Scientific Research and Essays Vol. 5(14), pp. 1856-1860, 18 July, 2010
Available online at http://www.academicjournals.org/SRE
ISSN 1992-2248 ©2010 Academic Journals

Full Length Research Paper

The effects of initial planting density on above- and below-ground biomass in a 25-year-old *Fagus orientalis* Lipsky plantation in Hopa, Turkey

Sinan Guner[1], Volkan Yagci[1], Fahrettin Tilki[1]* and Nejat Celik[2]

[1]Faculty of Forestry, Artvin Coruh University, Artvin-08000, Turkey.
[2]Eskisehir Forest, Soil and Ecology Research Institute, Eskisehir-26160, Turkey.

Accepted 4 May, 2010

The aim of this study was to determine the influence of initial planting density on above- and below-ground biomass in 25 years old oriental beech stands located in Hopa, Artvin, Turkey. The initial spacings used in this study were 0.7 x 2.0 m (high planting density) and 2.0 x 2.0 m (low planting density). To analyse the planting density response of trees of different sizes (diameter), the sample trees within each stand density class were classified into four dbh classes (dbh1, dbh2, dbh3, dbh4) according to their diameter at the time of measurement. In each planting density stems, basal area, volume, aboveground biomass and C showed significant differences among diameter classes. In high density stand dbh2 (5.0 - 9.9 cm) had the highest basal area, volume, biomass and C. While, these measured data were the highest in db3 (10.0 - 14.9 cm) in low density stand. Although volume and aboveground biomass showed significant differences in diameter classes in each planting density, they were not affected by planting density. In high planting density dbh2 trees with a diameter of 0 - 4.9 cm had the highest volume (52 m^3 ha^{-1}), above-ground biomass (7.7 ton ha^{-1}) and C (3.4 ton ha^{-1}), whereas in low planting density dbh3 with a diameter of 5.0 - 9.9 cm had the highest volume (46 m^3 ha^{-1}), biomass (6.22 ton ha^{-1}) and C (2.80 ton ha^{-1}). However, stand basal area, belowground root biomass and C was higher in high planting density stand than in low planting density stand.

Key words: Biomass, growth, initial spacing, oriental beech, root mass.

INTRODUCTION

Oriental beech (*Fagus orientalis* Lipsky) is a shade-tolerant species that occurs in Turkey, Syria and north of Asia Minor and Iran (Czecozott, 1932; Timbal, 1981). It is one of the most abundant and wide spread tree species in the northern Turkey and penetrates towards the inner and backward parts of both the Black Sea and Marmara geographical regions. In addition to this, oriental beech communities are also found on the north and northwest facing slopes of the Amanos Mountains in the Eastern Mediterranean geographical region of Turkey. Optimum growth conditions of the beech forests are found on the north-facing slopes of the Northern Anatolian orogenic belt in the Black Sea Region and the Istranca Mountains in Thrace (Atalay, 1994; Mayer and Aksoy, 1998).

Canopy gaps affects survival and growth of tree species in temperate forests (Runkle, 1981; Canham, 1989; Tabari et al., 2005). Changing canopy architecture shifts pattern of biomass partitioning among above-and below-ground components (Cannell, 1985; Santantonio and Santantonio, 1987). Beets (1982) found important shifts in dry matter partitioning from branches and foliage to stems in a young plantations of *Pinus radiata* D. Don.

Fine and small roots represent an important biomass component of forest ecosystems. Production of fine roots can account for 8 (Keyes and Grier, 1981) to 67% (Grier et al., 1981) of the net production. The wide range in these values indicates that important variation exists in

*Corresponding author. E-mail: fahrettintilki@yahoo.com. Tel: +90-466-215-1035. Fax: +90-466-215-1034.

the allocation of dry matter to fine and small roots. It could be possible through silvicultural practices to direct some of the production normally lost through fine root turnover to another tree component such as stem wood. Stand density affects the properties of both single trees and whole stand. In dense stands acute branch angle may be associated with the combined effects of reduced wood and foliage mass, reduced branch size (James, 2001; Medhurst and Beadle, 2001) and greater competition for light (Henskens et al., 2001; Comeau et al., 2006). Furthermore, the increased competition for environmental resources (light, water and nutrients) with increased stocking density can reduce average stem diameter within the stand (Schonau and Coetzee, 1989; Niemisto, 1995; Kearney, 1999; Neilsen and Gerrand, 1999). Good un-derstanding of C dynamics requires careful examination of both above- and belowground biomass dynamics, but few studies of above- and below-ground biomass, and biomass C partitioning have been conducted in oriental beech stands.

Over the past 30 years, a body of literature has built up on the subject of the effect of initial spacing on growth and form of trees (Wardle, 1967; Smith, 1978; Eastham and Rose, 1990; Galinski et al., 1994; McClain et al., 1994; Xie et al., 1995; Gaul and Stuber, 1996; Knowe and Hibbs, 1996; Scott et al., 1998; Alcorn et al., 2007). The main reasons why spacing is of great interest to foresters are as follows: (*i*) the decision on spacing is a major factor affecting cost - close spacing requires more trees, and therefore will be more expensive, and (*ii*) closer spacings can induce branch mortality sooner and also provide a greater pool of stems from which to select the final crop, both of which help improve tree form and timber quality (MacKenzie, 1951). Traditionally, silviculturists have always been clear that where timber production is an important objective of management (Kerr and Evans, 1993), or where new woodlands are being created on bare land (Kerr, 1993), spacings of no more than 2.0 × 2.0 m should be used for most broad-leaved tree species. The difference between silvicultural recommendations and practice caused great debate on the effects of spacing on the growth and form of broad-leaved trees and was based on little objective information (Savill and Spillsbury, 1991).

The primary objective of this study was to determine the influence of initial planting density on above- and belowground biomass in 25 years old oriental beech stands located in Upper Hopa, Artvin, Turkey.

MATERIALS AND METHODS

The present study was conducted in a planted beech stand (25 years old) located in the northeastern part of the province of Black Sea region 20 km south of Hopa, Turkey. The site selected for the trial was in north-facing slope with 30% slope, and characterized by a humid climate (about 2400 mm of annual precipitation) that is favorable to the development of beech stands (elevation is about 800 m). Prior to installation of the plantings, the immediate area was in native forest occupied by oriental beech stand and several hardwood tree and shrub species (*Castanea sativa, Alnus glutinosa, Rhododendron* spp., *Ilex* spp.).

The natural oriented beech stand was removed by a clear-cut conducted in 1984 - 1985 by Artvin Regional Forest Directorate, planted with bareroot seedlings and was left untreated until 2008. Two-year-old seedlings were planted at the spacings 0.7 x 2.0 m (7143 trees ha^{-1}, high planting density) and 2.0 x 2.0 m (2500 trees ha^{-1}, low planting density) by the Forest Directorate. The experimental layout for the study was comprised 18 square plots (each 20 x 20 m in size) (9 plots for each planting density).

To analyse the planting density response of trees of different size (diameter), the sample trees within each stand density class were classified into four dbh classes (dbh1, dbh2, dbh3, dbh4) according to their diameter at the time of measurement. Dbh1 consisted of trees with a diameter of 0 - 4.9 cm, dbh2 trees with a diameter of 5.0 - 9.9 cm, dbh3 trees with a diameter of 10.0 - 14.9 cm, and dbh4 trees with a diameter of 15.0 - 20.0 cm. There were no trees in the other stand density classes.

The plots were measured in September - October, 2008. Basal area calculations were made using diameter at breast height (dbh) for each tree. The sub-samples consisted of 12 trees per plot were selected to represent all the diameter classes of the plots.

Destructive sampling of the trees was used to develop allometric equations based on diameter at breast height (dbh) to estimate aboveground biomass of oriental beech. Ten trees per plot, represented different diameter classes on the plot, were cut and dry weights of stems, branches and leaves were determined. Plant samples were oven-dried at 70°C and were ground to pass through 1 mm mesh sieves, and then aboveground biomass and C were determined.

Allometric equations were developed based on dbh using total aboveground tree dry weight as the dependent variable. The derived regression:

Tree mass (kg) = 0.2758 x $dbh^{2.214}$

$R^2 = 0.99$

where dbh is in cm,

Sequential soil coring technique was used to determine fine (0 - 2 mm) and small (2 - 5 mm) root biomass (Joslin and Henderson, 1987). Five soil cores of 6.4 cm diameter were removed from each sampling plot from the surface 0 - 30 cm of soil. Cores that could not be sorted immediately were placed into a cold room (4°C) until they could be. Roots were separated from the soil by soaking in water and then gently washing them over a series of sieves with mesh sizes of 2.0 and 0.5 mm. Roots were sorted into diameter classes of 0 - 2 mm (fine root) and 2 - 5 mm (small root). The roots from each size category were oven-dried at 70°C, weighed, ground to pass through 1-mm mesh size sieves and root biomass and C were determined. Coarse root (>5 mm) biomass data were obtained by directly measuring coarse roots in two 0.6 × 1.8 m soil pits dug to rooting depth in each plot, as reported in Tufekcioglu et al. (1999). Two additional soil cores were taken from each plot to determine soil texture and soil pH. Soil samples were air-dried, ground and pass through 2 mm mesh-sized sieve.

The statistical significance of the differences was analyzed using one-way analysis of variance. The means were separated according to Duncan's New Multiple Range Test at the 0.05 level of probability.

RESULTS AND DISCUSSION

The average sand content of the high density stand site was significantly higher than the other site (84.3 and

69.0% for low stand density and high stand density sites, respectively). The proportions of clay and silt in the soil to a depth of 20 cm in low stand density were 6.4 and 9.28%, respectively. The proportions of clay and silt in low stand density were 11.7 and 19.30%, respectively. The soil pH is 4.01 and 4.40 in low and high stand density stands, respectively.

In each planting density stems, basal area, volume, aboveground biomass and C showed differences among diameter classes (Tables 1 and 2). In high density dbh2 had the highest basal area, volume, biomass and C, while, these measured data were the highest in db3 in low density stand.

In high density stand 32.5% of trees per ha was found in dbh1, 55% of trees in dbh2, 12.1% of trees in dbh3 and only 0.4% in dbh4, whereas, in low density stand 9.5% of the trees per ha was found in dbh1, 47.5% of trees in dbh2, 35 % in dbh3, and 7.4% in dbh4.

Although volume and above-ground biomass showed significant differences in diameter classes in each planting density, they were not affected by planting density (Tables 1 - 3). In high planting density dbh2 had the highest volume (52 m^3 ha^{-1}), above-ground biomass (7.7 ton ha^{-1}) and C (3.4 ton ha^{-1}), whereas in low planting density dbh3 had the highest volume (46 m^3 ha^{-1}), biomass (6.22 ton ha^{-1}) and C (2.80 ton ha^{-1}). In terms of diameter growth, wider spacing increases diameter growth.This supports the hypothesis that wider spacing increases the rates of early diameter growth due to reduced competition for natural resources such as light, moisture and nutrients (Daniel et al., 1979; Macdonald and Hubert, 2002; Mehari and Habte, 2006).

In high planting density stand belowground root biomass and C was higher in high density stand than in low planting density stand (Table 4).

Increasing initial stockings have been shown to reduce maximum (Kearney, 1999; Neilsen and Gerrand, 1999; Garber and Maguire, 2005) and average branch size (Malimbwi et al., 1992; Pinkard and Neilsen, 2003) and cause an earlier rise of the green crown above the ground relative to stands established at lower planting densities across a broad range of species and sites (Neilsen and Gerrand, 1999; Baldwin et al., 2000). The increased competition for environmental resources (light, water and nutrients) with increased stocking density can reduce average stem diameter within the stand (Alcorn et al., 2007; Niemisto, 1995; Neilsen and Gerrand, 1999). In high density dbh2 had the highest basal area, volume, biomass and C. While, these measured data were highest in db3 in low density stand. In high density stand only 12.5% of trees per ha was found in dbh3 and dbh4, whereas, in low density stand 43% of trees per ha in dbh3 and dbh4. In general higher density caused small diameter. It might be said that diameter increment was significantly higher in low planting density than high planting density. As a result of high stocking level, the high density stand is not favorable for the development of vigorous, high quality oriental beech trees.

Tufekcioglu et al. (2005) found that light and heavy thinning didn’t affect fine root biomass over the 3-year-period following thinning in 25-year-old oriental beech stands. Heavy and light thinning treatments had higher mean coarse root biomass than did control in that study. The present study shows that 25 years time period might be long enough to cause significant changes in root biomass and C between stands. Although volume, aboveground biomass and C were not affected by planting density after 25 years, they showed significant differences in diameter classes in each planting density. Basal area, belowground root biomass and C were higher in high planting density stand.

Examples of studies of the effects of spacing in other species include that of Scott et al. (1998), who investigated a series of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) test plantations on similar sites with six initial planting densities from 300 - 2960 trees/ha. A size–density relationship was apparent after 4 years, and after 6 years, height and diameter at the widest spacing were 75 and 67%, respectively, of those at the closest spacing. Data from an 8-year-old Latin square spacing trial of *Fraxinus uhdei* Lindl. in southwestern U.S.A. showed that spacing did not affect height or diameter (Burgan, 1971).

Height, stem diameter, and stem volume decreased with increasing spacing in common ash; at one site, shoot and root dry mass also showed the same trend (Kerr, 2003). By age 3, poplar trees grown at wider spacings were taller and had larger diameters than those grown at closer spacings. Due to fewer number of trees per unit area, however, biomass production was maximized in narrow spacings during the initial years after planting. The wider the spacing, the more uniform were tree diameters and heights. Total aboveground oven-dry woody yield decreased as spacing increased (DeBell and Harrington, 1997). Baldwin et al. (2000) stated that height/diameter ratios for 38-year-old *Pinus contorta* Dougl. var. *contorta* decreased from 96 to 84 as spacing increased from 1.8 × 1.8 m - 3.7 × 3.7 m.

Although volume and aboveground biomass showed significant differences in diameter classes in each planting density, volume, aboveground biomass and C were not affected by planting density in the present study. Further research is needed to determine the long term affect of standing density on above- and belowground biomass and wood quality.

ACKNOWLEDGEMENTS

This research has been supported by Scientific and Technological Research Council of Turkey (TUBITAK) (Project Number: 108O113). We also express appreciation to Artvin Forest Enterprise for providing the study site and for its cooperation in establishment of the study,

Table 1. Basal area, volume, aboveground biomass and C in four diameter classes at high stand density in a 25-year-old *F. orientalis* plantation.

Diameter class	Stems (ha^{-1})	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Aboveground biomass (ton ha^{-1})	Carbon (ton ha^{-1})
dbh1	2067b	2.13c	11c	0.92c	0.42c
dbh2	3493a	13.99a	52a	7.70a	3.46a
dbh3	770c	7.01b	28b	4.03b	1.82b
dbh4	27d	0.53d	3d	0.26c	0.12d

Means in the column followed by the same letter are not significantly different at $p < 0.05$.

Table 2. Basal area, volume, aboveground biomass and C in four diameter classes at low stand density in a 25-year-old *F. orientalis* plantation.

Diameter class	Stems (ha^{-1})	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Aboveground biomass (ton ha^{-1})	Carbon (ton ha^{-1})
dbh1	237c	0.33d	2d	0.16d	0.07c
dbh2	1180a	5.65b	19c	3.11b	1.40b
dbh3	883b	10.34a	46a	6.22a	2.80a
dbh4	183d	3.89c	25b	2.49c	1.12b

Means in the column followed by the same letter are not significantly different at $p < 0.05$.

Table 3. Effects of planting density on basal area, volume and aboveground biomass in a 25-year-old *F. orientalis* plantation.

Planting density	Diameter	Basal area cm^2 ha^{-1}	Volume m^3 ha^{-1}	Aboveground biomass ton ha^{-1}	Carbon ton ha^{-1}
Low	9.52a	20.2b	92	13.00	5.85
High	7.75b	23.6a	94	12.94	5.83

Means in the column with the different letter are significantly different ($p < 0.05$).

Table 4. Effects of planting density on belowground root biomass and C in a 25-year-old *F. orientalis* plantation.

Planting density	Root biomass ton ha^{-1}				Carbon ton ha^{-1}			
	Fine roots	Small roots	Coarse roots	Total	Fine roots	Small roots	Coarse roots	Total
Low	2.97	3.17	1.50	7.64b	0.89	1.05	0.45	2.39b
High	4.38	3.49	1.82	9.68a	1.31	1.05	0.54	2.90a

Means in the column with the different letter are significantly different ($p < 0.05$).

and specially thank Kezban Yildiz and Ahmet Duman for assistance in the field-work.

REFERENCES

Alcorn PJ, Pyttel P, Bauhus J, Geoff R, Smith B, Thomas D, James R, Nicotra A (2007). Effects of initial planting density on branch development in 4-year-old plantation grown *Eucalyptus pilularis* and *Eucalyptus cloeziana* trees. For. Ecol. Manage., 252: 41-51.

Atalay I (1994). Turkiye Vejetasyon Cografyasi (Vegetation Geography of Turkey). Ege Univ. Basimevi, Bornova, Izmir.

Baldwin VC, Peterson KD, Clark A, Ferguson RB, Strub MR, Bower DR (2000). The effects of spacing and thinning on stand and tree characteristics of 38-year-old loblolly pine. For. Ecol. Manage., 137: 91-102.

Beets PN (1982). Modeling dry matter content of a managed stand of *Pinus radiata* in New Zealand. PhD dissertation, University of Georgia, Athens.

Burgan RE (1971). A spacing trial in tropical ash: an interim report. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. PSW-RN-226. Berkeley, CA.

Canham CD (1989). Diffeent responses to gaps among shade tolerant tree secies. Ecology, 70: 548-550.

Cannell MGR (1985). Dry matter partitioning in tree crops. In: Cannell MGR, Jackson, JE (eds). Attributes of trees as crop plants. Institute of Terrestrial Ecology, Huntington, England, pp. 160-193.

Comeau PG, Heineman J, Newsome T (2006). Evaluation of relationships between understory light and aspen basal area in the British Columbia central interior. For. Ecol. Manage., 226: 80-87.

Czecozott H (1932). Distribution of *Fagus orientalis* Lipsky. In: Rubel E (eds). Die Buchenwalder Europas. Vlg. Hans Huber, Bern/Berlin, pp. 95-102.

Daniel TW, Helms JA, Baker FD (1979). Principles of Silviculture, 2nd ed. McGraw-Hill series in forest resources, New York.

DeBell DS, Harrington CA (1997). Productivity of *Populus* in monoclonal and polyclonal blocks at three spacings. Can. J. For. Res., 27: 978-985.

Eastham J, Rose CW (1990). Tree pasture interactions at a range of tree densities in an agroforestry experiment. 1. Rooting patterns. Aust. J. Agric. Res., 41: 683-695.

Galinski W, Witowski J, Zwieniecki M (1994). Non-random height pattern formation in even aged Scots pine (*Pinussylvestris* L.) Nelder plots as affected by spacing and site quality. Forestry, 67: 49–61.

Garber SM, Maguire DA (2005). Vertical trends in maximum branch diameter in two mixed-species spacing trials in the central Oregon Cascades. Can. J. For. Res., 35: 295-307.

Gaul T, Stuber V (1996). The oak Nelder experiment at Göhrde. Forst Holzwirt, 51: 70-75.

Grier CC, Vogt KA, Keyes MR, Edmonds RL (1981). Biomass distribution above-and below-ground in young and mature *Abies amabilis* zone ecosystems in the Washington Cascades. Can. J. For. Res., 11: 155-167.

Henskens FL, Battaglia M, Cherry ML, Beadle CL (2001). Physiological basis of spacing effects on tree growth and form in Eucalyptus globulus. Trees, 15: 365-377.

James R (2001). Some silvicultural characteristics of plantation grown Flooded Gum and Black Butt on the North Coast, NSW. In: Lott R (eds) National Farm Forestry Silviculture Project Workshop. QFRI, AFFA and RIRDC, Brisbane, pp 1-10.

Joslin JD, Henderson GS (1987). Organic matter and nutrients associated with fine root turnover in a white oak stand. For. Sci., 33: 330-346.

Kearney D (1999). Characterisation of branching patterns, changes caused by variations in initial stocking and implications for silviculture, for E. Grandis and E. pilularis plantations in the North Coast region of NSW. Honours Thesis. Department of Forestry. The Australian National University, Canberra.

Kerr G (1993). Robust woodland establishment. Quart. J. For., 87: 302-304.

Kerr G (2003). Effects of spacing on the early growth of planted *Fraxinus excelsior* L. Can. J. For. Res., 33: 1196-1207.

Kerr G, Evans J (1993). Growing broadleaves for timber. HMSO Publications Centre, London, U.K. For. Comm. Handb. 9.

Keyes MR, Grier CC (1981). Above- and below-ground net production in 40-year-old Douglas-fir stands on low and high productivity sites. Can. J. For. Res., 11: 599-605.

Knowe SA, Hibbs DE (1996). Stand structure and Dynamics of young red alder as affected by planting density. For. Ecol. Manage., 82: 69-85.

Macdonald E, Hubert J (2002). A review of the effect of silviculture on timber quality of Sitka spruce. Forestry, 75: 107-138.

MacKenzie AM (1951). Spacing experiments in conifers. HMSO Publications Centre, London, U.K. For. Comm. Rep. For. Res., 1949/50, pp. 59-61.

Malimbwi RE, Persson A, Iddi S, Chamshama SAO, Mwihomeke ST (1992). Effects of spacing on yield and some wood properties of Pinus patula at Rongai, northern Tanzania. For. Ecol. Manage., 53: 297-306.

Mayer H, Aksoy H (1998). Turkiye Ormanları (translated by Aksoy H., Ozalp, G.). Abant Izzet Baysal Univ. Basimevi. Bolu, Turkey.

McClain KM, Morris DM, Hills SC, Buse LJ (1994). The effects of initial spacing on growth and crown development for planted northern conifers: 37-year results. For. Chron., 70: 174-182.

Medhurst JL, Beadle CL (2001). Crown structure and leaf area index development in thinned and unthinned Eucalyptus nitens plantations. Tree Physiol., 21: 989-999.

Mehari A, Habte B (2006). Influence of initial spacing on growth and branching characteristics of Cordia africana trees established on Eritrean highland. New For., 31: 185-193.

Neilsen WA, Gerrand AM (1999). Growth and branching habit of Eucalyptus nitens at different spacing and the effect on final crop selection. For. Ecol. Manage., 123: 217-229.

Niemisto P (1995). Influence of initial spacing and row-to-row distance on the growth and yield of silver birch (*Betula pendula*). Scand. J. For. Res., 10: 245-255.

Pinkard EA, Neilsen WA (2003). Crown and stand characteristics of Eucalyptus nitens in response to initial spacing: implications for thinning. For. Ecol. Manage., 172: 215-227.

Runkle JR (1981). Gap regeneration in some old-growth forests of eastern United States. Ecology, 62: 1041-1051.

Santantonio D, Santantonio E (1987). Effect of thinning on production and mortality of fine roots in a *Pinus radiata* plantation on a fertile site in New Zealand. Can. J. For. Res., 17: 919-927.

Savill PS, Spillsbury MJ (1991). Growing oaks at closer spacing. Forestry, 64: 373-384.

Schonau APG, Coetzee J (1989). Initial spacing, stand density and thinning in eucalypt plantations. For. Ecol. Manage., 29: 245–266.

Scott W, Meade R, Leon R, Hyinck D, Miller M (1998). Planting density and tree-size relations in coast Douglas-fir. Can. J. For. Res., 28: 74-78.

Smith JHG (1978). Design factors from Nelder and other spacing trials to age 20. Commonw. For. Rev., 57: 109–119.

Tabari M, Fayaz P, Espahbodi K, Staelens J, Nachtergale L (2005). Response of oriental beech (*Fagus orientalis* Lipsky) seedlings to ganopy size. Forestry, 78: 443-450.

Timbal J (1981). Repartion en Europe et en France. In: Teissier E., du Cros (eds) Le Hetre, INRA, Paris, pp. 68-71.

Tufekcioglu A, Guner S, Tilki F (2005). Thinning effects on production, root biomass and soil properties in a young oriental beech stand in Artvin, Turkey. J. Environ. Biol., 26(1): 91-95.

Tufekcioglu A, Raich JW, Isenhart TM, Schultz RC (1999). Fine root dynamics, coarse root biomass, root distribution, and soil respiration in a multispecies riparian buffer in Central Iowa, USA. Agrofor. Syst., 44: 163-174.

Wardle PA (1967). Spacing in plantations-a management investigation. Forestry, 40: 47-69.

Xie CY, Johnstone WD, Ying CC (1995). Spacing and provenance effects on the performance of shore pine (*Pinus contorta* var. *contorta*): 20-year test results. Can. J. For. Res., 25: 567-576.