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DENSITY OF BASIC COMPONENTS OF ABOVE-GROUND BIOMASS OF POPLAR CLONES

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ABSTRACT

The experimental material was obtained from 20 trees of Robusta clone and 21 trees of I-214 clone on the territory of Slovakia. Samples of wood and bark were taken from three parts of stem and two parts of tree crown. Volume of the green samples was determined in calibrated graduated cylinders with precision of 1 ml and their dry weight with precision of 0.01 gram. Influence of 7 predictors, of them 3 factors (biomass fraction, location on tree and clone) and 4 variables (site index and age of stand, height and diameter of tree) on density of biomass fractions (wood, bark and small-wood) was analyzed by the generalized analysis of variance. Statistically significant influence appeared for all predictors except for height and diameter of tree. Average density of all biomass fractions were approximately in the range of 350-470 kg.m^{-3} and variation coefficients in the range of 4-13 %. Statistical tests showed that Robusta clone has higher wood density than I-214 clone. These differences are approximately 15 % on stem base and in middle stem, 10 % on crown part of trees and 4 % for small-wood. Differences in bark density between clones were not confirmed.

KEY WORDS: biomass, wood density, bark density, poplar clones

INTRODUCTION

At detailed investigation of forest production it is common knowledge that wood is basic but not the only component of above-ground biomass. In addition to wood, the biomass consists of bark, leaves, seeds and fruits too, and they in a natural fresh state contain also water. Their composition at the tree is changing according to tree species, growth medium of trees, but also with age. In work forest history of quantity of biomass fractions is presented mostly by volume in m^3. But experience has proved that for objective assessment it is necessary to indicate their production also by weight. In order to need not to determine biomass production in the forest in weight unit, be enough to recalculate their known volume in m^3 to weight. It is necessary to know density of single components of biomass for using such procedure. In order to exclude influence of water proportion, density is expressed in oven-dried weight. The density of a substance (Husch et al. 2003) is its mass per unit volume:

$$D = \frac{W_d}{V_g} \tag{1}$$

where: D – density of substance (kg.m^{-3}),
W_d – oven-dried weight of substance (kg),
V_g – green volume of substance (m^3).

When the density of a substance is divided by the density of water, the quotient is refereed as the specific gravity SG (Husch et al. 2003):

$$SG = \frac{D}{D_w} \tag{2}$$

where: D – density of substance (kg.m^{-3}),
D_w – density of water (1000 kg.m^{-3}).

Up to now the most a wood density was searched and according to several authors of soft leafy tree species have the lowest values of wood density. They are followed by coniferous and hardwood species. Požgaj et al. (1997) published for example these values of wood density: for spruce, fir and poplar of 370 kg.m^{-3}, for pine of 440 kg.m^{-3}, for beech of 560 kg.m^{-3} and for black locust and hornbeam of 600-650 kg.m^{-3}. Klašnja and Kopitovič evaluated for biomass of samplings of white willow of density of 377-402 kg.m^{-3} and for black locust of 576-580 kg.m^{-3}. Trendelenburg (1939) in Šmelko et al. (1992, p. 140) shows these values of density: for coniferous species 370-470 kg.m^{-3} and for hardwood species 510-570 kg.m^{-3}. Knigge and Schulz (1966) show similar values in Pretzsch (2009, p. 67). They are for poplars 377 kg.m^{-3}, coniferous species approximately 380-490 kg.m^{-3}, hardwood species 520-560 kg.m^{-3} and for False acacia till 650 kg.m^{-3}. The wood density with bark for determination of volume of pulp wood by weighting in Slovakia according to Šmelko at al. (2003) was stabilized for soft leafy species approximately 425 kg.m^3, for coniferous species 410-450 kg.m^3 and for hardwood species 550-630 kg.m^3. Požgaj et al. (1997) and Husch at al. (2003) shows that density is changed no only according to tree species but also according to the location on the tree. For most species there is a tendency to decrease of density from base to tip of stem and in the cross section of stems increase from the pith to the cambium. For more accurately recalculation of forest biomass from volume to weighted units, the density of single components of tree is necessary to know. In the concrete they are density of large timber, bark and small-wood (small timber with bark to 7 cm).

The aim of the work is to investigate density the basic components of above-ground biomass of trees (wood, bark and small-wood) of Robusta and I-214 poplars clones, to review variability of examined values and to evaluate model values necessary for recalculation their volume production to substance production.

MATERIAL AND METHODS

The experimental material was obtained from exploited 20 trees of Robusta clone and 21 trees of I-214 clone. The trees grew in forest stands of southern regions of western, central and eastern Slovakia with altitude for about 100-300 m. Most of the poplar stands were under the impression of ground water from surrounding rivers. A site index expresses a quality of location on which the trees grew. Stand index presents mean height of trees which given stand will reach at the age of 30 years (Petráš and Mecko 2005). The site index was in the range 22-40 m, at an average 31 m. The following values of age, breast height diameter ($d_{1.3}$) and height the best characterize of the choice trees:

	Minimum	Maximum	Mean
Age of trees	17	40	34
Diameter of trees $d_{1.3}$ (cm)	22	62	40
Height of trees (m)	23	41	34

Five samples of wood with bark were cat off from each tree. The first sample was from stem base, the second one from middle part of stem (for about under tree-top) and the third one from crown part of stem. All the samples were divided into wood and bark. Another two samples were taken from crown part of trees. The fourth one from branches of thickness for about 4-6 cm and the fifth one with thickness < 4 cm. Wood with bark stayed on these two samples together. For all 41 exploited trees were together analysed 328 samples, of this for wood 123, for bark 123 and for small-wood 82 (two by 41) samples.

The volume of fresh samples was stated in calibrated graduated cylinders with precision of 1 ml. The smallest sample had the volume of 320 ml and the biggest one 1,310 ml. All samples were dried at temperature 105 °C and their oven-dried weight was evaluated with precision of 0.01 g. The lightest sample had 140 g and the heaviest 575 g. The density of substance was calculated for each sample according to equation (1). Their variability was investigated and the most important factors by which depends density of the single component of above-ground biomass of poplar clones were defined.

The ANOVA generalized analysis of variance (more factors and variables) by means of QC.Expert computer programme (Kupka 2003) was used. The ANOVA go out from principle of addition of variances of known reasons (factors or variables) σ_i^2 and unknown ones (random) cause $\sigma^2_{residual}$ to the total variance σ^2_{total}:

$$\sigma^2_{total} = \sum \sigma_i^2 + \sigma^2_{residual} \qquad (3)$$

In the analysis of variance were used as reasons of 3 factors (clone, biomass fraction and location on tree):

– Clone with 2 levels – Robusta and I-214,
– Biomass fraction with 3 levels – wood, bark, wood with bark,
– Location on the tree with 5 levels – 3 locations on the stem (tree foot, middle of stem, in tree-top) and 2 locations of small-wood (4-6 cm, < 4 cm).

The additional 4 reasons (site index, age of stand, diameter and height of tree) were numerical variable. The total analysis was as a result of analysis of variance, where the total influence of all the factors and variables on the biomass density was assessed. In addition the analysis of variance according to single factors and variables was performed too. The concrete differences between the average values at the single levels were tested by Student's t-test.

RESULTS AND DISCUSSION

An influence of 7 predictors, there of impact of 3 factors and 4 variables on the 328 of density values of components of biomass was analysed by the generalized analysis of variance ANOVA. We can state (Tab. 1) that their overall influence on the density of biomass is statistical significance, p-value is less then the chosen significance level p=0.05.

Tab. 1: The overall test if the predictors have any influence at the density

Source of the Variability	Degrees of Freedom	Sum of Squares	Mean Square	F-statistic	p-value
Total variability	327	813992	2489	-	-
Explained variability	4	520483	-	2.74	2.48E-19
Residual variability	323	293509	909	-	-

The ANOVA was applied also in determine influence of the concrete factor on the biomass density (Tab. 2). The statistical significance influence, p-value is less then the chosen significance level p = 0.05 was showed to all predictors except for diameter and height of tree. The negation of parameter for site index pointed to the fact that density of biomass components with higher site index, i.e. with better site class is decreased. The opposite trend is for age of trees. The density is increased with higher age.

Tab. 2: The amount of variance explained by the predictors (factors and variables) at the density

Predictors (factors and variables)	Parameter	Sum of Squares	F-statistic	p-value
Biomass fraction	-	299340	94.52	4.84E-33
Location on the tree	-	427010	89.10	6.02E-51
Clone	-	39536	16.64	5.69E-05
Site index	-0.491952	24643	10.21	0.002
Age	0.801083	23308	9.64	0.002
Diameter breast height	0.681103	1598	0.64	0.423
Height	-1.968404	8575	3.48	0.063

The average densities and their standard deviations were calculated for single levels of all the three factors (Fig. 1). Theirs variability is relatively great. The average values of density are in the range for about 350-470 $kg.m^{-3}$ and variation coefficients for about 4-13 %.

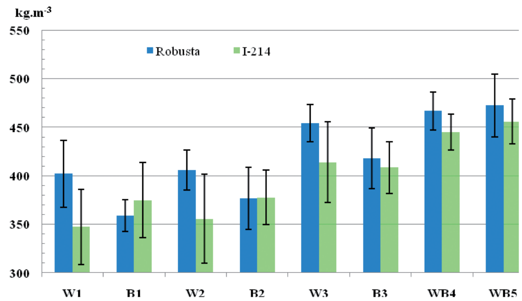

Fig. 1: The density of the elementary fractions of biomass of Robusta and I-214 of poplar clones. (W – wood, B – bark, WB – wood with bark, 1 – on tree foot, 2 – at middle of stem, 3 – in tree–top part, 4- small-wood of 4-6 cm, 5- small-wood of <4 cm)

The concrete differences between all the average densities on the single levels were tested by the Student's t-test ($p<0.05$). The test confirmed equivalent density for:

– the wood on tree foot (W1) and at middle of stem (W2), different according to clones,
– the bark on tree foot (B1) and at middle of stem (B2), without exception of clone,
– the bark in tree-top part (B3), without exception of clone,
– the wood (W3) and the bark (B3) of I-214 clone in tree-top part,
– the wood with bark of I-214 clone (W3B3) with bark of both clones in tree-top part (B3),
– the whole small-wood of wood with bark (WB4 and WB5), different for both clones.

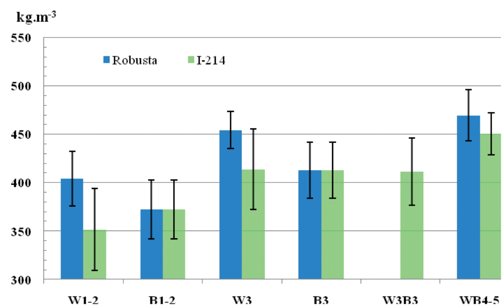

Fig. 2: The density of the aggregate fractions of biomass of Robusta and I-214 of poplar clones. (W – wood, B – bark, WB – wood with bark, 1 – on tree foot, 2 – at middle of stem, 3 – in tree–top part, 4- small-wood of 4-6 cm, 5- small-wood of <4 cm)

We can state (Fig. 2 and Tab. 3) that Robusta clone has higher wood density than I-214 clone. These differences are following: on tree foot and at middle of stem for about 15 %, in tree-top part about 10 % and for small-wood as little as 4 %. The differences in bark density between clones were not confirmed. Wood density but also bark density is changed with location on tree. It is increased from tree foot until tree-tops. Robusta clone has higher wood density than bark in a whole tree. This to be false for I-214 clone, that has of the wood density only 351 $kg.m^{-3}$ on tree foot and middle of stem, what is compared to bark in those same parts about 21 $kg.m^{-3}$ less. The density of the both fractions (W3 and B3) is equalized approximately in value 411 $kg.m^{-3}$ in tree-top part. In addition to an average density is interesting its variability too. I-214 clone has almost for all fractions higher relative variability like Robusta clone. The variation coefficients of I-214 are in interval 5-12 %. The average variability of Robusta is only in the range 4-8 %. The small-wood for both of clones has relative the lowest variability of 5-6 %.

Tab. 3: The statistical characteristics of density (kg.m^{-3}) of the elementary fractions of above-ground biomass of trees of poplar clones

Clone	Variable	Wood 1-2	Bark 1-2	Wood 3	Bark 3	Wood 3 with Bark 3	Small-wood 4-5
Robusta	Mean	403.9	372.2	454.2	413.1	-	469.6
	SD	28.3	30.5	19.2	29.0	-	26.4
	SD %	7.0	8.2	4.2	7.0	-	5.6
I-214	Mean	351.5	372.2	413.9	413.1	411.2	450.6
	SD	42.2	30.5	41.6	29.0	34.6	21.5
	SD %	12.0	8.2	10.1	7.0	8.4	4.8

The reached results correspond partly with up to now published knowledge. Differences between two clones were supported our results too. Robusta clone has on the full side wood density as I-214 clone, namely in a lower half of stems. Wood density is varied not only according to wood species but also by location on the stem (Požgaj et al., 1997 and Husch et al., 2003). It is higher near a ground and lower in tree-top. According to us results is the biomass density in tree-top higher for Robusta for about 11-16 % and for I-214 about 11-28 %. The oven-dried density we can compare only for wood. Knige and Schulz (1966) in Pretzsch (2009) and Požgaj et al. (1997) state its values for poplar wood of 377 and 370 kg.m^{-3}. These values in comparison with our values of 351-454 kg.m^{-3} for pure wood of both clones are low. If we were evaluated only I-214 clone, so compared wood density is only by 7 % higher to our wood density in middle part of stem. Our values of Robusta are about 7-20 % higher like compared values of 377 (370) kg.m^{-3} showed by Požgaj et al. (1997). The ones authors stated the wood density of main coniferous species in the range of 370-490 kg.m^{-3}. The wood density of Robusta clone with the range of 404-454 kg.m^{-3} would be fall within this range.

Šmelko et al. (2003) stated that in work history of volume determination of pulpwood by weighting for coniferous wood, then also for all poplar clones of wood density with bark is utilised the value of 425 kg.m^{-3}. This one is higher not only for Robusta clone but also for I-214 clone. The differences would be enlarged if we were added of lower density of pure bark to our values of density of pure wood. Petráš and Mecko (2005) were published of the growth and production models of Robusta and I-214 of poplar clones and they recommended to evaluate according to these two representatives also another poplar clones in Slovakia, That means, according to Robusta also Baka, P-275 and Palárikovo clones and according to I-214 also Blanc du pointou, Pannonia and Gigant clones.

CONLUSIONS

The density of the single components of above-ground tree biomass is crucial parameter in evaluation its natural production and possibilities their economic utilization. The poplar clones are characterized by very quickly growth and high production, especially of wood material. A high volume production and short rotation period is for them dominant namely in comparison to other tree species. They were evaluated in detail in Slovakia by Petráš, Mecko (2001, 2005). The weight of produced biomass for objective evaluation of production of poplar clones is necessary to know too. For its determination that means recalculation of volume to weight it is necessary to know of the density according to single components.

The experimental material form 20 trees of Robusta clone and 21 trees of I-214 clone from the territory of Slovakia. Five samples of wood with bark were cat from each tree. The first sample was from stem base, the second one from middle part of stem (for about under tree-top) and the third one from crown part of stem. All the samples were divided into wood and bark. Another two samples were taken from crown part of trees. The fourth one from branches of thickness for about 4-6 cm and the fifth one with thickness < 4 cm. Wood with bark stayed on these two samples together. For all 41 trees were together analysed 328 samples, of this for wood 123, for bark 123 and for small-wood 82 (two by 41) samples. A volume of fresh samples were stated in calibrated graduated cylinders with precision of 1 ml. All samples were dried at temperature 105 °C and were evaluated their oven-dried weight with precision of 0.01 g. A density of substance was calculated for each sample according to equation (1). Their variability was searched and the most important factors by which depends density of the single components were defined. The ANOVA generalized analysis of variance (more factors and variables) by means of QC. Expert computer programme (Kupka 2003) was used.

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