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Radial variation in modulus of elasticity (MOE) in wood of Scots pine (*Pinus sylvestris* L.) growing in stands particularly exposed to wind

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Abstract: *Radial variation in modulus of elasticity (MOE) in wood of Scots pine (Pinus sylvestris L.) growing in stands particularly exposed to wind.* The study comprised an analysis of radial variation in modulus of elasticity (MOE) in wood of Scots pines growing in mature stands particularly exposed to wind. Investigations were conducted in eight different localities of this species in the Regional Directorate of the State Forests in Szczecinek. Analyses of modulus of elasticity in wood of 72 pines growing in different wind load zones proved the existence of differences in modulus of elasticity between the eastern and western exposure of tree stems. An effect was found for wind load of trees on radial variation in properties of wood tissue only on the western side of tree trunks.

Keywords: Scots pine, modulus of elasticity, radial variation, wind

INTRODUCTION

Wind modifies several characteristics of the stand, at the same time influencing its composition and structure and to a certain degree also its growth and condition (Ennos 1997). Susceptibility of stands to damage caused by wind depends on its specific character as well as stand structure. Much attention in literature on the subject has been devoted to the description of the effect of wind on forest ecosystems, including problems connected with the effect of wind on morphology and mechanics of the trunk (Peltola et al. 2006; England et al. 2000; Spatz et al. 2000, Jelonek et al. 2013). It is known that its action may cause several responses, including also physiological reactions, which at the stage of wood tissue formation leads to changes in its structure and properties (Wade and Hewson 1997).

A growing tree strives to develop an optimal structure, in which both physiological and mechanical functionality will be maintained (Mencuccini et al. 1997). Wind is one of the factors modifying growth conditions, physically influencing plant development. Sub-critical loads imposed by wind induce changes in wood structure, while loads exceeding this value lead to mechanical damage (Tomczak et al. 2013).

With the tree biometrics changing in time (with age) and with the increasing risk of wind damage, wood ultrastructure and properties undergo natural modifications. Wood within the stem of a single tree is thus highly heterogeneous and is characterised by variation both in the radial and axial system of the stem (Jelonek 2013). These changes from the point of view of mechanics may be one of the basic determinants of tree resistance to the action of wind.

This study comprised an analysis of adaptation growth in pines exposed to the action of wind. Radial variation in modulus of elasticity (MOE) was investigated in stands particularly exposed to wind.

METHODS

Investigations were conducted in 8 pine stands of age class V growing in the Regional Directorate of the State Forests in Szczecinek. The stands were selected to ensure similarity in terms of taxation characteristics, while at the same time in the west they were adjacent to open space. In each stand one experimental site was selected in the form of a rectangle, which one side (100 m) was adjacent to the stand edge neighbouring the open space. The second of the sides reached deep into the stand at a distance equivalent to three mean tree heights in the stand. Next each experimental site was divided into three zones of wind load on trees. Zone A – the strongest load, the zone neighbouring the open space. Zone B – average load, zone C – the smallest load, the zone most distant from the stand edge.

In each plot all breast height diameters and tree heights were measured and on this basis 9 sample trees were selected, three in each wind load zone. Mean sample trees were felled and from each tree material of 20 x 20 x 300 mm was collected to be further used in the determination of modulus of elasticity of wood. Wood with moisture content above fibre saturation point was tested, since such a wood tissue is found in a living tree, which corresponds to its actual elasticity and resistance to the action of external factors causing mechanical stress.

Collected empirical data were analysed using statistical methods with the application of the *STATISTICA 10PL* software package.

RESULTS

On average modulus of elasticity in wood of Scots pine was 5018 [MPa], its variation determined for the entire group of tested trees was 201385 [MPa].

In the radial east-west distribution statistically significantly higher values of modulus of elasticity were found on the western side of the trunk and on average the modulus was 5113 [MPa], while in the eastern side it was 4945 [MPa]. The western side of trunks of examined trees exhibited also a much greater variation in the discussed properties. Variance of modulus of elasticity on the western part of the stem was 23769 [MPa], while on eastern side it was 173073 [MPa] (Tab. 1).

Tab. 1 Basic statistical characteristics of modulus of elasticity of wood and the results of the analysis of variance

Direction	MOE [MPa]					
	Mean	Standard deviation	Variance	Minimum	Maximum	p
W	5113.35	1538.73	236769	1790.26	30204.35	0.006763
E	4945.39	1315.57	173073	1588.50	12319.93	
Total	5018.48	1419.10	201385	1588.50	30204.35	

Next the analysis of variation was conducted on modulus of elasticity in relation to the location of wood in the stem in each of the compared zones (A, B, C) of wind load on trees (Fig. 1).

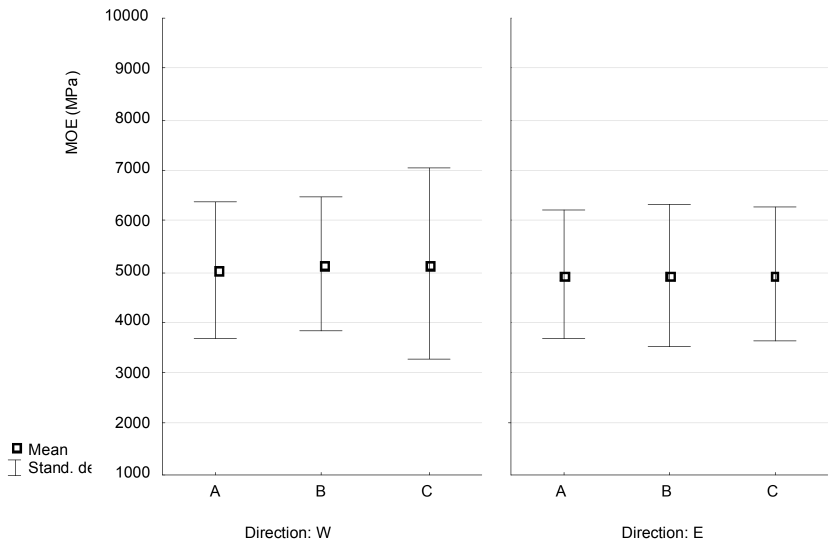

Fig. 1 Radial variation of modulus of elasticity in wood of trees growing in different wind load zones

On the western side of stems in the analysed pines a significant difference was found in modulus of elasticity between the investigated zones. The highest values of the analysed property were recorded in trees growing in wind load zones B (5163 MPa) and C (5155 MPa), while they were lowest, amounting to 5026 [MPa], in the zone of the strongest wind load. In turn, on the eastern side of trunks no significant differences were found in modulus of elasticity of wood between the compared zones (A, B and C). In all the zones on the eastern side of trees the values of modulus of elasticity of wood were very similar, amounting to 4947 [MPa] in zone A, 4923 [MPa] in zone B and 4965 [MPa] in zone C, respectively.

CONCLUDING REMARKS AND DISCUSSION

Wind significantly modifies forest ecosystems and it is one of the factors determining the formation of trees, landscape and site. Moreover, it continuously causes considerable economic losses in commercial forests and for this reason its effect has been investigated by many researchers (Zajączkowski et al. 1991; Peltola 2006; Quine and Gardiner 2007; Jelonek et al. 2012).

Changes occurring in wood structure and properties under the influence of stresses caused by wind load are usually adaptation responses. This term refers to non-hereditary individual changes developing under the influence of the environment, i.e. caused by e.g. mechanical stress. Under the influence of wind on the tree trunk bending, torsional, compressive stresses and their conjugated forms develop in tree stems (Tomczak et al. 2012).

Analyses indicate adaptation growth of the wood tissue subjected to dynamic loads imposed by wind. Properties of tree stems exposed to the action of wind were significantly different depending on the geographical east-west orientation (the leeward side and the windward side). Moreover, significant differences were found in modulus of elasticity between wind load zones of trees compared in this study. However, these differences were observed only for the western side of stems in the examined pines.

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Streszczenie: *Promieniowa zmienność modułu sprężystości(MOE) drewna sosny zwyczajnej (Pinus sylvestris L.) wyrosłej w drzewostanach szczególnie narażonych na działanie wiatru.* W pracy przeprowadzono analizę promieniowej zmienności modułu elastyczności (MOE) drewna sosny zwyczajnej wyrosłej w drzewostanach rębnych szczególnie eksponowanych na działanie wiatru. Badania przeprowadzono na w ośmiu różnych stanowiskach tego gatunku na terenie RDLP Szczecinek. Analizy modułu elastyczności drewna 72 sosen wyrosłych w różnych strefach obciążenia wiatrem dowiodły istnienia różnic w module elastyczności pomiędzy wschodnią a zachodnią stroną pni drzew. Stwierdzono również występowanie wpływu obciążenia drzew wiatrem na promieniową zmienność właściwości tkanki drzewnej jedynie po zachodniej stronie pni drzew.

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