Quality of wood in the stands of poplar clones

R. Petráš, J. Mecko, V. Nociar

National Forest Centre – Forest Research Institute in Zvolen, Zvolen, Slovakia

ABSTRACT: The results obtained in research on the quality of raw timber by means of the structure of assortments for the stands of poplar clones Robusta and I-214 are presented in the paper. Models for an estimation of the structure of basic assortments of poplar stands were constructed separately for each clone in dependence on mean diameter, quality of stems, and damage to stems in the stand. The clone Robusta has higher proportions of higher-quality assortments than the clone I-214. The accuracy of models was determined on empirical material. It was confirmed by statistical tests that the models did not have a systematic error. The relative root mean-square error for main assortments of the clone I-214 is 15–27% and Robusta 13–24%.

Keywords: poplar clones; wood quality; assortment structure

In wood production not only the quantity is important but also the quality of wood is of increasingly growing importance. Higher-quality wood has the higher utility value and price. Relatively great attention is paid to these issues in Slovakia. In the past models of tree and stand assortment tables were constructed for 8 commercially important tree species, namely for spruce, fir, pine, oak and beech (Petráš, Nociar 1990, 1991), and for larch, hornbeam and birch (Mecko et al. 1993). Together with the models of yield tables (Halaj et al. 1987; Halaj, Petráš 1998) they were also used for the construction of assortment yield tables (Petráš et al. 1996), and together with the prices of wood and costs of wood logging also for the construction of the models of value production (Halaj et al. 1990). After a short break research on the production of poplar clones Robusta and I-214 continued, Petráš and Mecko (2001, 2005) elaborated the volume production of these clones in the form of models of yield tables. The research of these authors on the production quality started by the construction of tree assortment tables (Petráš et al. 2007) and continued by constructing stand assortment tables.

The aim of the paper is the construction of the models of stand assortment tables for poplar clones Robusta and I-214.

MATERIALS AND METHODS

We used the methodology of simulation by means of partial models, namely the following models:
– Tree assortments tables,
– Uniform height and volume curves,
– Probability density function of diameters.

Models of tree assortment tables

Models of Petráš et al. (2007) were used. They give the proportions of assortments in percent (quality and diameter classes of logs) in dependence on tree diameter d, stem quality qua and damage to stem dam according to the relation:

$$v\% = f(d, qua, dam) \qquad (1)$$

Quality classes of logs are characterized by quantitative and qualitative attributes specified in the Slovak technical standard STN 48 0056 of 2004 as follows:

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Quality class — Basic permitted attributes of the logs

*A*1 – minimal diameter 40 cm, upright, knot-free, twisted growth within 2%, without oblateness, heartwood decays within $^{1}/_{10}$.

*B*1 – minimal diameter 20 cm, upright, knots within 2 cm, twisted growth within 2%, without oblations, heartwood decays within 8 cm.

*C*1.1 – minimal diameter 20 cm, upright, 2 sound knots per m within 6 cm, 1 not sound knot per m within 4 cm, without decay, false heart within 40% of butt end, flame-like heart not permitted.

*C*1.2 – minimal diameter 20 cm, curvature within 4%, 2 sound knots per m within 12 cm, 1 not sound knot per m within 6 cm, without decay, false heart within 70%, flame-like heart within 40% of butt end.

*C*1.3 – minimal diameter 20 cm, curvature within 5%, sound knots without limit, 1 not sound knot per m within 8 cm, decay within $^{1}/_{3}$ of butt end, false heart permitted, flame-like heart within 50% of butt end.

*C*3 – not sound knots of 4–6 cm size, 6 per m, decay within 2/5 of butt end.

D1 – wood of worse quality than in *C*3 class intended as fuel wood.

Waste – volume of decayed wood that is not suitable even as fuel wood.

According to the purpose of industrial use classes *A*1 and *B*1 are the highest-quality classes being intended mainly for the production of industrial veneer while class *B*1 has slightly lower requirements on the wood quality than class *A*1 and it starts already with minimal diameter of logs 20 cm. Quality classes *C*1.1–*C*1.3 represent good quality, average quality and lower quality saw logs, and all have minimal diameter 20 cm. Class *C*3 is intended mainly for the pulp industry and class *D*1 includes fuel wood. The volume of larger decay or cavity, mainly in lower parts of stems, was included in waste. In 2007 the standard STN 48 0056 was amended and traditional marking of the quality classes of logs used in Central and Western Europe was re-introduced as follows: *A*1–I, *B*1–II, *C*1.1–III*A*, *C*1.2–III*B*, *C*1.3–III*C*, *C*3–V and *D*1–VI. Quality attributes of these classes remained in fact the same also in the amended standard of 2007. Diameter classes 1–6+ are defined according to the mean diameter of logs without bark.

Quality of stems was evaluated on standing trees according to their lower third as follows:

Class A – stems of the highest quality, upright, not oblate, without knots and twisted growth of wood fibres or some other technical defects. Only the most valuable logs could be produced from the evaluated part of stems.

Class B – stems of average quality with small technical defects (curvature, twisted growth of fibres), sound knots are permitted within 12 cm and not sound within 6 cm. Superior saw logs could be produced from the evaluated parts of stems.

Class C – low quality stems with great technical defects (curvature, twisted growth of fibres, other stem defects), sound knots are allowable without limit, not sound within 8 cm. Mainly low-quality saw logs and pulp wood could be produced from the evaluated part of stems.

Damage to stems was evaluated according to external visible signs. The most frequent were decays after mechanical damage to butts and buttresses, but in some localities also large damage to stems by woodborers.

Model of uniform height and volume curves

The model derived by Petráš and Mecko (2005) was used. It gives the dependence of the height of tree h in the stand on its mean diameter d_v, mean height h_v and individual diameter of concrete tree d according to the relation:

$$h = f(d_v, h_v, d) \tag{2}$$

Through connecting it with the model of volume tables by Mecko et al. (1994) a model of uniform volume curves is formed:

$$v = f(d_v, h_v, d) \tag{3}$$

It expresses the volume of tree v in dependence on mean diameter d_v, mean height h_v and tree diameter d. For simplification only the mean curve was selected from the model of height curves according to relation (2). Its position was determined according to the relation between mean diameter and height for average yield classes. Clone Robusta has yield class 32 and clone I-214 yield class 34.

Models of the probability density function of diameters

Three-parameter Weibull function was used, whose distribution form has the following shape:

$$F(d) = 1 - \exp\left(-\left(\frac{d - A}{B}\right)^{C}\right), d > 0, A \leq d < \infty,$$

$$B > 0, C > 0 \tag{4}$$

The first derivation of distribution function is the probability density function:

$$f(d) = \frac{C}{d} \times \left(\frac{d-A}{B}\right)^{C-1} \times \exp\left(-\left(\frac{d-A}{B}\right)^{C}\right) \tag{5}$$

Expected probability in the diameter degree n_i was calculated from the distribution function as a difference of its values in neighbouring diameter degrees:

$$n_i\,(d_i, \Delta d, N) = N \times \left[\exp\left(-\left(\frac{d-A-\Delta d}{B}\right)\right)^{C}\right.$$

$$\left. - \exp\left(-\left(\frac{d-A+\Delta d}{B}\right)\right)^{C}\right] \tag{6}$$

where: d – tree diameter or the middle of diameter degree,
A, B, C – parameters of the function,
Δd – half width of diameter degrees,
N – total probability.

Parameter A indicates the position or more exactly it determines the minimal diameter and beginning of distribution. Although parameter B indicates the scale and parameter C the shape of the function, the final shape of diameter distribution, i.e. its excess and asymmetry, is determined by the combination of parameters B and C (Gadow 1984).

For each measurement of sample plots a statistical model of diameter distribution according to function (4) was derived. Parameters A, B, C of likelihood model L were calculated by maximum likelihood estimate according to the logarithm of probability density function. Statistical package of programs QC.Expert was used. Likelihood of estimate, i.e. the rate of correspondence between the empirical and model distribution of diameters was evaluated by probability linearity of P-P graph (Meloun, Militký 2002). Selective density probabilities balanced according to function (5) were processed into continuous mathematical models where the density probability of trees in stands n_i is the function of their diameters d_i and mean diameter of the stand d_g according to the relation:

$$n_i = f\,(d_i, d_g) \tag{7}$$

We used the method of regression balancing of the parameters A, B, C of Weibull function of selective sets in dependence on their mean diameter d_g:

$$A, B, C = f\,(d_g) \tag{8}$$

Final models of the probability density function of diameters according to relation (7) were derived separately for clone Robusta and I-214. Empirical material consisted of the measurements of trees diameters $d_{1.3}$ on permanent research plots for poplar clones, and it was used also for the construction of their yield tables (Petráš, Mecko 2001). The measurements of research plots were also used for assorting (Petráš et al. 2007). In total 142 measurements for Robusta and 90 measurements for I-214 were used.

A model of stand assortment tables was constructed by connecting a partial model of tree assortment tables according to relation (1), uniform volume curves according to relation (3) and probability density function of diameters according to relation (7). It gives the amount of concrete assortment V in the stand in dependence on its mean diameter d_v, quality of stems *qua* and damage to stems *dam* according to the relation:

$$V = f\,(d_v, qua, dam) \tag{9}$$

The amount of assortments in the stand, particularly quality classes of logs I–VI (A1–D1) and diameter classes 1–6+, may be expressed by their volume or proportion in percent. The proportion of the number of trees in quality classes A, B, C gives the quality *qua* of stems in the stand. Similarly, their proportion in the total number gives damage *dam* to stems.

RESULTS AND DISCUSSION

Model structure of assortments

Model proportions of the quality classes of logs I to VI were derived separately for both clones according to relation (9). An example is 100% proportion of the highest quality stems of class A and 40% proportion of damaged stems. They are illustrated in Fig. 1 for the clone Robusta and in Fig. 2 for the clone I-214. It is obvious that the mean diameter of the stand affects the structure of the assortments in a decisive way. In general it is valid that with higher mean diameter the proportion of pulpwood assortments of class V decreases markedly and the proportion of round wood assortments of class I–IIIC increases. Their slight turn with contrary tendency occurs with the mean diameter of about 30–40 cm. The effect of damage to stems is logical but not so significant. With 40% proportion of damaged stems there are less high-quality logs and more good-quality logs only by 2–3% in the stands. After generalization we can state that with the same mean diameters the clone Robusta has higher proportions of the most valuable classes by about 7–8% than the clone I-214. But a high proportion of round wood assortments of class I–IIIC is very significant for both clones. It is for example almost 80% for undamaged stems of mean diameter 40 cm.

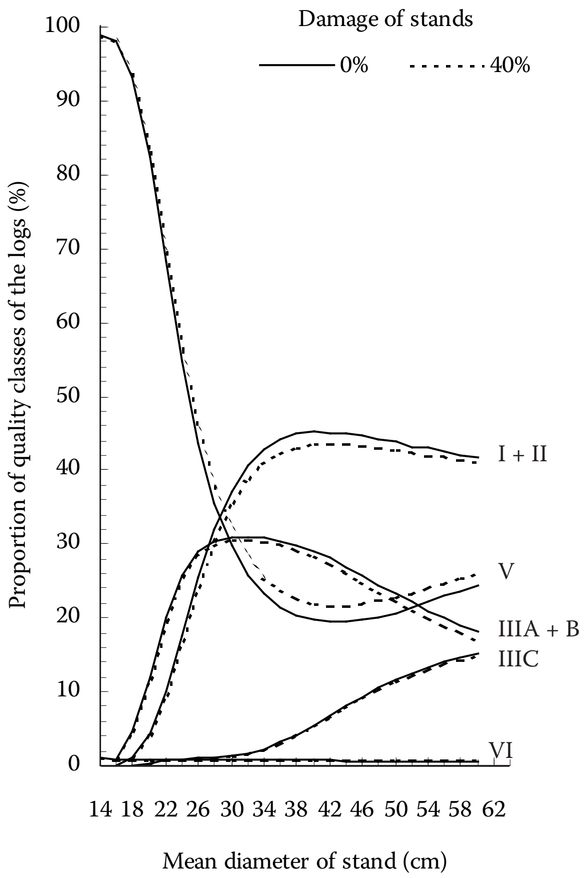

Fig. 1. Proportions of the quality classes of logs of clone Robusta with zero and 40% damage of stems of quality class *A*

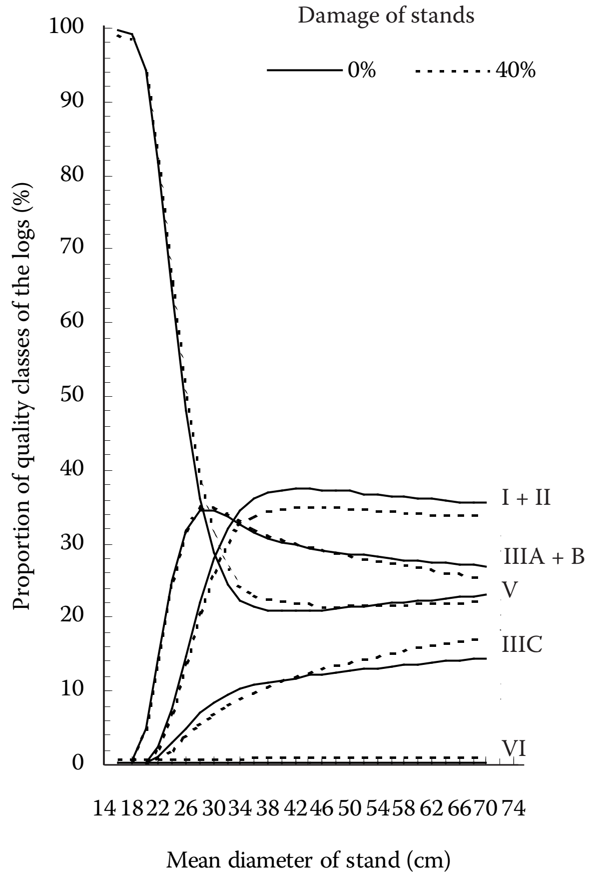

Fig. 2. Proportions of the quality classes of logs of clone I-214 with zero and 40% damage of stems of quality class *A*

The structure of the assortments for the stands with average quality of stems of class *B* is illustrated in Figs. 3 and 4. In these stands the proportion of pulpwood assortments of class V also decreases very significantly with higher mean diameter. It is about 26% for the clone I-214 and 20% for the clone Robusta. For both clones sawn wood logs of class III*A* and III*B* have the highest proportions in the whole range of mean diameters. They culminate with mean diameter 32–35 cm when the proportions reach 54–55%. These proportions slightly decrease with larger diameters but the proportions of lower sawn wood class III*C* increase. Also for the stems of average quality Robusta reaches about 17% proportion of the highest quality logs of class I and II. The clone I-214 reaches only 10% proportion with mean diameter 50 cm. With larger mean diameter these proportions decrease slightly.

If the structure of the assortments is compared with other broadleaved tree species, for example with oak and beech, we can state that Robusta with its highest proportion of the most valuable assortments is closer to oak and clone I-214 is closer to beech.

Correctness and accuracy of derived models

The correctness of stand assortment models as presented by Šmelko (2000) was assessed according to differences between the actual proportions of assortments (quality classes of logs) on sample plots and the proportions of assortments on these plots determined by assortment models. Actual proportions of the assortments on sample plots were obtained during the collection of empirical material for the construction of tree assortment tables. Petráš et al. (2007) present their detailed description and the proportions of assortments. Model proportions were calculated for each sample plot according to relation (9) on the basis of their actual mean diameter, proportion of quality classes of stems and proportion of damaged stems. Their differences, which we can note also as errors, were calculated according to the formula:

$$e = p_r - p_m \quad (10)$$

where: e – error of assortment estimate on sample plot,
p_r – real proportion of assortment on sample plot,
p_m – proportion of assortment on sample plot derived according to assortment models.

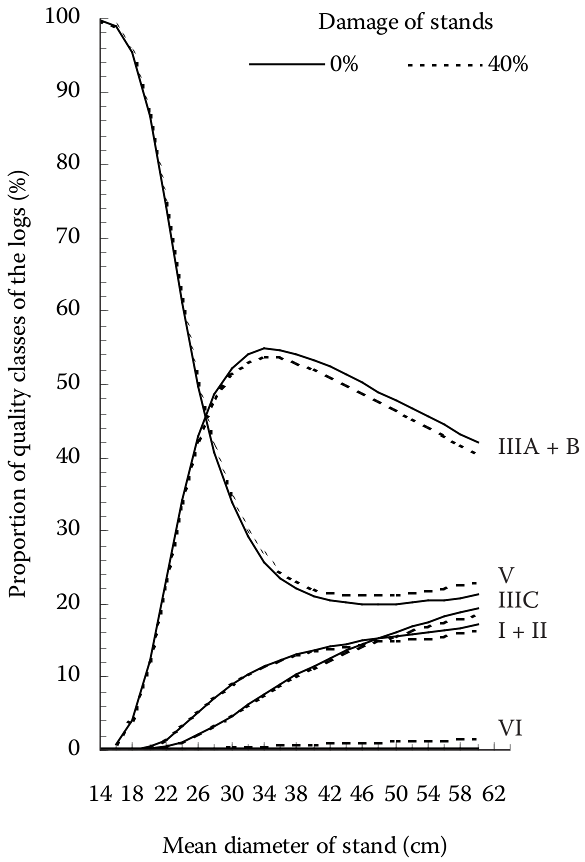

Fig. 3. Proportions of the quality classes of logs of clone Robusta with zero and 40% damage of stems of quality class *B*

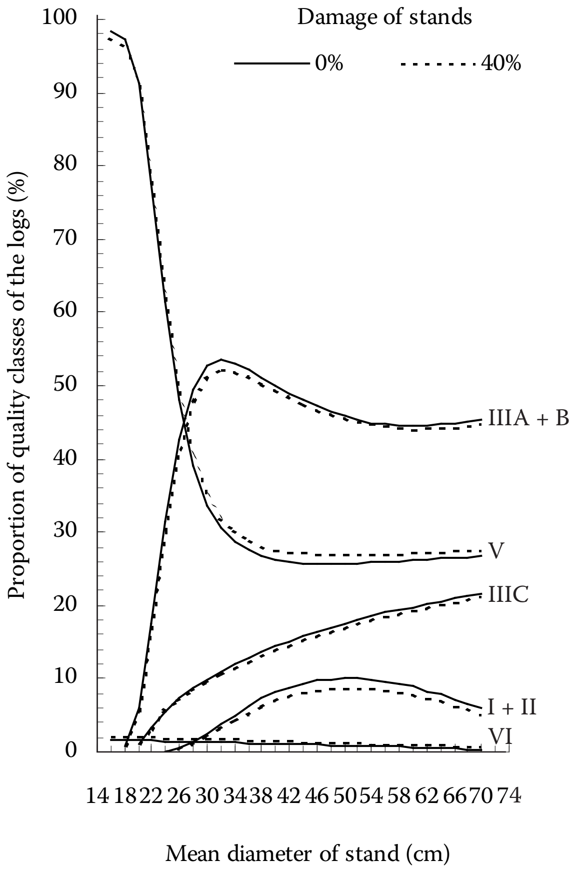

Fig. 4. Proportions of the quality classes of logs of clone I-214 with zero and 40% damage of stems of quality class *B*

The arithmetic mean of errors was calculated for each clone and its quality class I–VI of logs, which characterizes their systematic component, and standard deviation that characterizes their random component, it means model accuracy. The root mean square error that quantified total error comprises systematic as well as random component of the error and characterizes the model appropriateness:

Arithmetic mean of errors $$\bar{e} = \frac{\sum_{i=1}^{n} e_i}{n} \tag{11}$$

Standard deviation $$s_e = \sqrt{\frac{\sum_{i=1}^{n} (e_i - \bar{e})^2}{n-1}} \tag{12}$$

Root mean square error $$m_e = \sqrt{\frac{\sum_{i=1}^{n} e_i^2}{n-1}} \tag{13}$$

Relative root mean square error

$$m_e\% = \frac{m_e}{\bar{x}_r} \times 100 \tag{14}$$

where: e_i – error of assortment estimate on sample plot according to relation (10),
n – number of errors (sample plots),
$\bar{x}_r$ – arithmetic mean of real proportions of assortments on sample plots.

Relative root mean square error (14) expresses the percentage proportion of error variability in relation to the average proportion of assortments on sample plots. Then the derived models are correct when they do not have significant systematic error and random error is as small as possible. The significance of systematic error was tested by means of *t*-test and the value of testing parameter *t* was calculated according to the formula:

$$t = \frac{|\bar{e}| \times \sqrt{n}}{s_e} \tag{15}$$

Twenty-two sample plots were available for Robusta with the number of trees on the plots 15–158 and 21 plots for I-214 with the number of trees 12–163.

According to the calculated statistical characteristics in Table 1 we can state that all arithmetic means of the errors are within –0.82 +1.20% for Robusta

Table 1. Basic statistical characteristics of the errors of derived models for quality classes of logs I–VI

	I	II	III*A*	III*B*	III*C*	V	VI
I-214							
Arithmetic mean of errors	1.53	–0.50	0.01	–0.07	–1.28	0.18	0.18
Arithmetic mean of real proportions	6.53	3.79	21.12	17.83	19.70	29.18	1.79
Standard deviation	2.67	2.06	4.80	3.34	5.27	4.47	1.68
Root mean square error	3.10	2.13	4.80	3.34	5.43	4.47	1.69
Relative root mean square	47.39	56.14	22.71	18.74	27.57	15.33	94.55
t-calculated	2.63	1.12	0.01	0.09	1.11	0.19	0.48
t 0.05	2.09	2.09	2.09	2.09	2.09	2.09	2.09
t 0.01	2.85	2.85	2.85	2.85	2.85	2.85	2.85
Robusta							
Arithmetic mean of errors	1.20	–0.69	–0.82	–0.70	0.72	0.18	0.12
Arithmetic mean of real proportions	13.06	10.90	19.88	15.22	15.85	24.05	1.02
Standard deviation	3.18	2.94	4.35	2.71	3.41	2.85	0.93
Root mean square error	4.05	3.45	4.85	2.84	3.54	3.05	0.96
Relative root mean square	30.99	31.64	24.40	18.65	22.36	12.69	93.59
t-calculated	1.19	1.64	1.58	1.70	0.30	0.57	0.92
t 0.05	2.08	2.08	2.08	2.08	2.08	2.08	2.08
t 0.01	2.83	2.83	2.83	2.83	2.83	2.83	2.83

and within –1.28 +1.53% for I-214. The statistical test proved that these values were not significantly different from zero with 95% probability. There is one exception for the clone I-214, namely quality class I of the logs with mean error +1.53%, where the probability of insignificant difference increases almost to 99%. In total we can state that the models of stand assortment tables do not have a systematic error. Root mean square errors are relatively high. For main classes I–V of the clone I-214 they are within ± 2.1–5.4% and the clone Robusta within ± 2.8–4.8%. Relatively to the proportion of quality classes of logs these errors are within ± 15–56% for the clone I-214 and ± 13–32% for Robusta. The logs of quality class I and quality class II, which have lower proportions, also have higher relative quadratic mean errors. These errors are lower for the prevailing group of the logs of quality classes III*A*, *B*, *C* and V. They are within ± 15–27% for the clone I-214 and within ± 13–24% for the clone Robusta.

In comparison with the main coniferous and broadleaved tree species (Petráš, Nociar 1990, 1991) the errors of poplar clones are slightly smaller. In comparison with the models of other mensurational tables, e.g. volume or yield tables, we can state that assortment tables have higher mean errors in general. A decisive reason may be the fact that besides quantitative parameters assortment models contain also qualitative parameters, which have in general higher variability and their assessment is not so exact as the measurement of quantitative parameters. The introduction of further stand characteristics, e.g. range of tree diameters, mean height, kind of damage to stems, age of damaged stems, quality of site, etc, could reduce existing variability in the proportion of assortments. But extending the models by further parameters would make their broad use in practice more difficult.

CONCLUSIONS

Poplar clones have an extraordinary capability to produce a great amount of high-quality large wood on good sites and in a relatively short time. Models of stand assortment tables of poplar clones Robusta and I-214 are presented in the paper. The poplar clones may be divided into two groups according to their growth and quality. Poplar clones I-214 represent a group of clones with strong diameter growth and lower quality stem including the clones Blanc du Poitou, Pannonia and Gigant. On the contrary, Robusta has weaker diameter growth but markedly higher quality and full-bole stems. The clones Baka, P-275 and Palárikovo can also be classified into this group. The models were constructed by the purposeful connection of models of tree assortment tables, uniform height and volume curves and frequency curves of diameters. Concrete clone, mean diameter of the stand and the quality of stems markedly influence the structure of the assortments in poplar stands. In general, Robusta has a higher proportion of more valuable assortments than I-214. The proportion of more valuable assortments increases with the diameter of the stand only to about 40 cm. With greater diameter their proportions already decrease slightly. It is logical that the proportion of the most valuable assortments increases with the higher quality of stems and this is also the reason why the stands of Robusta have a higher proportion of more valuable assortments than the stands of I-214. Although the model accepted the damage to stems, its effect on the quality of wood is relatively low. The accuracy of derived models is different according to concrete assortments. In saw logs of class III*A*, III*B*, III*C* and pulpwood logs of class V, which have the highest proportion, the relative mean quadratic error is within 13–24% for the stands of Robusta and within 15–27% for the stands of I-214. These errors are approximately about 1–2% higher than in the case of models of tree assortment tables. Mean quadratic errors indicate frameworks of the model accuracy in the case of their application to one stand. Provided that they are used for larger sets, the accuracy increases. The mean error of estimation of the proportion of a concrete assortment decreases proportionally $\sqrt{n}$. This fact may be expected also because the derived models do not have a systematic error.

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Kvalita dreva v porastoch topoľových klonov

ABSTRAKT: V práci sa prezentujú výsledky, ktoré sa dosiahli pri výskume kvality surového dreva prostredníctvom štruktúry sortimentov pre porasty topoľových klonov Robusta a I-214. Zostavili sa modely pre odhad štruktúry základných sortimentov topoľových porastov osobitne pre každý klon v závislosti od strednej hrúbky, kvality a poškodenia kmeňov v poraste. Klon Robusta má vyššie podiely kvalitnejších sortimentov ako I-214. Presnosť modelov sa stanovila na empirickom materiále. Štatistickými testmi sa dokázalo, že modely nemajú systematickú chybu. Relatívna stredná kvadratická chyba pre hlavné sortimenty klonu I-214 je 15–27 % a pre Robustu 13–24 %.

Kľúčové slová: topoľové klony; kvalita dreva; štruktúra sortimentov

Corresponding author:

Doc. Ing. Rudolf Petráš, CSc., Národné lesnícke centrum – Lesnícky výskumný ústav Zvolen, T. G. Masaryka 22, 960 92 Zvolen, Slovensko
tel.: + 421 455 314 231, fax: + 421 455 314 192, e-mail: rudolf.petras@nlcsk.org