JOURNAL OF FOREST SCIENCE, *58*, 2012 (11): 513–518

Investigating the out-of-roundness and pith-off-centre in stems of three broadleaved species in Hyrcanian forests

A. Fallah[1], N. Riahifar[2], K. Barari[3], A. Parsakhoo[4]

[1,2,4]*Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari, Iran*

[3]*Mazandaran Wood and Paper Industries, Sari, Iran*

ABSTRACT: The out-of-roundness and pith-off-centre of *Alnus subcordata*, *Acer velutinum* and *Quercus castaneifolia* growing in Hyrcanian forests of Iran were investigated. Stem disks were cut from the breast height and stump height of felled trees in diameter classes of 20 cm to 90 cm. Results indicated that the pith eccentricity for *Acer velutinum* was significantly greater than that of *Alnus subcordata* and *Quercus castaneifolia* ($P < 0.01$). The pith-off-centre significantly increased with increasing stem diameter from 20 cm to 50 cm, while no significant difference were observed for pith-off-centre index from diameter class of 55 cm to 90 cm. The out-of-roundness in stems of *Acer velutinum* and *Alnus subcordata* was significantly greater than that of *Quercus castaneifolia* ($P < 0.01$). Moreover, out-of-roundness significantly decreased with increasing stem diameters from 20 cm to 45 cm except for 35 cm. There were no significant differences among diameter classes from 60 cm to 85 cm with respect to out-of-roundness. For all the species, the out-of-roundness and pith-off-centre at stump height were greater than those at breast height.

Keywords: stem diameter; felled trees; *Alnus subcordata*; *Acer velutinum*; *Quercus castaneifolia*

A stem cross-section provides the complete radial growth series of a tree (Bakker 2005). The ellipticity of log cross-sections is described by terms such as noncircularity, ovality or out-of-roundness (Biging, Wensel 1988). Deviation from the circular shape of stem may cause a loss of raw material in industry and errors in calculating stem volumes and information about changes in wood quality and properties. Therefore, understanding and assessing this variation in bole roundness and eccentricity are of economic interest (Mäkinen 1998). Pith is a small central core of the primary parenchyma tissue formed by the apical meristem at the growing tip (Moya et al. 2008). Pith eccentricity refers to the deviation of the pith from the geometric centre of the section (Pawsey 1966; Todoroki et al. 2007). Because pith eccentricity is associated with reaction wood, the degree of pith eccentricity is an index of the wood quality of trunk or branch (Akachuku, Abolarin 1989; Ren et al. 2006). Mäkinen (1998) showed that the pith eccentricity of Scots pine in Finland was greatest at stump height and diminished on moving up the stem. At breast height, it varied from 2% to 9% irrespective of the stand age or relative tree size.

The tree disk is cross cut from a log (Saint-André, Leban 2000). Kang and Lee (2004) reported that the pith eccentricity of tree was greater for disks from the tree bottom than for those from the tree top. Warensjö and Rune (2004) studied the stem straightness and compression wood in a 22-year-old Scots pine stand in Sweden. They found that out-of-roundness was correlated with pith eccentricity but not with severe compression wood content, for the basal 2.4 m part of the stems. Moreover, compression wood and pith eccentricity were most pronounced near the stem base but not significantly correlated with basal sweep. Severe compression wood content is correlated with pith eccentricity and bow height (Warensjö, Rune 2004).

Singleton et al. (2003) demonstrated that the lower portion of the bole was more out-of-round than higher portions of the bole. Out-of-roundness had a weak positive correlation with tree age. The up-

per end of the tree stem is not used for out-of-roundness calculation, because the stem cross-section deforms due to the transition to the crown branches (Pfeifer, Winterhalder 2004). Moreover, pith-off centre and out-of roundness may be influenced by tree lean, slope and wind (Kellogg, Barber 1981). One study found a positive linear relationship between eccentricity and tree diameter at breast height (DBH) in Douglas-fir (Williamson 1975). A similar result was also observed for DBH and out-of roundness. Previous studies in eastern Canada showed that the eccentricity of commercial softwoods (Balsam fir, jack pine and black spruce) at breast height was very close to 1 (Tong, Zhang 2008).

Skatter and Høibø (1998) tested different models of the cross-sectional shape of tree trunks on samples of Scots pine and Norway spruce logs. They reported that for sawmills, the utilization of non-circular cross sectional shapes represented a challenge. If circle models are used, any deviation in shape from circularity will normally reduce the yield. Ferreira et al. (2008) evaluated the pith eccentricity in stems of four Eucalyptus clone trees. The results showed that the eccentricity of the pith occurred in all clones changing from 2.53% to 4.55%. For the trees planted on sloped terrains there was observed a tendency of the piths to be positioned at the side of the disks opposite to the slope of the terrain. According to Duncker et al. (2005) reports, it was not possible to prove that the slope had an effect on the formation of compression wood and on pith eccentricity. The directions are in fact dominated by the exposure of the site to the prevailing wind direction.

This study deals with three broadleaved species including *Alnus subcordata*, *Acer velutinum* and *Quercus castaneifolia*. Alder (*Alnus subcordata* C.A. Mey.) is a species in the family Betulaceae, native to Hyrcanian forests of Iran and the Caucasus. It is a deciduous tree growing to a height of 15–25 m (Parsakhoo et al. 2009; Jalilvand et al. 2010). Maple (*Acer velutinum*) from the family Aceraceae is a native to the plain and mountain areas of northern Iran. It is superior to the deciduous species in having larger leaves and flowers. The bark is grey-brown and smooth (Taheri Abkenar, Safarpour 2007). Oak (*Quercus castaneifolia* (C.A. Meyer) from the family Fagaceae is one of the most prevalent deciduous species growing in the north of Iran. Reduction of standing volume as well as failure of natural regeneration in *Q. castaneifolia* stands in recent decades has made Iranian silviculturists concerned (Karami, Tabari 2009). The objectives of this research were to characterize out-of-roundness and pith-off-centre in stems of *Alnus subcordata*, *Acer velutinum* and *Quercus castaneifolia* growing in Hyrcanian forests with respect to tree height and diameter.

MATERIALS AND METHODS

Description of the study area

The study area (Neka-Zalemrood forests) is located within the northern broadleaved forests of Iran (36°25' to 36°29'N latitude and 53°25' to 53°31'E longitude), in the south to southeast of the city of Neka and covers an area of 13,511 ha. 1,817 ha of the total area is field land and villages and 11,694 ha is forest. This zone is composed of marl, sandstone, siltstone, claystone and limestone bedrocks. Soil types of the study area are brown and washed brown forest soil with pseudogley. Minimum altitude is about 350 m and maximum altitude is 1,430 m. The general aspect of the hillside is north and its average slope is 25%. The average temperature is from 28.4°C in July to 0.4°C in February. Mean annual air temperature is 15.3°C. The region receives 1,110 mm of precipitation annually. Minimum and maximum rainfall is 64 and 201 mm which occurs in August and February, respectively. The mean relative air humidity is 80%. The growing season lasts 240 days from April to November (Fig. 1).

Data collection

In this study, pith-off-centre and out-of-roundness of *Alnus subcordata*, *Acer velutinum* and *Quercus castaneifolia* were measured on cross-sections of 225 trees felled in mixed forest stands of Neka-Zalemrood. Pith eccentricity was pronounced on the lower part of the stem and diminished on moving towards the midpoint on the stem. In this study, stem disks were cut from the breast height and stump height in five replications. The disks were chosen systematically so that the sample contained disks from the diameter classes of 20–90 cm (Fig. 2).

Different equations were used to calculate the geometric variables pith eccentricity and out-of-roundness of the disks. Out-of-roundness index was calculated according to Eq. (1).

$$OOR = \frac{(D_{max} - D_{min})}{D_{max}} \quad (1)$$

where:

OOR – index of out-of-roundness,

D_{max} – maximum cross sectional diameter,

D_{min} – minimum cross sectional diameter.

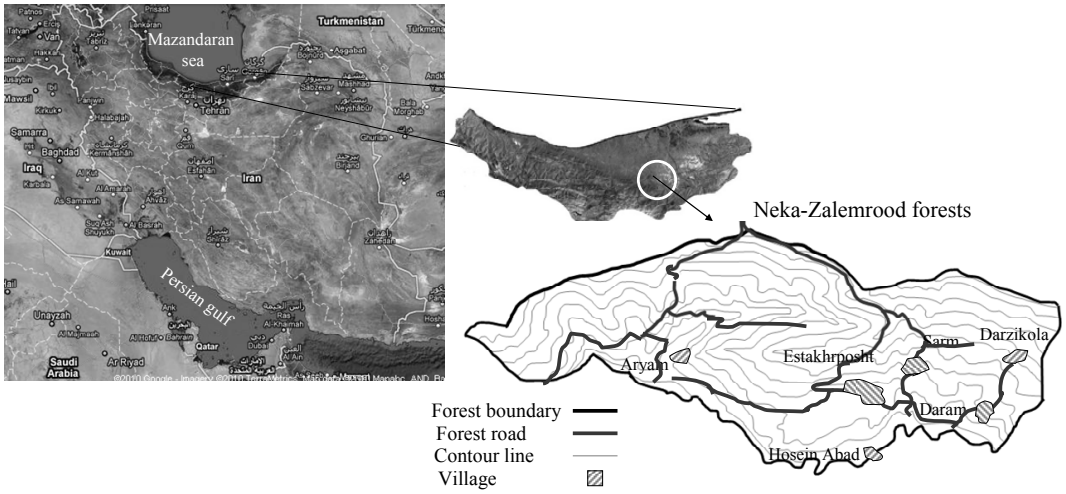

Fig. 1. The geographical position of the study area

Higher values of *OOR* are associated with more eccentric stems, while a circular stem would have the value of zero (Singleton et al. 2003). The pith-off-centre was calculated as Eq. (2) (Kang, Lee 2004). Moreover, the formula for the average sample radius (R_{avg}) was as follows (Eq. (3)).

$$POC = \frac{(R_{avg} - R_S)}{R_{avg}} \quad (2)$$

$$R_{avg} = \frac{(R_S + R_L)}{2} \quad (3)$$

where:

POC – index of pith-off-centre,

R_{avg} – average sample radius,

R_S, R_L – shortest and longest radii, respectively.

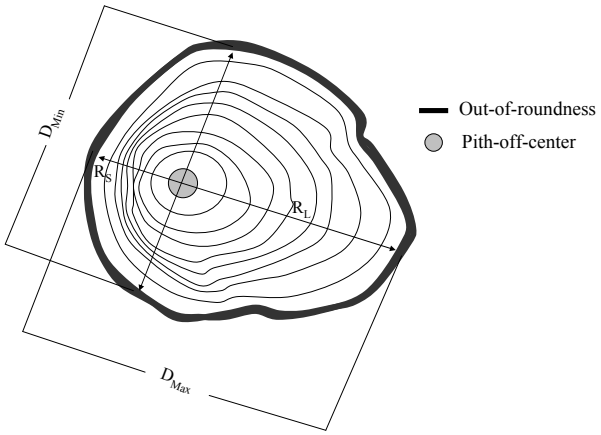

Fig. 2. Cross-section of a tree and schematic of out-of-roundness and pith-off-centre; D_{max} – maximum cross-sectional diameter, D_{min} – minimum cross-sectional diameter, R_S – shortest radii and R_L – longest radii

Higher POC values indicate the pith is more off-centred.

Statistical Analysis

All the data were analysed by GLM procedure in SPSS software version 11.5, besides the diagram was drawn in Excel software. The statistical significance of the differences among means was evaluated using Duncan's and Student-Newman-Kouls (SNK) tests at a probability level of 1%.

RESULTS AND DISCUSSION

Pith-off-centre in stems of species

Cross-section shapes of trees are of interest to forest managers, because economically important measures can be derived from them (Pfeifer, Winterhalder 2004). The annual rings of Norway spruce are rather circular near the pith and at the top of the tree stem and rather elliptical close to the bark and at the bottom of the stem (Saint-André, Leban 2000).

There was a significant difference between the stump height and breast height with respect to pith eccentricity ($P < 0.01$). Moreover, the present study clearly demonstrated that pith-off-centre was influenced not only by the species type but also by the diameter classes ($P < 0.01$). Similar results were obtained in Williamson (1975) studies. It was detected that there was a positive linear relationship between pith eccentricity and tree DBH. Nevertheless, in our research the interaction among species

Table 1. Effect of the species, diameter, sampling height and their interaction on pith-off-centre index

Sources of variation	Sum of squares	Mean of squares	Degrees of freedom	*F*
Species	0.49	0.24	2	24.98**
Diameter classes	3.56	0.25	14	25.83**
Stump and breast height	0.07	0.07	1	7.13**
Species × diameter classes	0.94	0.03	28	3.4**
Diameter classes × stump and breast height	0.51	0.03	14	3.72**
Species × stump and breast height	0.01	0.006	2	0.55^{ns}
Species × diameter classes × stump and breast height	0.87	0.03	28	3.18**
Error	3.5	0.01	356	0

** indicates significance at a probability level of 1%, ns – not significant

type, stump and breast heights on pith eccentricity was not statistically significant ($P < 0.01$). There were significant differences in pith-off-centre index in response to other interactions ($P < 0.01$, Table 1).

The pith eccentricity for *Acer velutinum* was significantly greater than that of *Alnus subcordata* and *Quercus castaneifolia* due to genetic properties ($P < 0.01$, Fig. 3a). The pith-off-centre significantly increased with increasing stem diameter from 20 cm to 50 cm, while no significant difference was observed for pith-off-centre index from diameter class of 55 cm to 90 cm ($P < 0.01$, Fig. 3b). Therefore in our study forest, tree competition for access to light in the first stages of growth as well as stand density cause changes in POC and OOR up to diameter of 50 cm. Similar results were also reported by Tong and Zhang (2008). At the same age, in the trees with larger diameter, splits move outwards. This latter aspect might have an influence from an economic point of view due to the Iranian Technical standard.

Out-of-roundness in stems of species

There was not a significant difference between the stump height and breast height with respect to out-of-roundness index ($P < 0.01$). Also, it was observed that out-of-roundness was influenced not only by the species type but also by the diameter classes ($P < 0.01$). The interaction among species type, stump and breast heights as well as species type, diameter classes, stump and breast heights on out-of-roundness was not statistically significant ($P < 0.01$). There were significant differences in out-of-roundness index in response to other interactions ($P < 0.01$, Table 2). This may be due to compression wood (Warensjö, Rune 2004), tree lean, slope and wind direction (Kellogg, Barber 1981).

In our study, the out-of-roundness in stems of *Acer velutinum* and *Alnus subcordata* was significantly greater than that of *Quercus castaneifolia* ($P < 0.01$, Fig. 4a). Moreover, out-of-roundness

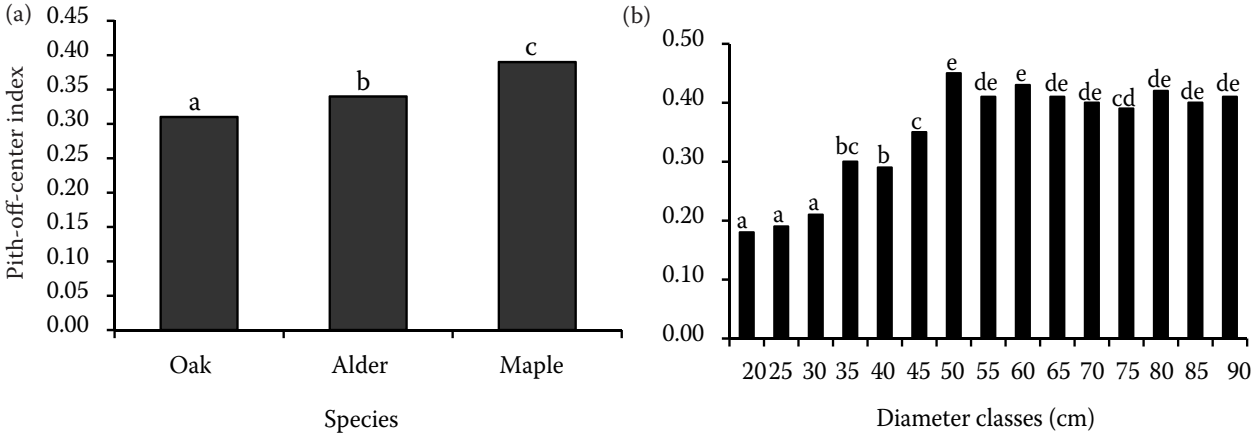

Fig. 3. Comparison of the pith-off-centre index for different species (a) and n different diameter classes (b); values with the same letter are not significantly different at a probability level of 1%, SNK test

Table 2. Effect of the species, diameter, sampling height and their interaction on out-of-roundness index

Sources of variation	Sum of squares	Mean of squares	Degrees of freedom	*F*
Species	0.22	0.11	2	33.63**
Diameter classes	0.25	0.018	14	5.61**
Stump and breast height	0.005	0.005	1	1.47ns
Species × diameter classes	0.22	0.008	28	2.45**
Diameter classes × stump and breast height	0.085	0.006	14	1.84*
Species × stump and breast height	0.002	0.001	2	0.25ns
Species × diameter classes × stump and breast height	0.075	0.003	28	0.81ns
Error	1.16	0.03	356	0

*, ** indicates significance at a probability level of 5 and 1%, respectively, ns – not significant

Table 3. Mean of pith-off-centre and out-of-roundness at different sampling heights

Index	Alder		Oak		Maple	
	stump height	breast height	stump height	breast height	stump height	breast height
Pith-off-centre	0.35	0.33	0.32	0.30	0.41	0.37
Pith-off-centre deviation	0.16	0.14	0.11	0.11	0.16	0.14
Out-of-roundness	0.100	0.098	0.056	0.055	0.100	0.090
Out-of-roundness deviation	0.079	0.053	0.041	0.043	0.079	0.053

significantly decreased with increasing stem diameters from 20 cm to 45 cm except for 35 cm. There were not any significant differences among diameter classes from 60 cm to 85 cm with respect to out-of-roundness (Fig. 4b). Indeed for all the species, out-of-roundness and pith-off-centre at stump height were greater than those at breast height (Table 3). These results are in agreement with the findings of other studies which reported that the pith eccentricity was greatest at stump height and diminished on moving up the stem (Mäkinen 1998; Kang, Lee 2004).

CONCLUSIONS

In summary, our results indicated that the pith eccentricity for *Acer velutinum* was greater than that of *Alnus subcordata* and *Quercus castaneifolia*. Be-

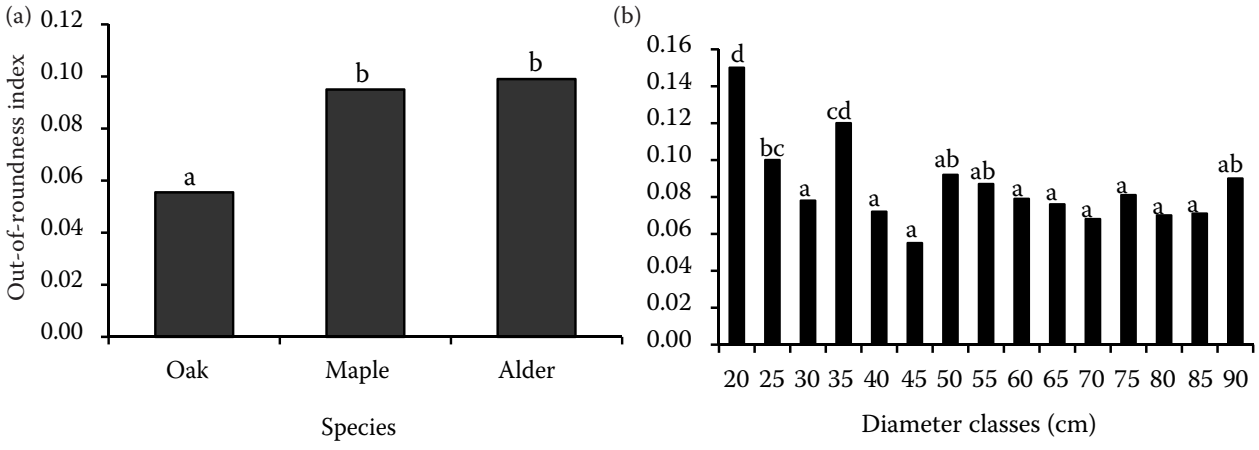

Fig. 4. Comparison of the out-of-roundness index for different species (a) and in different diameter classes (b); values with the same letter are not significantly different at a probability level of 1%, SNK test

sides, the pith-off-centre index increased with increasing stem diameter from 20 cm to 50 cm, while this case was not observed for larger diameters. The out-of-roundness in stems of *Acer velutinum* and *Alnus subcordata* was greater than that of *Quercus castaneifolia*. For all the species, out-of-roundness and pith-off-centre were greatest at stump height and diminished on moving up the stem.

References

Akachuku A.E., Abolarin D.A. (1989): Variations in pith eccentricity and ring width in teak (*Tectona grandis* L. F.). Trees, ***3***: 111–116.

Bakker J.D. (2005): A new, proportional method for reconstructing historical tree diameters. Canadian Journal of Forest Research, ***35***: 2515–2520.

Biging G.S., Wensel L.C. (1988): The effect of eccentricity on the estimation of basal area and basal area increment of coniferous trees. Forest Sciences, ***34***: 621–633.

Duncker P., Spiecker H. (2005): Compression wood formation and pith eccentricity in *Picea abies* L. depending on selected site-related factors: Detection of compression wood by its spectral properties in reflected light. In: Gärtner H., Esper J., Schleser G. (eds): TRACE – Tree Rings in Archaeology, Climatology and Ecology. Proceedings of the Dendrosymposium 2004. Volume 3. Birmensdorf, 22.–24. April 2004. Jülich, Forschungszentrum Jülich: 150–158.

Ferreira S., Lima J.T., Trugilho P.F., Monteiro T.C. (2008): Pith eccentricity in Eucalyptus clone stems cultivated on different topographies. Cerne, ***14***: 335–340.

Jalilvand H., Hosseini S.A., Parsakhoo A. (2010): Annual ring growth of Caspian Alder in the forest road edges. Pakistan Journal of Botany, ***42***: 721–730.

Karami J., Tabari M. (2009): Morphology and nutrient of leaf in *Quercus castaneifolia* seedling as affected by blackberry (*Rubus fructicosus* L.). Research Journal of Environmental Science, ***3***: 257–261.

Kang W., Lee N.H. (2004): Relationship between radial variations in shrinkage and drying defects of tree disks. Journal of Wood Sciences, ***50***: 209–216.

Kellogg R.M., Barber F.J. (1981): Stem eccentricity in coastal western hemlock. Canadian Journal of Forest Research, ***11***: 714–718.

Mäkinen H. (1998): Effect of thinning and natural variation in bole roundness in Scots pine (*Pinus sylvestris* L.). Forest Ecology and Management, ***107***: 231–239.

Moya R., Araya L., Vilchez B. (2008): Variation in pith parameter of *Gmeliarborea* trees from fast growth plantation in Costa Rica. Annals Journal of Forest Science, ***65***: 1–10.

Pawsey C.K. (1966): Lean and eccentricity in *Pinus radiate* (D. Don) in the southeast of South Australia. Australian Journal of Forest Research, ***2***: 22–35.

Parsakhoo A., Jalilvand H., Sheikhi M. (2009): *Alnus subcordata* cambium cells dynamics along transport corridors in Hyrcanian forests. American Journal of Applied Sciences, ***6***: 1186–1190.

Pfeifer N., Winterhalder D. (2004): Modeling of tree cross sections from terrestrial laser scanning data with free-form curves. In: Proceedings of the International Achieves of Photogrammetry and Remote Sensing. Processing Methods for Applied Analysis of Laser-Scanner Data. Freiburg, 3.–4. October. Freiburg, Institute for Forest Growth, Institute for Remote Sensing and Landscape Information Systems, Albert Ludwigs University: 78–81.

Ren H., Wu Y., Zhu X. (2006): The quadratic B-spline curve fitting for the shape of log cross sections. Journal of Forestry Research, ***17***: 150–152.

Saint-André L., Leban J.M. (2000): An elliptical model for the ring shape in transverse section, methodology and case study on Norway Spruce. HolzalsRoh- und Werkstoff, ***58***: 368–374.

Skatter S., Høibø O.A. (1998): Cross-sectional shape models of Scots pine (*Pinus silvestris*) and Norway Spruce (*Picea abies*). European Journal of Wood and Wood Products, ***56***: 187–191.

Singleton R., De Bell D.S., Marshall D.D., Gartner B.L. (2003): Eccentricity and fluting in young-growth Western Hemlock in Oregon. WJAF, ***18***: 221–228.

Taheri Abkenar K., Safarpour E. (2007): Performance of planted Maple in western Guilan province, Iran. Asian Journal of Plant Science, ***6***: 1143–1146.

Tong Q.J., Zhang S.Y. (2008): Stem form variations in the natural stands of major commercial softwoods in eastern Canada. Forest Ecology and Management, ***256***: 1303–1310.

Todoroki C.L., Monserud R.A., Parry D.L. (2007): Lumber volume and value from elliptical western hemlock logs. Forest Products Journal, ***57***: 76–82.

Warensjö M., Rune G. (2004): Stem straightness and compression wood in a 22-year-old stand of container-grown Scots pine trees. Silva Fennica, ***38***: 143–153.

Williamson R.W. (1975): Out-of-roundness in Douglas-fir stems. Forestry Sciences, ***21***: 365–370.

Received for publication February 25, 2012
Accepted after corrections November 7, 2012

Corresponding author:
Aidin Parsakhoo, Sari Agricultural Sciences and Natural Resources University, Faculty of Natural Resources, Department of Forestry, P.O. Box 737, Mazandaran Province, Sari, Iran
e-mail: Aidinparsakhoo@yahoo.com