Height of the Mass Point and Some Properties of Crown of 26 Year Old Scots Pine and Lodgepole Pine as Potential Parameters for Wind Damage in Zvirgzde, Latvia

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Abstract

Experimental plantation of exotic species and provenances of trees have been established to assess possibilities to increase productivity of stands. However, risks related with various hazards must be evaluated before commercial use of novel (introduced or exotic) tree provenances or species. One of such risks is wind damage, which can be related with crown properties and physical stability of trees. Lodgepole pine (*Pinus contorta* var. *latifolia*) from three provenances and local Scots pine (*Pinus sylvestris*) at the age of 26 years from experimental trial in central part of Latvia in Zvirgzde were sampled. Mass of branches in four quarters of crown, mass of stem and parameters of branches were measured. Height of the mass point of aboveground part of trees and distribution of crown biomass was determined and compared between provenances of lodgepole pine (LP) and Scots pine (SP). Similarity of distribution of crown biomass was determined by cluster analysis and the relationship between crown biomass and properties of stems and crowns were determined.

Height of mass point correlated with height of the tree, which was significantly higher for Summit Lake provenance of LP. However, the relative height of mass point was similar for LP and SP, ranging from 31.8 to 43.6% of tree height. The properties of crowns and trees differed between species; aboveground biomass was higher, branches were longer and thicker for SP. LP had higher ratios of branch mass-tree height, and branch mass-branch length. Only several parameters such as ratio of branch-stem mass, height of lowest living branch and diameter of the thickest branch in first two meters differed between provenances of LP. Four groups of trees established according to cluster analysis of crown biomass distribution consisted of trees from different provenances and species of trees and had different patterns of crown biomass distribution. Biomass of upper half of crown, length of crown, and branch length differed between groups of trees distinguished according to the distribution of crown mass.

Key words: tree provenances, crown properties, mass point of tree

Introduction

Increase in stand productivity, gaining higher yield in shorter time, is one of the main goals of forest management. Tree genetics play an important role determining necessary management for development of high quality stands (Burton 2011). In order to better understand an influence of genetics on tree growth and survival, many experiments, such as common garden and progeny trials of diverse provenances of native and exotic species have been established (Matyas 1994, Savill et al. 1997; Oleksyn et al. 1998, Spiecker and Hein 2009). Although the increase in wood volume increment is an important factor that affects the yield of stand (Kellomäki and Kolström 1993, Peng 2000, Mäkinen and Isomäki 2004), the estimation of risks related with various natural hazards, which may damage stands, are crucial for maintenance of stands economic value (Valinger and Fridman 1997, von Gadow and Hui 2001, Elie and Ruel 2005, Burton 2011). The damage caused by environmental hazards to a certain extent may be diminished by sustainable management or application of tree species and provenances with higher resistance (von Gadow and Hui 2001, Elie and Ruel 2005). However, all possible knowledge on growth and related risks for novel (introduced) tree species or provenances should be acquired before application in commercial use.

Mechanical damage to forest stands caused by wind and snow is one of the natural hazards resulting in notable economic losses (von Gadow and Hui 2001, Schelhaas et al. 2003). The importance of wind damage might be increasing in the future as increasing frequency and magnitude of storms is forecasted (Peltola et al. 1999a, IPCC 2007). The effect (damage) of wind depends on many factors like landscape, stand location and structure, individual properties of trees stems and crowns (Valinger and Fridman 1997, Peltola et al. 1999a, b, Talkkari et al. 2000, Rudnicki et al. 2004, Zeng et al. 2004, Lanquaye-Opoku and Mitchell 2005, Scott and Mitchell 2005). The risks related to landscape and stand structure may be minimized by stand management (von Gadow and Hui 2001, Donis 2006, Jactel et al. 2009), while individual properties of trees might be improved via tree breeding (Zobel and Talbert 2003). Among many characteristics of a tree that influence the effect of wind, the height of tree and properties of crown like width, density, branch thickness etc., have been described as the main factors affecting wind damage (Nykänen et al. 1997, Peltola et al. 1999b, Cucchi et al. 2005, Scott and Mitchell 2005). Although complex models, that include many stand and tree parameters have been developed to predict the effect of wind damage in a stand (Ancelin et al. 2004, Cucchi et al. 2005, Scott and Mitchell 2005), the height of the mass point (centre of mass) of tree may be used as proxy to estimate the risks of windthrow (Cucchi et al. 2005, Nicoll et al. 2006). Distribution of mass of the crown and properties of branches can be related to the density of crown (Elie and Ruel 2005, Tahvanainen and Forss 2008) and, therefore, it can be related also to the windage and possible damage caused by wind (Nykänen et al. 1997, Peltola et al. 1999b, Scott and Mitchell 2005).

SP is the most common tree species in Latvia; therefore, it has been subjected to more biotic hazards, such as pests, compared with exotic LP (Karlman 1981, Baumanis et al. 1992). Additionally LP had shown faster growth and higher wood increment compared with SP under similar conditions in Europe (Gallagher et al. 1987, Elfving et al. 2001). For this reason, experimental plantations of LP have been established in Zvirgzde Latvia in 1970s (Baumanis et al. 1992). Considering potential increase in pest activity due to climate change (Dale et al. 2001, Logan et al. 2003), wider use of LP in forestry might be considered. However, in central and northern Sweden, LP is also known to be more affected by wind and snow damage than SP (Elfving and Norgren 1993). Therefore, the knowledge on mechanic stability and windage of SP and LP in relation to susceptibility to the effect of wind in Latvia is necessary. The aim of the study was to compare the height of mass point of tree and distribution of crown biomass between 26-year-old SP and LP in the experimental plantation located in central part of Latvia in Zvirgzde and to determine the relationships between the crown mass distribution and properties of crown and tree.

Materials and Methods

Study area

The study area was located in the central part of Latvia, near Zvirgzde (56°28'20'' N lat., 24°17'20'' E long.) (Figure 1) on the flat relief, elevation was ~ 30 m a.s.l. According to data from Latvian Environment, Geology and Meteorology Centre (LEGMC), the mean annual temperature is ~ 5.5 °C, annual precipitation ranges from 500 to 650 mm. The coldest month is January (mean temperature is ~ -5 °C) and the warmest month is July (mean temperature is ~17 °C). Most of the precipitation falls during summer (June-August) and, therefore, decreases the risk of drought. Length of the vegetation period (the mean diurnal temperature being >5 °C) is ~185–190 days.

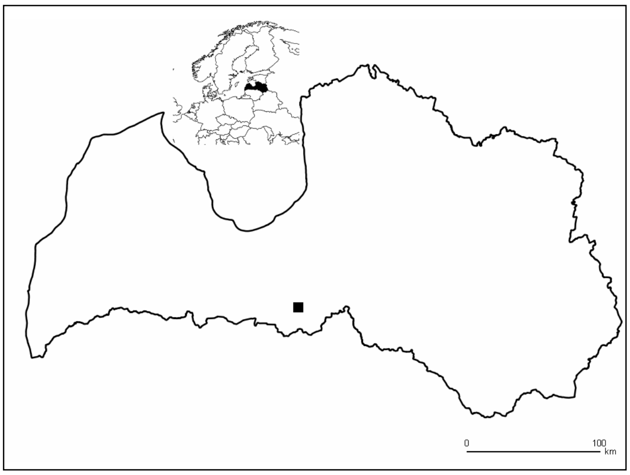

Figure 1. Location of the study site (black square)

The sampling site was the provenance trial of LP and trial of SP located directly besides it. Both trials were planted in 1985 by two years old bare rooted seedlings in *Vacciniosa* forest type (classification by Bušs (1976)). Initial spacing of trees in both trails was 2 × 1m (5,000 trees per ha), no thinning was made prior to sampling. The trials consisted of three provenances Pink Mountain (57°00' N lat., 122°15' W long.), Fort Nelson (58°38' N lat., 122°41' W long.) and Summit Lake (54°24' N lat., 122°37' W long.) of LP, each represented by 5 open-pollinated families, planted in 60 tree block plots and randomly distributed in 4 replications and open-pollinated progenies of local SP from the first generation seed orchards, planted in 50 or 100 tree block-plots and randomly distributed in 5 replications. Both trials were enclosed by three buffering rows of trees and they were surrounded by commercial plantations of the same age and similar height, thus reducing edge effect.

Sampling

Trees were sampled in autumn 2009. In total, 159 living LP (48, 52 and 59 trees for Fort Nelson, Pink Mountain and Summit Lake provenances, respectively) and 135 SP trees, representing height and diameter variability of the trials, were selected based on the trial inventory and felled. Trees, which might be subjected to the edge effect (i.e. distinct differences in height of neighbouring blocks) or had asymmetrical crowns, were not sampled. Cutting was done as close as possible to the root collar. For each tree, height and height of the lowest living branch (covered with green needles) were measured to the nearest centimetre. Diameter at breast height (DBH) was measured with precision of one millimetre. The stems were pruned, cut into one metre long fragments (beginning from the base) and weighted (the fresh weight) with precision of 0.01 kilogramme. Living branches and needles (dry branches were ignored) were divided in four quarters of crown of the equal length (accordingly from the lowest living branch (crown base) upwards) and weighted (the fresh weight) with precision of 0.01 kilogramme. Additionally, the diameter of all the branches and length of one randomly selected branch from each whorl within each part of crown were measured with precision of one millimetre and one centimetre, respectively.

Data analysis

For each tree, height of the mass point was calculated as the weighted average value of height of middle point and mass of each part of the tree (stem and crown segments) as $h_{mass\ point} = \frac{\Sigma m \times h}{\Sigma h}$, where m – mass or part of the tree and h – height of middle point of part of the tree. Relative height of the mass point was calculated as $h_{rel.\ mass\ point} = \frac{h_{mass\ point}}{H}$, where H – height of tree. Relationships between height of the mass point and height of trees were determined by Pearson correlation analysis (Sokal and Rohlf 1995). Univariate GLM was used to verify the effect of provenance on the mass point height, using tree height and diameter as covariates (Sokal and Rohlf 1995). Differences of the mass point height and crown parameters (height of tree and first living branch, DBH, diameter of the thickest branch up to 2 m height, length of living part of crown (stem with living branches), mean length of branch, approximation of mean and total branch cross-section area (calculated as sum of squares of branch radius) within each quarter of crown and whole crown, the mass of first meter of stem, slope and intercept coefficients of linear model of stem mass by height, total branch mass and ratios of tree height-DBH, branch mass-branch length, total branch mass-DBH, mean branch length-DBH, total branch mass-stem mass, and total branch mass-tree height) among provenances of LP and SP were compared with ANOVA and Tukey's HSD (Honest Significant Difference) test (Miller 1981).

To test if distribution of the biomass in living part of crown (beginning from first live branches upwards) differs between trees, the total mass of each quarter of crown was determined as the sum of mass of branches (with needles) and stem. For the estimation of stem mass according to quarters of crown, linear models were empirically fitted to mass data of stem segments (we assumed that the mass point of each segment was located in its centre and it also approved empirically during verification of models) for each tree; all models showed good fit and R^2 values were > 0.96. Stem mass of crown quarters was determined by definite integral of fitted linear functions (models) (Mellor 2007). The distribution of mass of crown quarters was determined as relativized (against total) sums of branch and stem mass. To test for grouping among trees based on distribution of crown biomass, a cluster analysis (McCune and Mefford 1999) (correlation used as the distance measure and group linkage assessed by Ward's method) was conducted in *R* (R Core Team 2012) using library "vegan" (Oksanen et al. 2013). Logical variable weather was used as grouping variable (trees were located on the edge or in the middle part of blocks). Proportions of trees from different provenances between four groups (established according to cluster analysis) were compared by chi-square test (Sokal and Rohlf 1995). Properties of trees and their crowns (described above) between provenances of LP and SP and between the groups established by cluster analysis were compared by ANOVA and Tukey's HSD test (Miller 1981).

Results

The height of trees and height of the mass point of tree was significantly (p-values < 0.01) higher for Summit Lake provenance of LP than for other provenances of LP and SP (Figure 2), that was also verified by GLM (using tree diameter or height as covariates). However, the height of mass point was positively and tightly correlated with height of tree in all four cases (r ranged from 0.88 to 0.96 for Summit Lake provenance

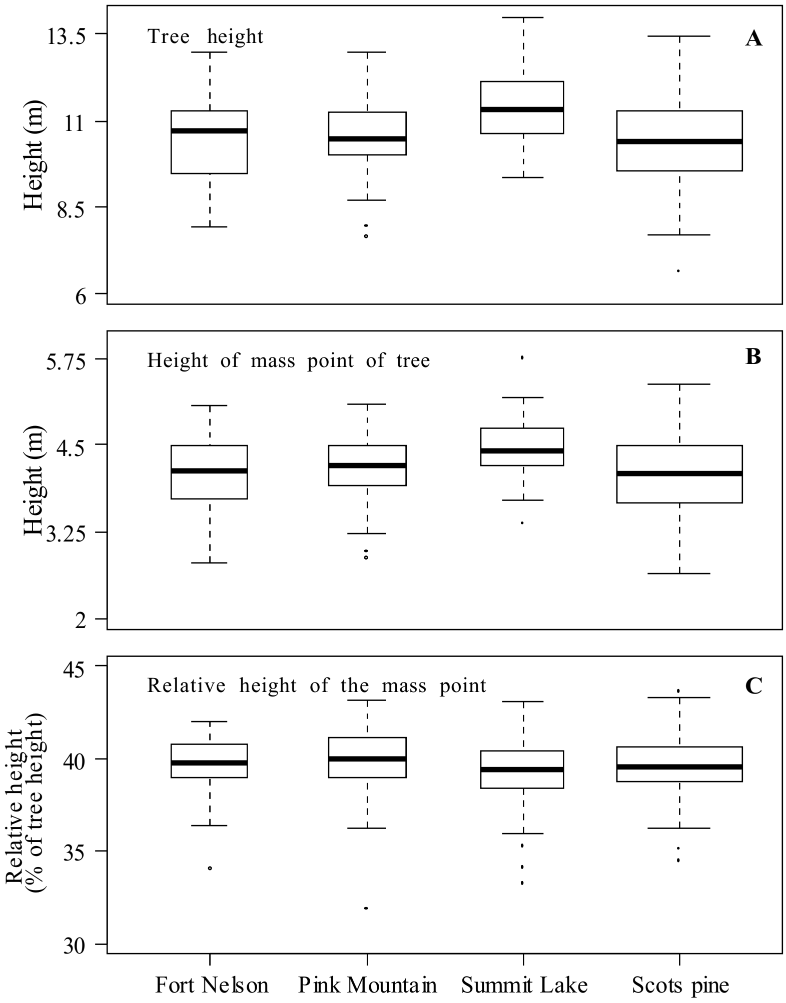

Figure 2. Height (A), height of mass point (B) and (C) relative height of the mass point (% of tree height) of sampled trees of LP (Fort Nelson, Pink mountain and Summit Lake provenances) and SP (C)

of LP and SP, respectively, (*p*-values < 0.01)), suggesting the height of mass point and height of tree have almost the same patterns of variation and other parameters affected up to 23 % of variation of height of mass point (Summit Lake). The differences of the relative mass point height between provenances of LP and SP were insignificant (*p*-values > 0.05. Most of the tested parameters of stems and crowns differed significantly between LP and SP (Table 1), suggesting differences in crown architecture. SP had significantly lower DBH, biomass of above ground parts (mass of quarters of crown and parts of stem, ratio of branch mass-DBH), while the branches were significantly longer (mean branch length and ratio of branch length-DBH) and thicker (higher mean cross-section) compared with LP. LP showed higher ratios of branch mass-tree height, and branch mass-branch length, thus more wood is allocated to branches. Only several of tested parameters differed between provenances of LP. Fort Nelson provenance had significantly higher ratio of branch-stem mass compared with Summit Lake provenance and SP. The height of lowest living branch was lower for Fort Nelson than for Summit Lake provenances. Diameter of the thickest branch in first two meters of stem significantly differed between provenances of LP and SP. The proportions of biomass of quarters of stem did not differ significantly between provenances of LP and SP, except for Pink Mountain provenance that had significantly higher proportion of biomass in third quarter compared with SP.

A cluster analysis of crown biomass distribution suggested that trees can be successfully grouped according to these criteria. The first two levels of division (used for establishment of groups) explained ~ 75 % of variation of data and four groups of trees were established. The distinguished groups differed by number of trees (from 24 to 123 trees for IV group and III group, respectively) (Table 1) and by composition of tree provenances (Table 2). Nevertheless, there were no tendencies regarding trees on edges of blocks, suggesting insignificant edge effect. Each group consisted of trees from all three provenances of LP and

Table 1. Differences of properties of sampled trees from provenances of LP and SP and from four groups of trees distinguished in cluster analysis. Effect of grouping was determined by ANOVA (*p*-values), differences between groups determined by pairwise Tukey's HSD test (*- *p*-value<0.05, letters indicate differences between specific pairs)

	Tree provenances (original groups)					Groups of trees distinguished by cluster analysis				
	Fort Nelson	Pink Mountain	Summit Lake	Scots pine	p-values	Custer I	Cluster II	Cluster III	Cluster IV	p-values
Number of trees	48	52	59	135		58	89	123	24	
Mean tree height (m)	10.42	10.51	11.31*	10.34	<0.01	10.23	10.65	10.65	10.81	0.12
DBH (cm)	11.8	11.6	11.7	10.7*	<0.01	11.1	11.2	11.3	11.3	0.95
Mass point height of tree (m)	4.14	4.20	4.43*	4.09	<0.01	3.97*	4.20	4.24	4.42	0.01
Relative height of mass point of tree (%)	39.71	39.96	39.18	39.58	0.10	38.76*	39.51*	39.76*	40.98*	<0.01
Height of the lowest living branch (m)	4.17*a	4.51	5.00a	4.90a	<0.01	4.92	4.66	4.70	4.77	0.51
Length of living part of crown (on stem) (m)	6.25	6.01	6.32	5.43*	<0.01	5.30*	5.99	5.96	6.04	0.01
Diameter of the thickest branch up to 2 m height (mm)	23.31*	20.59*	19.83*	17.45*	<0.01	19.40	19.59	19.58	18.21	0.96
Mass of first meter of stem (kg)	12.93	12.74	12.96	10.83*	<0.01	11.07	11.96	12.24	12.46	0.36
Mass of stem from first meter upwards (kg)	54.76	55.69	61.69	44.87*	<0.01	46.08	52.36	53.20	56.12	0.21
Branch mass (kg)	22.01a	20.22a	19.27	15.27*a	0.01	15.23	17.54	19.32	20.23	0.10
Mass of the first quarter of crown (kg)	16.74	15.41	16.01	11.22*	<0.01	12.53	14.73	13.88	13.34	0.52
Mass of the second quarter of crown (kg)	16.39	15.13	14.66	10.87*	0.01	10.68	11.88	15.41*	13.87	0.01
Mass of the third quarter of crown (kg)	11.29	10.62	10.57	6.92*	<0.01	5.86*	9.70	9.37	12.37	<0.01
Mass of the fourth quarter of crown (kg)	2.90	2.76	2.68	1.73*	<0.01	1.72*	2.28	2.50	2.74	0.01
Proportion of mass in the first quarter of stem (%)	36.21	35.30	36.78	36.53	0.31	41.29*	38.23*	33.50*	31.58*	<0.01
Proportion of mass in the second quarter of stem (%)	34.13	34.02	33.20	34.91	0.06	34.57*	30.38*	37.37*	32.17*	<0.01
Proportion of mass in the third quarter of stem (%)	23.44	24.13*a	23.62	22.47a	0.04	18.70*	25.23*	22.54*	29.37*	<0.01
Proportion of mass in the fourth quarter of stem (%)	6.22	6.54	6.40	6.08	0.60	5.43*a	6.15	6.57a	6.87a	0.01
Slope of model of stem mass and height	-1.31	-1.23	-1.18	-1.03*	<0.01	-1.12	-1.14	-1.15	-1.19	0.89
Intercept of model of stem mass and height	13.21	12.86	13.25	10.61*	<0.01	11.20	11.99	12.17	12.67	0.46
Mean length of branch in the first quarter of crown (m)	1.53	1.35	1.49	1.78*	<0.01	1.63	1.58	1.60	1.66	0.90
Mean length of branch in the second quarter of crown (m)	1.05	1.02	1.10	1.43*	<0.01	1.22	1.14a*	1.26	1.42a*	0.03
Mean length of branch in the third quarter of crown (m)	0.80	0.72	0.83	1.03*	<0.01	0.86	0.91	0.88	1.06*	0.03
Mean length of branch in the fourth quarter of crown (m)	0.37	0.33	0.38	0.43*	<0.01	0.38	0.38	0.40	0.45	0.06
Mean length of branch in the whole crown (m)	0.90	0.83	0.93	1.18*	<0.01	102.19	99.39	102.14	113.24	0.22
Total cross-section of branches in the first quarter of crown (cm^2)	40.64	39.46	38.61	27.62*	<0.01	37.79	36.92a	32.09a	24.53*a	0.01
Total cross-section of branches in the second quarter of crown (cm^2)	53.67a	50.75a	44.00	35.33*a	<0.01	37.93a	35.25a	50.39*a	43.58	0.01
Total cross-section of branches in the third quarter of crown (cm^2)	43.83	39.99	37.39	25.66*	<0.01	23.29*	35.72	34.48	45.14	<0.01
Total cross-section of branches in the fourth quarter of crown (cm^2)	15.97	13.74	13.03	9.48*	<0.01	9.53*a	11.47	13.39a	12.98	0.01
Total cross-section of branches in crown (cm^2)	154.95	144.16	134.27	98.82*	<0.01	109.51	120.22	130.77	127.57	0.20
Mean cross-section of branches in the first quarter of crown (cm^2)	8.14	7.08	7.21	10.63*	<0.01	11.05*	8.72	8.26	7.73	0.01
Mean cross-section of branches in the second quarter of crown (cm^2)	8.04	7.42	7.10	14.97*	<0.01	11.74	8.79*a	11.53a	13.69a	0.01
Mean cross-section of branches in the third quarter of crown (cm^2)	5.68	5.61	5.61	10.45*	<0.01	7.30	7.18	7.87	11.46*	0.01
Mean cross-section of branches in the fourth quarter of crown (cm^2)	2.35	2.06	2.10	3.80*	<0.01	2.83	2.54*a	3.07a	3.66a	0.01
Mean cross-section of branches in crown (cm^2)	5.88	5.42	5.42	9.81*	<0.01	8.06	6.69	7.55	9.03	0.05
Tree height-DBH ratio	88.50*a	90.91	97.09a	97.16a	<0.01	90.91	95.24	94.34	95.24	0.32
Branch mass-DBH ratio	1.78	1.65	1.59	1.30*	<0.01	1.29*a	1.48	1.62a	1.60	0.04
Branch length-DBH ratio (x 0.01)	7.61	7.16	7.98	11.00*	<0.01	9.19	8.88	8.98	9.78	0.39
Branch mass-tree height ratio	2.08a	1.88a	1.65	1.44*a	<0.01	1.46	1.61	1.77	1.85	0.15
Branch mass-branch length ratio	0.24	0.23	0.20	0.12*	<0.01	0.15	0.18	0.19	0.18	0.06
Branch mass-stem mass ratio	0.31*a	0.28	0.24a	0.26a	<0.01	0.26	0.27	0.28	0.28	0.45

SP; however, differences of tree composition were significant only between group I and group II (higher proportion of SP in group I) (Table 2). The pattern of crown biomass distribution among distinguished groups of trees differed significantly (Figure 3). Groups I and II consisted of trees, which showed similar decrease of proportion of biomass from lower to upper quarter of crown; group II had slightly higher proportion of biomass in third quarter of crown. Trees from group III had the highest proportion of biomass is second quarter of crown, while trees from group IV had similar distribution of biomass in first three quarters of crown. Proportions of biomass among first three quarters of crowns differed significantly between all four groups of trees, while proportion of biomass in fourth quarter of crown was significantly higher only in group I compared with group IV (Table 1). Several parameters of stems and crowns differed significantly between distinguished groups of trees. Trees from group I had significantly lower mass of third and fourth quarter of crown and length of crown but the mean cross-section of branches in first quarter of stem was higher. Trees from group II had shorter and thinner branches in second quarter of crown. Second quarter of crown was significantly heavier and total cross-section of branches was higher for trees in group III. Trees from group IV had significantly longer branches in the lower two quarters of crown; the branches

Table 2. Number of trees from different provenances of LP (Fort Nelson, Pink Mountain and Summit Lake) and SP in groups of trees distinguished by cluster analysis and significance of the differences between tree composition between groups (*p*-values of chi-square test)

Number of trees				
	Group I	Group II	Group III	Group IV
Fort Nelson	9	16	19	4
Pink Mountain	7	19	23	3
Summit Lake	7	24	24	4
Scots Pine	35	30	57	13
Differences in compositioin of trees between groups, p-values				
	Group I	Group II	Group III	Group IV
Group I		0.01	0.28	0.94
Group II			0.30	0.30
Group III				0.85
Group IV				

were thicker in the second quarter of crown; however, their total cross-section area was significantly smaller.

Discussion and conclusions

Height and DBH differed between provenances of LP and SP; LP overall had higher DBH and tree height compared with SP (Figure 2), therefore, suggesting higher wood increment, as observed in Scandinavia (Gallagher et al. 1987, Routsalainen and Velling 1993, Rosvall et al. 1998, Elfving et al. 2001). LP from Summit Lake provenance were the highest among the studied (Figure 2), similarly as observed in previous inventories of trials in Zvirgzde (Baumanis et al. 1992). Therefore, the faster growing Summit lake provenance might be more affected by wind if grown in mixture with slower growing trees (Ancelin et al. 2004, Cucchi et al. 2005). Although higher trees showed elevated mass point, the relative height of mass point was similar for both LP and SP (Figure 2), suggesting that properties of crown and stem might influence potential susceptibility to wind damage. Most of the tested crown parameters differed between LP and SP (Table 1) suggesting differences in stem and crown architecture and distribution of biomass.

SP had higher tree height-DBH ratio (stem taper (Burton 2011)) and lower slope coefficient from stem mass-height equations (Table 1), which might increase risk of windbreak (Mickovski et al. 2005); however, crown biomass was lower and branches were longer, lighter and thinner apparently suggesting lower crown density (Kellomäki 1986, Mäkelä and Vanninen 2001) and, therefore, lowering susceptibility to wind damage (windbreak) (Rudnicki et al. 2004, Scott and Mitchell 2005). In contrast, LP had heavier crown with higher density (thicker, shorter and heavier branches), but stem taper was lower; additionally, LP has slightly higher wood density and durability (Sable et al. 2012). Apparently there are no obvious advantages for any of studied species since the studied crown parameters increasing and decreasing susceptibility to wind damage seemed to countervail.

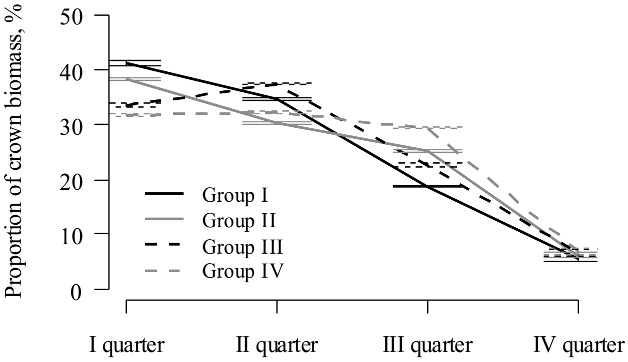

Figure 3. Mean distribution of crown biomass (branches and stem) by four quarters of crown for four groups of trees distinguished by cluster analysis. Error bars represent confidence intervals

Differences in crown parameters between provenances of LP were lesser than those observed between species as only several factors differed between one or two pairs of provenances (Table 1). This suggested that properties of crown and biomass distribution were rather similar for LP trees and there are species specific strategy of aboveground biomass allocation. Nevertheless, the ratio of tree height-DBH was higher for LP Fort Nelson provenance (Table 1), suggesting that these trees might be more resistant to windbreak due to relatively thicker stem (Valinger and Fridman 1997, Ancelin et al. 2004). However, it also had relatively higher branch mass (higher ratio of branch-stem mass) and the lowest mass of stem among LP (Table 1) suggesting distinct pattern of carbon allocation as less carbon is utilized in stem (log) growth. Branch diameter in lowest two metres of stem was the smallest for Summit Lake provenance of LP, suggesting higher quality of timber for these trees due to lower branchiness of stem (Savill et al. 1997, Spiecker and Hein 2009). This is also supported by lower total cross-section area and mean cross-section area of branches in crown for LP that implies smaller branches in upper parts of stem. However, stem taper was higher for Summit Lake provenance of LP, thus increasing susceptibility to windbreak (Mickovski et al. 2005).

Four groups of trees distinguished by a cluster analysis based on crown biomass distribution consisted of trees from all three provenances of LP and SP

(Table 2) suggesting differences in crown mass distribution might be related to different functional traits present within each provenance (Galinski 1989, Cornelissen et al. 2003, Geber and Griffen 2003, Reich et al. 2003). These differences in the crown mass distribution are likely caused by intrinsic factors (which might not be distinguished at provenance level) rather than local competition of crowns (Rouvinen and Kuuluvainen 1997), considering spacing of trees in plantation, as there was no significant difference in the tree height and DBH between distinguished groups of trees (Table 1), as shown by Rouvinen and Kuuluvainen (1997).

Crown mass distribution patterns between groups differed significantly (Table 1, Figure 3), suggesting different potential susceptibility to wind damage (Rudnicki et al. 2004, Scott and Mitchell 2005). Apparently, trees from groups I might be less susceptible to wind damage as higher proportion of crown mass is located in lower parts of crown (Galinski 1989, Peltola et al. 1999b, Mickovski et al. 2005). Trees from group IV appear as more subjected to damage by wind due to larger proportion of mass in higher parts of crown. This is also supported by differences in several tree properties among the groups of trees: group I had the lower mass point and group IV had the highest mass point, while height of trees were similar (Table 1). Additionally trees from group I had the lowest total cross-section of branches in third quarter of crown and the highest mean cross-section of branches in first quarter of stem (Table 1) that might also decrease potential effect of wind (Peltola et al. 1999b, Rudnicki et al. 2004). This differences, however, might be explained by the increased proportion of SP in group I compared with remaining three groups (Table 2). The size of the groups (number of trees) differed, suggesting that some patterns of crown mass distribution are more common. Group III was the largest (123 trees) (Table 1) suggesting that trees with the highest proportion of crown mass in the second quarter were the most common in the studied trials. Considering that group III had the second highest (relatively) mass point and the highest mass of stem and total cross-section area of breaches in second quarter of stem, these trees might be considered as rather susceptible to damage by wind (Rudnicki et al. 2004, Cucchi et al. 2005, Scott and Mitchell 2005). Group IV, which might be considered as the most subjected to damage by wind due to higher mass point and the longest branches, was the smallest (24 trees). Size of group I (which was considered as the less subjected to wind damage) was intermediate (58 trees). Thus about 20% of trees had crowns that might be less subjected to wind damage; however, about 50% of trees (III and IV group) showed relatively higher susceptibility to wind damage.

Height of mass point of studied LP and SP trees was generally determined by height of the tree, but the relative height of mass point was similar between LP and SP and expressed rather small variation, likely due to similar growing conditions. However, there were several properties of trees, which might be related with the potential damage of wind and which differed between provenances and species. Nevertheless, these properties seemed to countervail. Mass of crown and branches, DBH and length of crown (along plant axis) and taper was higher for LP, while SP had lighter, thinner and longer branches and lower taper. Thus there were no clear evidence of higher susceptibility to wind damage for LP based on crown architecture and biomass in Zvirgzde. Still, irrespectively of provenance or species, four groups of trees with different crown mass distribution and potentially differing possibility of wing damage (windthrow) were distinguished. About one fifth of trees, which had the highest proportion of crown mass in the lower part of crown, could be considered as less susceptible to wind damage. There were a half of studied trees, which had higher proportion of mass located in higher parts of crown, thus potentially having increased susceptibility to wind damage. Considering that trees with different crown properties were present in each provenance of LP and SP, tree breeding might be applied to decrease effect of wind damage. More detailed study dealing also with parameters of damaged trees and crown form (competition) is necessary to evaluate potential effects of tree genetics on susceptibility to wind damage that might result in recommendations for tree breeding program.

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ВЫСОТА ТОЧКИ МАССЫ И НЕКОТОРЫЕ СВОЙСТВА КОРОН У 26 ЛЕТНЕЙ СОСНЫ ОБЫКНОВЕННОЙ И СОСНЫ СКРУЧЕННОЙ В ЗИРГЗДЕ, ЛАТВИЯ

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Резюме

Экспериментальные плантации экзотических видов и происхождений деревьев создаются для повышения производительности насаждений. Тем не менее, риски, связанные с различными стихийными бедствиями, должны быть оценены, прежде коммерческого использования новых видов или происхождений деревьев. Одним из таких рисков является урон, наносимый ветром, который может быть отнесен к свойствами короны и физической стабильности деревьев. Скрученная сосна (*Pinus contorta* var. *latifolia*) из трех происхождений и сосна обыкновенная (*Pinus sylvestris*) возрастом 26 лет из экспериментальных плантаций в центральной части Латвии в Звиргзде были изучены. Масса ветвей , масса ствола дерева и параметры ветвей были измерены в четырех четвертях кроны дерева. Высота материальной точки надземной части деревьев и распределение биомассы кроны деревьев были определены и сравнены между тремя происхождений сосны скрученной (LP) и сосной обыкновенной (SP). Сходство распределения корону биомассы определяли с помощью кластерного анализа и отношений между биомассой корону и свойствами стволов деревьев и корон были определены.

Высота материальной точки коррелировала с высотой дерева, которая была значительно выше для Summit Lake происхождение LP. Однако относительная высота материальная точка была похожа для LP и SP, колебалась от 31,8 до 43,6% от высоты дерева. Свойства кроны деревьев отличались между видами; надземная биомасса была выше, ветви деревьев были длиннее и толще у SP. LP имели более высокие соотношения массы ветвей и высоты деревьев и масса и длина ветви дерева. Только несколько параметров, таких как отношение массы ветвь и ствола, высота самой низкой живой ветви дерева и диаметр самой толстой ветви в первых двух метров отличались между происхождений LP. Четыре группы деревьев, которые были выделены в соответствии с распределением биомассы кроны дерева, состояла из деревьев из разных происхождений и видов и имели различные закономерности распределения биомассы. Биомасса верхней половины кроны деревьев, длина корону, и длина ветвей дерева отличались между группами деревьев, которые были выделены в соответствии распределение массы короны.

Ключевые слова: происхождений деревьев, свойства кроны деревьев, материальная точка деревьев.