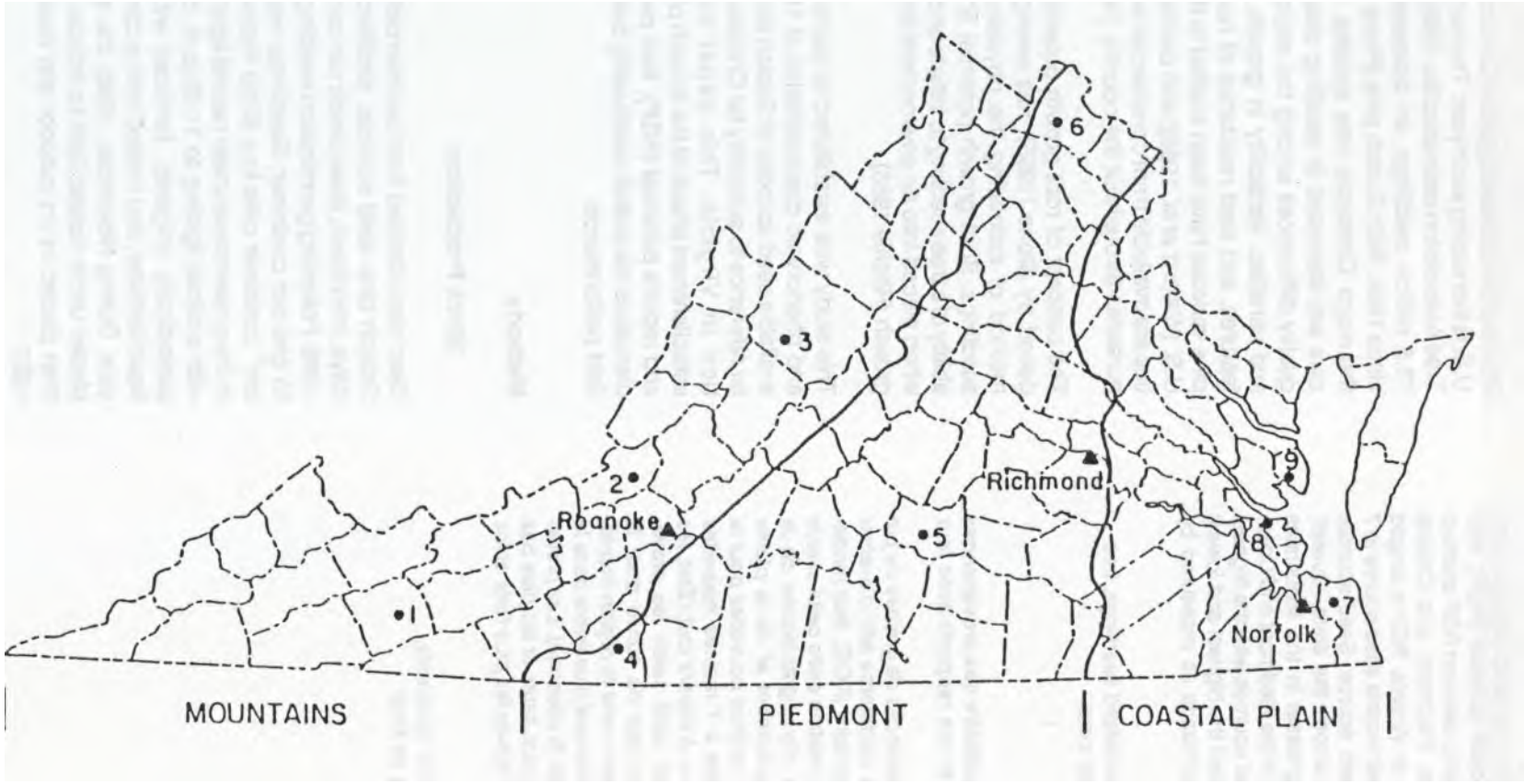

Figure 1. Locations of nine Scotch pine plantations in the Mountains, Piedmont, and Coastal Plain of Virginia

RGP Test

During March of 1987, 30 seedlings of each seed source were removed from the containers and all potting medium was washed from the root systems. The seedlings were placed in a well-aerated water bath held at a constant 18°C temperature for 21 days. Day length was supplemented by artificial light to 16 hours per day. Following the test period the seedlings were removed from the water bath, and all new roots were counted. RGP was expressed as the total number of new roots which grew during the test period. The RGP test was not conducted on the Musser Forest's seed source due to inadequate germination of this seed source leading to an insufficient number of seedlings. The entire RGP test was repeated three times to coincide with the beginning, middle, and end of the planting season.

Field Planting

Sites for field planting were selected within each of the three physiographic regions of Virginia. Accordingly, three sites were located in the Coastal Plain, Piedmont, and Appalachian Mountains (Figure 1). All of the planting sites were previously abandoned fields, with a mixture of annual grasses and broadleaved weeks.

Planting sites included a wide variety of soil and climatic conditions. Soil testing data for the surface 15 cm of each of the planting sites is provided in Table 1. The soils varied in texture from sandy loams to loams, and included a range of soil fertility levels. Climatic characteristics vary greatly throughout the study area. In the Mountains the average temperatures range from –7°C in winter to 28°C in summer, with an average annual precipitation of 102 cm. The normal growing season is about 129 days long. Climatic conditions in the Piedmont vary considerably, but on the average the temperatures range between –3°C in winter and 31°C in summer. Total annual precipitation averages 110 cm, and the growing season is about 190 days long. In the Coastal Plain average temperatures range from 0°C in winter to 30°C in summer, with the average precipitation totaling 113 cm. The growing season in the Coastal Plain is the longest in the state, averaging 214 days.

The plantations were established during March and April, 1987, by hand-planting the containerized seedlings in hand-scalped planting spots. In each plantation, each seed source was represented by 15 seedlings planted at random locations on a 2 m by 2 m grid (i.e. single-tree plots).

Plantation Maintenance and Seedling Measurements

In all plantations weed control was accomplished using a combination of fall glyphosate applications and spring simizine applications, both applied as directed sprays. In some plantations additional weed control was accomplished by mowing. In all plantations the seedlings were kept in a free-to-grow condition, above the grass and herbaceous competition. Woody brush competition was not a factor in any plantation.

After the 1987 and 1988 growing seasons, all plantations were checked for survival, and seedling heights and ground-line diameters were measured.

Results **and discussion**

RGP Difference Between Varieties

RGP varied considerably between the 14 Scotch pine seed sources tested (Table 2). The Lower Austria and Belgium sources had an RGP of 41 and 35 new roots, respectively. The seed sources with the lowest RGP included Eastern U.S., Turkey, Guadarrama, Guadalaraja, and Burgos, ranging from 16 to 7 new roots (Table 2). All other varieties had an RGP of between 17 and 29 new roots.

Differences in RGP between species, grown under identical test conditions, can be dramatic (RITCHIE and DUNLAP 1980). Likewise, differences among seed sources and among families within a species have also been reported (RITCHIE 1985, SUTTON 1983, DEWALD *et al.* 1985). Generally, RGP is thought to be under strong genetic influence. Even when differences in RGP between provenances of eastern white pine *(Pinus strobus* L.) were not significant, differences in RGP between individual families were apparent (JOHNSEN *et al.* 1988).

Due to the great geographic variation of the natural range of Scotch pine, it is highly likely that different seed sources have different chilling requirements necessary to break bud dormancy. There is evidence that the peak of RGP is related to the dormancy cycle, with the peak occurring in midwinter, followed by the main root growth activity in early spring, which then declines with the advent of shoot growth (RITCHIE and DUNLAP 1980). The chilling conditions provided in this experiment may have been optimum for some of the seed sources,

Table 1. Means of soil characterization data for study sites in the Coastal Plain, Mountains, and Piedmont of Virginia

Region	Anaeronic Mineralized N	Extractable P	K	Ca	Mg	pH	Organic Carbon	Sand	Silt	Clay	Textural Class
	mg/kg						%				
Coastal Plain	75	47	80	369	59	6.4	0.86	65.6	20.9	13.5	Sandy loam
Mountains	127	10	91	876	90	5.9	1.79	35.2	40.1	24.7	Loam
Piedmont	112	15	92	843	127	6.5	1.40	42.0	35.8	21.1	Loam

Table 2. Seedling root growth potential for 14 seed sources of Scotch Pine

Variety	Root Growth Potential		
	Mean number of new roots	% of survival[2]	Volume[2] (cm^3)
Lower Austria	41 a[1]	74	75
Belgium	35 ab	69	66
Burgenland	29 abc	74	62
Alpine	27 abc	77	32
French Auvergne	25 bcd	78	33
Central Massif	20 bcde	77	26
Better Forest	23 bcd	71	34
Riga	20 bcde	75	36
Casadeen Massif	17 cde	72	26
Eastern U.S.	16 cde	61	46
Turkey	16 cde	73	27
Guadarrama	14 cde	73	25
Guadalaraja	12 de	49	23
Burgos	7 e	42	26

[1] Means followed by the same letter are not significantly different at the 0.05 level.
[2] Means of all planting sites, second year measurements.

Table 3. Second-year survival for each Scotch pine variety by physiographic region.

Scotch Pine Seed Source	Physiographic Region		
	Coastal Plain	Mountains	Piedmont
	% survival		
Burgos	38 d[1]	53 d[1]	36 a[1]
Guadalarja	49 cd	62 bcd	36 a
Eastern U.S.	56 bcd	71 abcd	56 a
Musser Forest	56 bcd	58 cd	69 a
Belgium	67 abc	78 abcd	62 a
Better Forest	64 abc	87 ab	62 a
Casadeen Massif	64 abc	80 abc	73 a
Turkey	58 abcd	89 a	73 a
Guadarrama	67 abc	87 ab	64 a
Burgenland	67 abc	84 ab	71 a
Riga	64 abc	89 a	73 a
Central Massif	71 abc	91 a	69 a
Alpine	71 abc	89 a	71 a
French Auvergne	84 a	76 abcd	73 a
Lower Austria	78 ab	91 a	69 a
Overall	64 b[2]	79 a	64 b

[1]Means within a column followed by the same letter are statistically similar ($p < 0.05$).
[2]Means within a row followed by the same letter are statistically similar ($p < 0.05$).

Table 4. Second-year height; diameter and volume for each Scotch pine seed source by physiographic region

Scotch Pine Variety	Physiographic Region: Coastal Plain Hgt (cm)	Coastal Plain Diam (mm)	Coastal Plain Vol (cm^3)	Mountains Hgt (cm)	Mountains Diam (mm)	Mountains Vol (cm^3)	Piedmont Hgt (cm)	Piedmont Diam (mm)	Piedmont Vol (cm^3)
Burgos	32a[1]	8a[1]	22c[1]	33cde[1]	9a[1]	34d[1]	30cde[1]	7d[1]	21c[1]
Guadalarja	30a	8a	30bc	31de	9a	26d	28de	7d	14c
Eastern U.S.	42a	10a	58abc	41b	10a	55bcd	34bcde	7cd	26c
Musser Forest	34a	9a	34bc	39b	10a	51cd	37abc	8abcd	32bc
Belgium	45a	11a	61ab	48a	12a	86ab	43a	10abc	52ab
Better Forest	32a	9a	28bc	37bcd	11a	47cd	33bcde	8abcd	28c
Casadeen Massif	32a	9a	29bc	32bcd	9a	31d	30cde	7d	19c
Turkey	34a	9a	36bc	29e	9a	27d	29de	7cd	19c
Guadarrama	30a	8a	24c	32cde	10a	34d	30cde	7d	18c
Burgenland	42a	11a	61ab	46a	12a	75abc	40ab	10ab	50ab
Riga	40a	10a	41abc	41b	9a	38d	37ab	8abcd	29c
Central Massif	32a	9a	34bc	30e	9a	32d	27e	6d	13c
Alpine	34a	9a	33bc	37bc	10a	42cd	31cde	8abcd	21c
French Auvergne	39a	10a	40bc	36bcd	9a	43cd	30cde	7d	16c
Lower Austria	46a	12a	75a	49a	13a	96a	44a	10a	54a
Overall	36a[2]	10a	40b	37a	10a	48a	33b	8b	27c

[1] Means within a column followed by the same letter are statistically similar (p 0.05)
[2] Means within this row followed by the same letter, for each measurement, are statistically similar (p 0.05).

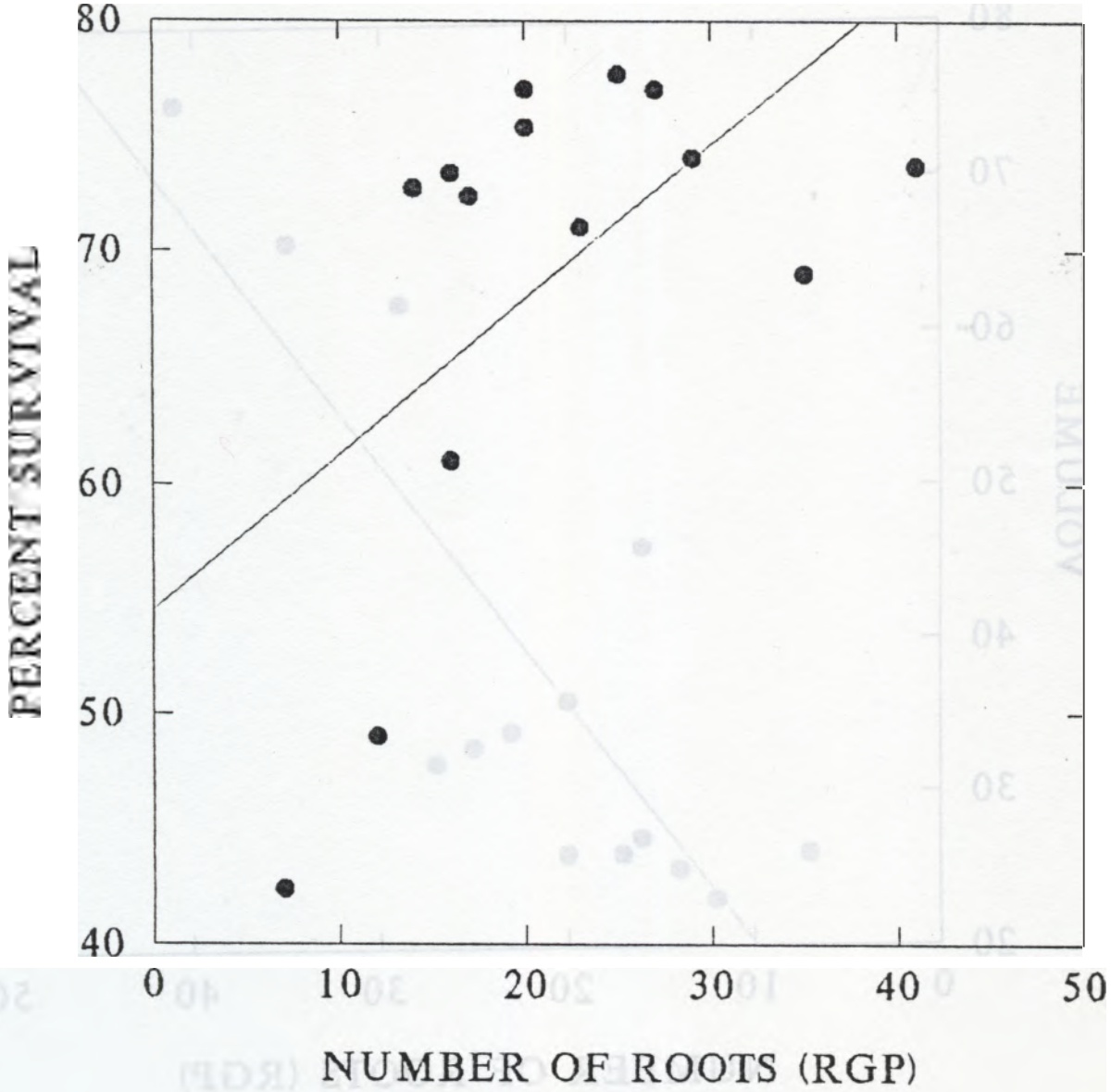

Figure 2. Number of new roots (RGP) by seed source as related to field survival as a mean of all physiographic regions

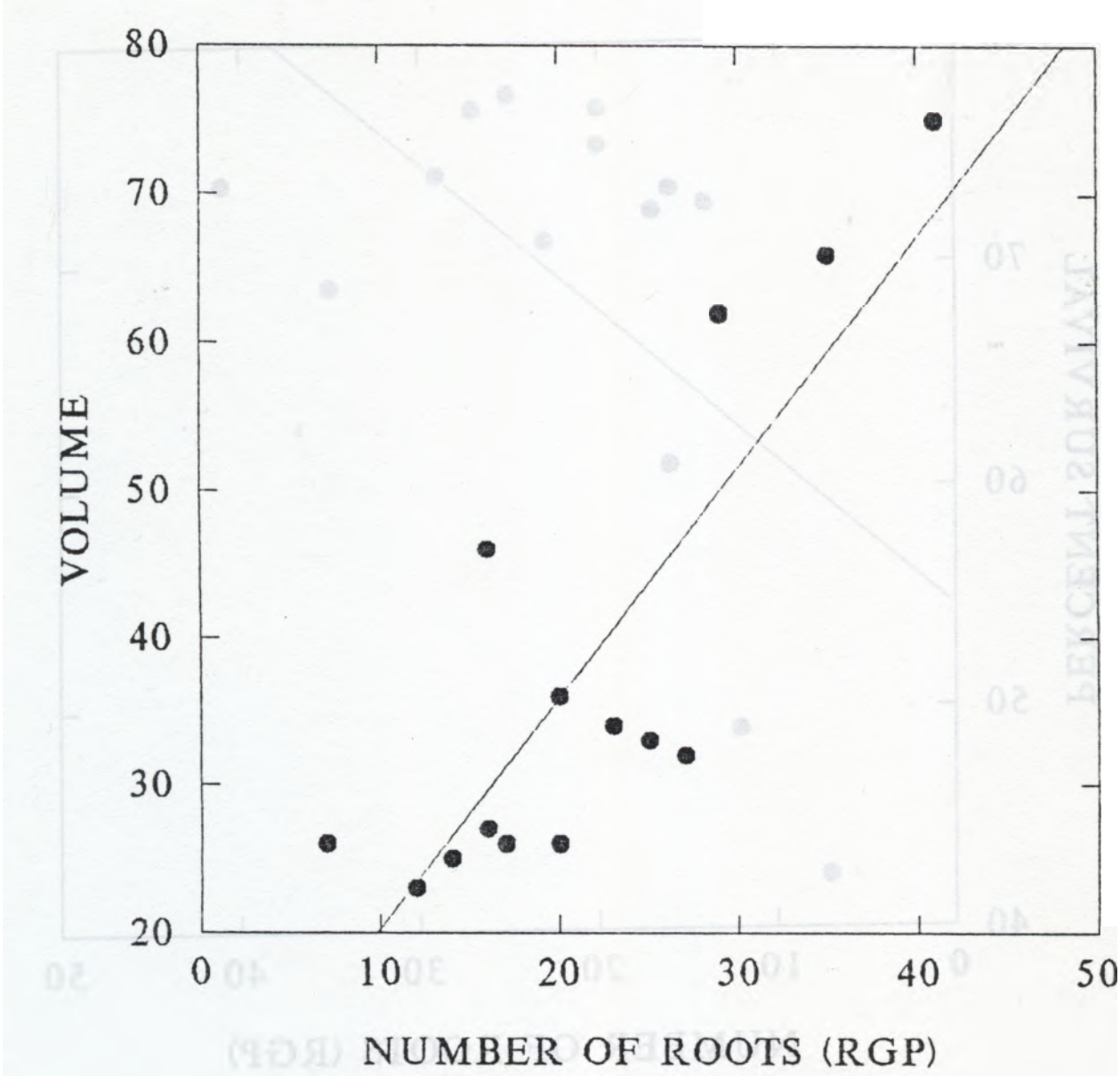

Figure 3. Number of new roots (RPG) by seed source as related to volume growth in the field as a mean of all physiographic regions

but not for others. Geographic variation in chilling requirement within a species has been observed (RITCHIE and DUNLAP 1980), and may partially explain the wide variety of RGP's reported here.

Field Performance

Second-year seedling survival is presented in Tables 2 and 3. Survival over all physiographic regions ranged from 42 to 78 percent (Table 2) with the lowest one being the Burgos seed source which also had the lowest RGP. Data in Table 3 are organized on a regional basis, with differences shown between seed sources within each region. Overall seedling survival was greatest in the Mountains (79%) as compared to the Piedmont and Coastal Plain (64% each).

Within each of the regions there were differences among seed source in survival. On the Coastal Plain a group of 11 seed sources had the highest survival rate, ranging from 58 to 84%. In the Mountains this same group, plus the Eastern U.S. variety, had the highest survival, ranging from 71 to 91%. Survival in the Piedmont was highly variable, ranging from 36 to 73%, with no significant differences between seed sources. On the Coastal Plain the French Auvergne and Lower Austria sources were the top survivors; in the Mountains the Lower Austria and Central Massif sources survived the best, and on the Coastal Plain the Casadeen Massif, Turkey, Riga, and French Auvergne sources topped the list (Table 3).

Seedling heights, ground line diameters, and volumes (expressed as d2h) are presented in Table 4. Although these variables are not growth variables per se, they are indicative of the overall vigor of the seedlings and consequently the degree to which they are adapted to the planting sites. Since the containerized seedlings were all similarly sized at the time of planting and had all been growing for two seasons, second-year seedling dimensions, prior to shearing, provide a good measure of seedling establishment.

The largest seedlings in terms of volume were produced by the Lower Austria seed source when averaged over all planting sites and corresponds to the one with the highest RGP (Table 2). On a physiographic basis, the largest seedlings grew in the Mountains, followed by the Coastal Plain and the Piedmont (Table 4). Within each region there were significant differences between sources in seedling height, diameter, and volume. Across all regions the Lower Austria source stands out as the fastest growing. This source also survived well throughout the state. Previous Scotch pine seed source studies have shown that seedling growth is closely correlated with origin of seed (KING 1965a, 1965b, WRIGHt *et al.* 1966). In the north central U.S., Scotch pine seed sources from central Europe grew most rapidly, while northern varieties were the slowest growing. Our study contains no Scandinavian seed sources; however, the largest seedlings tended to be from central European locations.

WRIGHT *et al.* (1966) found that Scotch pine sources often perform similarly across a wide variety of sites, and that the seed source X site interaction only accounted for about five percent of the variation in seedling height. The varieties in this study also tended to perform similarly throughout the regions. For example, the Spearman rank correlation coefficient for seedling volume between the Mountain and Piedmont sites was 0.82. The largest seedlings in the top three sources in the Mountains (Lower Austria, Belgium, and Bugenland) were also the largest in the Coastal Plain and Piedmont. All sources tended to perform poorly on the Piedmont. Climatically this region is intermediate between the Coastal Plain and Mountains; however, the soils tended to be much more similar to those of the Mountain sites. Unfortunately this region experienced unusual drought periods in the first and second year of the study which confounded performance similarities. WRIGHT *et al.* (1966) found the best growth of Scotch pine seedlings on sandy loam to loam soils. It may be that the combination of climate and soils found in the Piedmont are the least desirable conditions for Scotch pine survival and growth.

Relationship Between *RGP and Field Performance*

Numerous studies have shown high RGP to be correlated with good field performance for a number of pine species, including loblolly pine *(Pinus taeda* L.) (FERET and KREH 1985), ponderosa pine *(Pinus ponderosa* Dougl. ex Laws) (STONE 1955), jack pine *(Pinus banksiana* Lamb.) (SUTTON 1987), and lodgepole pine *(Pinus contorta* Dougl. ex Loud) (BURDETTE *et al.*1983). Presumably RGP is positively correlated with seedling characteristics important to survival and growth during the first year following planting. Alternatively RGP may be the direct cause of survival and early growth because of its relationship to root-soil contact. RITCHIE (1985) indicated that with Douglas fir *(Pseudotsuga menziesii* (Mirb.) Franco), RGP may be related to cold and stress resistance, while CARLSON (1986) indicated that

NICHOLS, T. J. 1989. Shearing. p. 79-103 In Johnson, J. E. (ed.) Christmas Tree Production Manual. VA Coop. Ext. Serv. Pub. 420-075. VA Polytech. Inst. and State Univ., Blacksburg, VA.

NOECKER, N. 1988. Scotch pine varieties, characteristics, and performance. Christmas Trees 16 : 34-41.

RITCHIE, G. A. 1985. Root growth potential : principles, procedures, and predictive ability. p. 93-105 In Duryea, M. L (ed.) Evaluating Seedling Quality : Principles, Procedures, and Predictive Abilities of Major Tests. Oregon State Univ., Forest Research Lab., Corvallis, OR.

RITCHIE, G. A., and J. R. DUNLAP. 1980. Root growth potential: its development and expression in forest tree seedlings. N.Z. J. For. Sci. 10 : 218-248.

STONE, E. C. 1955. Poor survival and the physiological condition of planting stock. For. Sci. 1 : 90-94.

SUTTON, R. F. 1983. *Root growth capacity: relationship with field root growth and performance in outplanted jack pine and black spruce*. Plant and Soil 71:111-122.

SUTTON, R. F. 1987. Root growth capacity and field performance of jack pine and black spruce in boreal stand establishment in Ontario. Can. J. For. Res. 17 : 194-804.

WRIGHT, J. W., S. S. PAULEY, R. B. POLK, J. J. JOKELA, and R. A. READ. 1966. *Performance of Scotch pine varieties in the North Central Region*. Silvae Genetica 15 : 101-110.