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The effect of wind exposure on selected stability parameters of Scots pine stands

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Abstract: *The effect of wind exposure on selected stability parameters of Scots pine stands.* It was attempted in this study to determine the effect of wind selected indexes of stability of trees and pine stands. Analyses were conducted on the slenderness factor of trees, proportion coefficient of crowns as well as static bending strength and modulus of elasticity at static bending for wood of trees broken by wind and undamaged trees. Conducted studies indicate that stability of trees is influenced first of all by biometric traits determining their stability, i.e. tree diameter in relation to its height and the size of the crown. In contrast, no significant differences were found in biomechanical properties between trees broken by wind and undamaged trees.

Keywords: Scots pine, biomechanical, wind and trees, tree stability

INTRODUCTION

Wind influences the structure and functioning of forest ecosystems in a continuous manner and causes considerable economic losses in commercial forests, thus it has been the object of interest of many researchers (Fournier 2006; Peltola 2006; Quine and Gardiner, 2007). It affects forest composition (Ulanova 2000), forest condition and forest growth (Meng et al., 2006).

Damage in forests caused by wind is not limited only to the high static load of trees connected with its considerable velocity. It may also be connected with the reaction of trees to dynamic loads (Mayer 1987; Peltola et al., 1993; Kerzenmacher and Gardiner, 1998; Flesch and Wilson, 1999). In order to alleviate the effect of strong winds, many studies are focused on the understanding of the manner in which wind affects trees (Mayer 1987; Gardiner 1994; Wood 1995).

James et al. (2006) stated that the size of trees, their shape and structure influence mechanical stability at dynamic loads. It has to be related with the growth of trees, which to a considerable degree is determined by physiological limitations, particularly those concerning photosynthesis and water transport, but even if they are not exceeded there are also limitations to the size and shape imposed by biomechanical systems (Spatz and Bruechert, 2000).

Biomechanical theories of tree growth claim that the radial tree growth is the response to mechanical stress caused by the action of wind forces on trees (Baker 1995, Peltola 2006), so they describe the biomechanics of the stem (statics of trees) as the response to tree growth and the translocation of the centre of gravity subjected to gravitation forces (Alméras and Fournier 2008). According to Jaworski (2004) trees break when the moment caused by the translocation of tree weight in combination with the moment resulting from wind pressure exceed the breaking strength of the stem.

The aim of the study is to make an attempt at the determination of the effect of wind on fluctuations in certain indexes describing tree stability.

METHODS

Investigations were conducted in pine stands being in the age class III, located in the Świdwin and Kolbudy Forest Divisions. Experimental plots were selected so that wind damage accounted for at least 20% stand damage (broken trees).

On each of the plots all broken trees and neighbouring, undamaged trees were numbered. Next breast height diameters were measured on all marked trees and height was measured on standing trees. Subsequently height at which trees broke was also measured. On the basis of collected data model trees were identified. A total of 15 model trees were selected, which were divided into three classes in terms of diameter and three classes in terms of the height of windthrow. Additionally, 6 control trees, which had not bee damaged, were selected. All model trees were cut and next all biometric traits of the crown were measured. On this basis the stem slenderness factor was calculated, being a ratio of tree height to its breast height diameter (Jaworski 2004) and the proportion coefficients of the crown were calculated.

From each model tree a block from the breast height plane was collected for further laboratory analyses. Analyses of wood properties were conducted in the direction in which the stem broke and in the opposite direction.

Collected material was used in the determination of static bending strength (Rg) and modulus of elasticity (MOE), which were determined on a Tira Test 2300 testing machine equipped with computer software by Matest Service. Analyses of properties were conducted in accordance with respective standards PN-77/D-04103 and PN-63/D-04117.

All determinations were accurate to 0.01 MPa.

Static bending strength testing was performed on absolutely dry samples ($W_{0\%}$) and wet samples ($W_{>30\%}$), in which moisture content exceeded fiber saturation point (30%).

Collected empirical material was analyzed using methods of mathematical statistics using the statistical software package Statistica 9.0 PL.

RESULTS

It was attempted in this study to analyze the effect of wind on fluctuations in selected indexes describing stability of pine stands. Analyses were conducted on the slenderness factor of trees, proportion coefficient of the crown as well as static bending strength and modulus of elasticity. It was found that in trees, which had been damaged by wind, the slenderness factor was statistically significantly higher and it amounted to 109,1 than it was in trees undamaged by wind, in which this index was 88,9 (tab. 1, Fig. 1).

Table 1. Descriptive statistics of mechanical properties and biometric traits of analyzed trees

			Mean	*Standard dewiation*	*Minimum*	*Maximum*	*Coefficient of variation*
slenderness factor	Z		88.98	39.88	17.00	253.85	44.82
	S		109.08	48.45	42.32	265.71	44.41
proportion coefficient of crown	Z		2.21	0.64	0.56	4.00	28.83
	S		1.64	0.66	0.50	5.23	40.48
Rg [Mpa]	Z	$W_{0\%}$	82.60	33.84	1.26	198.12	40.97
		$W_{30\%}$	38.59	11.17	16.32	68.61	28.94
	S	$W_{0\%}$	85.18	31.64	21.08	148.33	37.14
		$W_{30\%}$	40.04	12.07	20.04	69.80	30.14
MOE [Mpa]	Z	$W_{0\%}$	6797	2532	116	15038	37.25
		$W_{30\%}$	3985	1769	1020	12395	44.38
	S	$W_{0\%}$	6774	2358	945	12003	34.80
		$W_{30\%}$	4189	1826	1915	8545	43.58

* differences statistically significant ($p \le 0.05$)

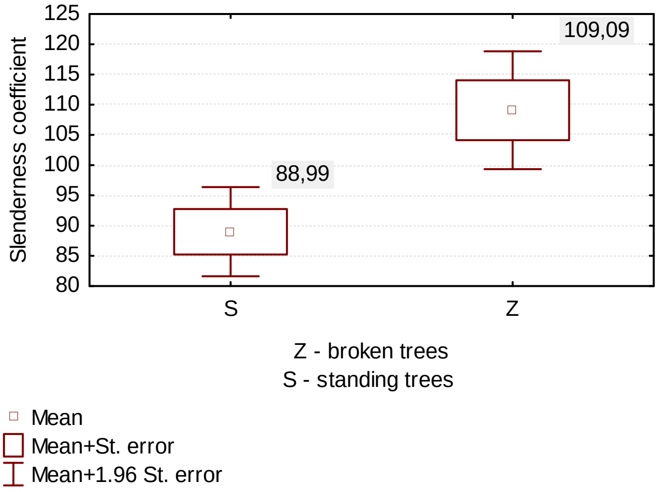

Fig. 1 Slenderness factor of trees

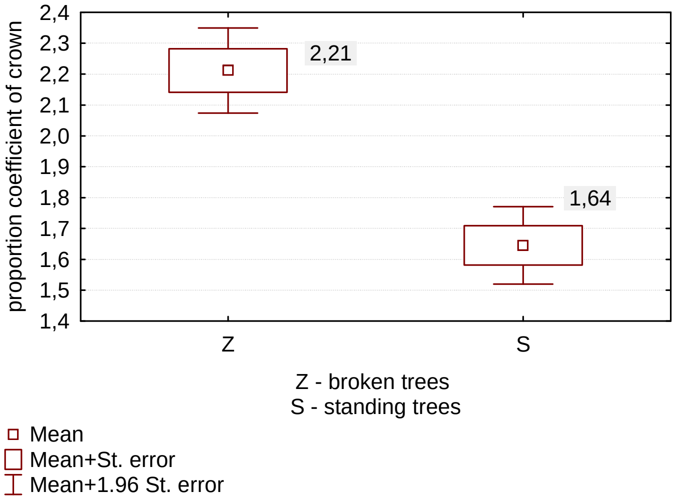

Fig. 2 The proportion coefficient of the crown

Similar results were obtained for the proportion coefficient of the crown, which in pines broken by wind was 2,2, while in undamaged trees it was 1,6 and it was statistically significantly lower (tab. 1, Fig. 2). This indicates that crowns of wind-damaged pines were less proportional in comparison to crowns of undamaged trees.

Next static bending strength was analyzed on absolutely dry wood and wood with a moisture content over the fiber saturation point. Windthrows were characterized on average by a slightly lower static bending strength both for absolutely dry wood (38,6 [MPa]) and wood with moisture content above the fiber saturation point (82,6 [MPa]) than it was in trees which had not been broken, in which these values were 40 [MPa] for dry wood and 85,2 [MPa] for wood at maximum fiber saturation (tab. 1, Fig. 3). At the same time it needs to be stressed that coefficients of variation were much higher in case of dry wood (tab. 1), which was most probably influenced by the desorption strengthening determined by the chemical structure of the wood tissue.

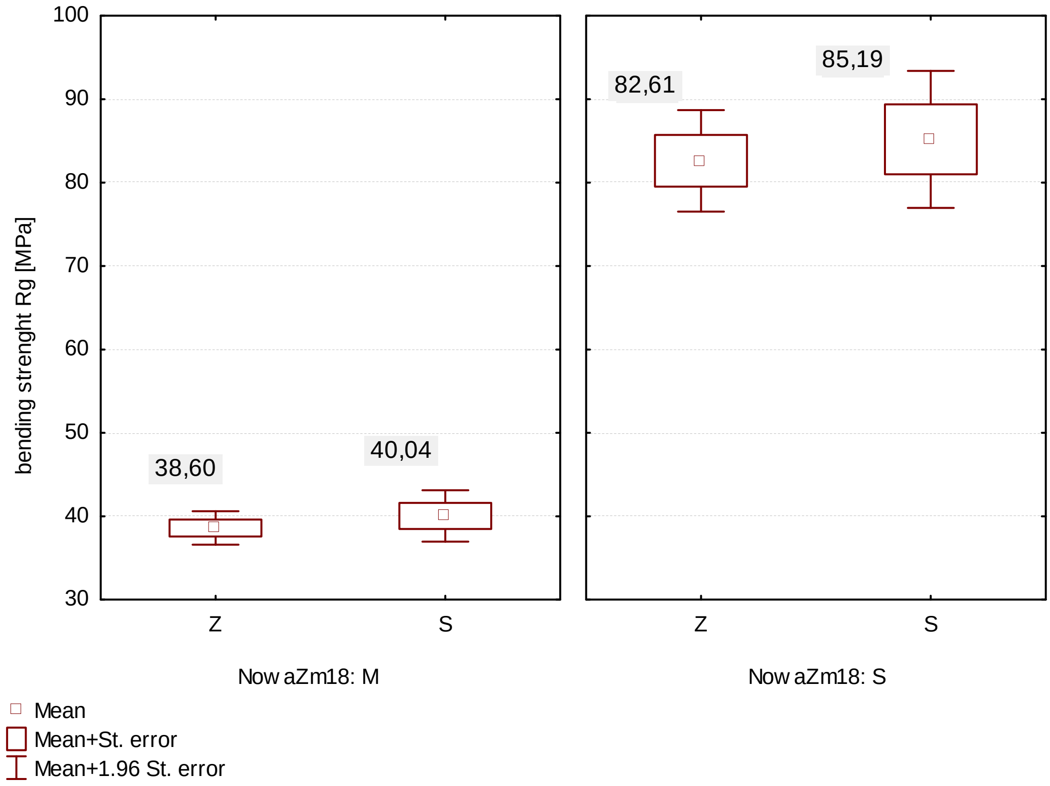

Fig. 3 Static bending strength (Rg) of wood with moisture content exceeding the fiber saturation point (M) and absolutely dry wood (S)

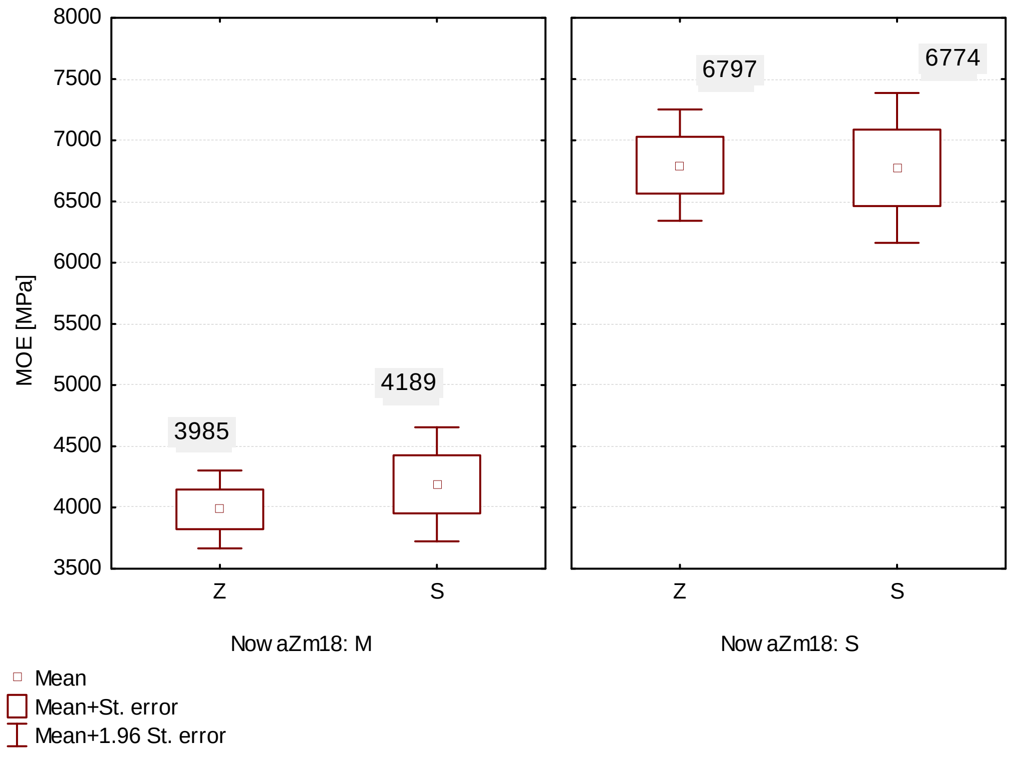

Fig. 4 Modulus of elasticity at static bending in wood with moisture content exceeding fiber saturation point (M) and absolutely dry wood (S)

Similarly as in case of static bending strength, the modulus of elasticity for wood with maximum saturation was slightly higher in case of undamaged trees and it was on average 4189

[MPa], while for wood coming from windthrows it was 3985 [MPa]. In turn, in case of the modulus of elasticity for absolutely dry wood slightly higher values were recorded for wood coming from windthrows (6797 [MPa]) than undamaged trees 6774 [MPa] (tab. 1, Fig. 4).

DISCUSSION AN CONCLUDIONS

A tree must be able to withstand all the physical loads throughout its life. For nearly all trees, the greatest load is from the wind that comes as gusts of rapid, periodic, dynamic events. Wind is the most persistent of the harmful natural forces to which any individual tree or forest stand is subjected (Jacobs 1936).

The main aim of the study was to make an attempt at the determination of the effect of wind on selected indexes of stability, described by individual biometric traits of trees and biomechanics of stems in Scots pines in stands damaged by wind.

Stability is determined by the slenderness factor and the proportion coefficient of the crown, which influences the statics of trees (Sellier 2009). In terms of biomechanics static bending strength was analyzed together with the modulus of elasticity in wood coming from damaged trees and trees undamaged by wind.

In different studies on the resistance of trees and stands to the action of wind stability of trees is defined by the slenderness factor (Erteld and Hengst 1966; Jaworski 2004; Peltola 2006). It is considered as an adequate measure for the determination of stability of trees and their resistance to the action of wind (Jaworski 2004; Peltola 2006). At the same time it needs to be stressed that less regular stands are more stable and thus more resistant to the action of wind than forest monocultures (Gardiner et al. 2005).

As a result of conducted investigations differences were found in the fluctuations of the slenderness factor and the proportion coefficient of the crown between trees, which were damaged by wind and undamaged trees. It was stated that damaged trees were those which were characterized by a high slenderness factor and proportion coefficient, i.e. trees with a relatively small breast height diameter at their considerable height and trees with long, slender crowns. The above statement is to a considerable degree consistent with the results reported by Sellier and Fourcaud on pines (2009). In turn, no significant differences were found between compared groups of trees in terms of static bending strength and in the modulus of elasticity. Thus it may be assumed that the resistance of trees to the action of wind is affected first of all by biometric traits, such as the ratio of tree height to breast height diameter or the size and symmetry of the crown.

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Streszczenie: *Wpływ działania wiatru na wybrane wskaźniki stabilności drzewostanów sosnowych.* W pracy podjęto próbę określenia wpływu wiatru na wybrane wskaźniki stabilności drzew i drzewostanów sosnowych. Analizie poddano współczynnik smukłości drzew, proporcjonalności koron oraz wytrzymałość na zginanie statyczne i współczynnik sprężystości przy zginaniu statycznym drewna drzew złamanych przez wiatr oraz drzew nieuszkodzonych. Przeprowadzone badania wskazują, że na stabilność drzew wpływ mają przede wszystkim cechy biometryczny warunkujące ich stabilność, to jest grubość drzewa w stosunku do jego wysokości oraz wielkość korony. Nie stwierdzono natomiast istotnych różnic we właściwości biomechaniczne pomiędzy drzewami połamanymi przez wiatr a drzewami nieuszkodzonymi.

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