# Variation of Colour Properties between and within New *Robinia* Varieties with Enhanced Growing Rates from Different Sites

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This research analysed the colour properties of new *Robinia* varieties with enhanced growing rates. The investigations comprised new *Robinia* varieties grown on different East Hungarian sites. The colour coordinates were determined in the international CIELab system. The mean colour values of the wood of the different varieties did not show significant differences. However, the standard deviation of the measured colour coordinates showed higher values in the case of almost all varieties with high growth rates, compared to the controls (non-fast-growing). The higher colour variegation of most of the fast-growing varieties is attributed to some genetic property, as the standard deviation is independent from the mean annual ring width and the production site.

*Keywords: Colour measurement; CIELab; Robinia pseudoacacia L.; Robinia varieties*

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## INTRODUCTION

Black locust (*Robinia pseudoacacia* L.) is one of Hungary's most valuable trees. It is fast-growing, durable, malleable, ductile, and versatile. The tree is characterised by its richness of colour. Its sapwood is light yellow to light yellowish-brown, and its heartwood is greenish gray (Molnár and Bariska 2005). In the past, *Robinia* has been used mainly for firewood, rather than for visible structural elements (*e.g.*, upholstered furniture frames). Today, it has become a valuable raw material for interior decoration. This radical change of perspective is caused by the various breeding procedures which make it possible to change the colour of mottled wood or homogenise its colour (Varga and Van der Zee 2008; Dianiskova *et al.* 2008; Tolvaj *et al.* 2010). Colour also has a huge impact on international fashion trends, which show up in both the home furniture industry and architecture. The increasing energy needs of our modern world require us to create energy-producing forests. Because of ever-increasing energy prices and limited supplies, attention is focused on alternative, renewable energy sources, which require the establishment of a shorter cut rotation period.

A significant portion of information about wood products is obtained from visual inspection. Today, the technical characteristics and the durability of wood are of great importance, in addition to its aesthetics and appearance. In many cases, the colour of the material is relevant to its end use. Otherwise, the colour of the wood material is characterised by a rich diversity of varieties (Teischinger *et al*. 2012). For the rapid growth varieties this is even more so.

The various physical, mechanical, and chemical characterisations of wood are widespread. In contrast, the identification of precise colours of wood does not get much attention, despite the fact that the procedure is simple and reliable (Katuscak and Kucera 2000). This method ensures objectivity to help choose the correct parameters, in addition to safely separating similar wood materials such as spruce (*Picea abies*) and silver fir (*Abies alba*) (Katuscak *et al.* 2002). In addition, the method can be used in the classification of tree varieties on the basis of colour, which in many cases is important for manufacturers, as well as for consumers of parquet floors and furniture (Defoirdt *et al.* 2012).

Wood colour is never completely homogeneous because it is influenced by several factors. These are the various environmental factors that impact forestry, genetic characteristics, and the age of the tree. Forest site, topography, and climate characteristics have a profound effect on the quality and composition of wood varieties. These effects will vary by varieties, of course, and are not always clearly ascertained because of the large number of cross-effects. For example, teak (*Tectona grandis*) is similar to black locust in its formation of a darker hue of the secondary material, which is linked to the drier climate and deeper, more fertile soils on the growing sites (Moya and Calvo-Alvarado 2012). For the same varieties there is good correlation between the individual colour characteristics and age, rate of growth (height and width increase), and planting density (Moya and Berrocal 2010). The deviation of genetic characteristics is often manifested by differences in growth rates. Certain coloured heartwood in the varieties (*Robinia melanoxylon*) demonstrated a correlation between colouring and growth rate, but in others there was only just a poor correlation, which indicates that the relationship between colour edge features and genetic characteristics are dependent on specific wood varieties (Montes *et al.* 2008; Moya *et al.* 2013). Typically, the faster-growing, lower-density custom wood material is lighter in colour (Bradbury *et al.* 2011a,b). Older wood is usually darker, but there is an increased chance of unwanted colours (Drouin *et al.* 2009; Klumpers and Janin 1992).

The degree of colour variation within each tree variety is different; in some varieties, it is very low (*e.g.*, *Fraxinus excelsior*), while in others it is much higher (*e.g.*, *Juglans regia*) (Buchelt and Wagenführ 2012). In most European varieties, a linear relationship can be established between the lightness ($L^*$) and hue angle ($h^*$), but with the high secondary material of locust (*Robinia pseudoacacia*) and oak (*Quercus robur*), this cannot be said. This result also shows the importance of the additional materials in the development of wood colour (Tolvaj *et al.* 2013).

However, differences in colour may depend on which part of the trunk the sample comes from. Diversity within the trunk, however, is generally lower than in the forest stand (Drouin *et al.* 2009). The colour difference between heartwood and sapwood is the most prominent in the trunk, but the distance from the centre and the trunk height also affect the colour of the wood (Grekin 2007; Amusant *et al.* 2004). Darker colour ($L^*$) and a stronger red hue ($a^*$) is usually associated with higher long-term biological durability (Moya and Berrocal 2010; Gierlinger *et al.* 2004). However, the opposite could occur as well (Amusant *et al.* 2004).

Because of the rapid growth of these varieties, they have different anatomical structures (tree ring width, early-late growth ratio). Based on previous mechanical and physical tests of the varieties, they might become an important industrial raw material, but the variegation of colour raises important questions (for example, computer optimisation and surface treatment). The primary goal of our work is to display the colour variability of *Robinia* varieties (clones) with high growth rates. Increased growth rate achieved by the breeders are likely to affect the colour of the wood, which affects its interior use and interior design.

## EXPERIMENTAL

The selection of *Robinia* breeding groups (clones, varieties) was done for nearly 20 years. Plain seedlings grown in nurseries were sorted out between 1983 and 1988. Individuals with outstanding growth rates were planted into 6 East Hungarian experimental afforestation areas. These fast-growing *Robinia* varieties achieved yields of up to 200% compared with the traditional *Robinia* varieties.

In total, 26 strains of 10 different fast-growing *Robinia* varieties from six East Hungarian regions were investigated. In total, 4 strains of 3 different non-fast growing *Robinia* varieties served as the control. Codes of the different varieties and basic characteristics are shown in Table 1. Figure 1 and 2 show the main characteristics of the trees investigated in this study. Disc-shaped samples with the thickness of 10 mm were taken from 1.3 m above the base of the tree, 1 sample from each tree. The disc-shaped samples were cut in radial direction to get a radial wood surface for colour measurements. The colour measurement was performed on each sample.

**Table 1.** Basic Data of the Samples

| | Varieties code | Origin site numbers | Planted | Harvested | Number of samples | Strain diameter (mm) | | Annual ring width (mm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Mean | SD | Mean | SD |
| Fast growing varieties | A2 | I; IV; V; VI | 1985; 1995; 1997; 1999 | 2005 | 4 | 108.57 | 49.47 | 6.03 | 2.99 |
| | A7 | I; IV; V | 1985; 1995; 1997 | 2005 | 3 | 108.94 | 53.26 | 6.05 | 2.61 |
| | A32 | I; III; V | 1986; 1995; 1997 | 2005 | 3 | 113.63 | 10.43 | 5.88 | 2.70 |
| | A33 | I; III; V | 1986; 1995; 1997 | 2005 | 3 | 106.67 | 21.82 | 5.93 | 3.07 |
| | A54 | I; III; V; VI | 1986; 1995; 1997; 1999 | 2005 | 4 | 114.19 | 38.38 | 6.96 | 3.57 |
| | B2 | I; II | 1997; 1999 | 2005 | 2 | 123.55 | 46.71 | 11.23 | 7.15 |
| | B7 | I; II | 1997; 1999 | 2005 | 2 | 135.44 | 23.93 | 13.54 | 3.46 |
| | B32 | I; II | 1997; 1999 | 2005 | 2 | 120.13 | 65.78 | 12.01 | 6.12 |
| | B33 | II | 1999 | 2005 | 1 | 150.86 | 22.32 | 13.71 | 4.62 |
| | B54 | I; II | 1997; 1999 | 2005 | 2 | 130.9 | 37.17 | 11.90 | 8.68 |
| Control varieties | 0 | III; IV | 1985; 1986 | 2005 | 2 | 101.19 | 49.78 | 3.99 | 1.63 |
| | Ü | III | 1986 | 2005 | 1 | 112.36 | - | 6.24 | 3.02 |
| | NY | III | 1986 | 2005 | 1 | 99.76 | - | 2.93 | 1.01 |

**Fig. 1.** Control *Robinia* disc (Variety code: *O*) (Age: 20 years)

**Fig. 2.** New Variety disc (Variety code: *A54*) (Age: 10 years)

Colour analysis was carried out according to the CIELab colour system. The moisture content of air-dried, conditioned (T=20°C; φ=65%) samples was measured. For colour measurements, a Konica-Minolta CM – 2600d model spectrophotometer was used. The measurement was made on the radial surfaces. The first measured point was located next to the pith and the other measuring points were every 1 cm distance towards the sapwood. The data referred to the light source D65; the angle measured 10°; and the diameter of the illuminated surface was 3 mm. Average values of heartwood and sapwood were analyzed.

## RESULTS AND DISCUSSION

The mean values of the colour coordinates in the heartwood showed no significant differences between the investigated varieties (Fig. 3). The fast-growing varieties have similar mean values than the control varieties. In the heartwood, *L**, *a**, and *b** coordinates showed values about 65, 7, and 28, respectively in the case of both fast-growing and control varieties. However, most of the fast-growing varieties showed slightly higher *L** values, which can indicate a lower extractive content. The lowest *L** value (61,65) was observed for the variety *B33*. The mean values of *a** and *b** in the heartwood showed small differences between the investigated *Robinia* varieties (between 6 to 8 and 25 to 30, respectively). This result shows that it is not possible to significantly differentiate the investigated *Robinia* varieties by the mean values of the colour coordinates.

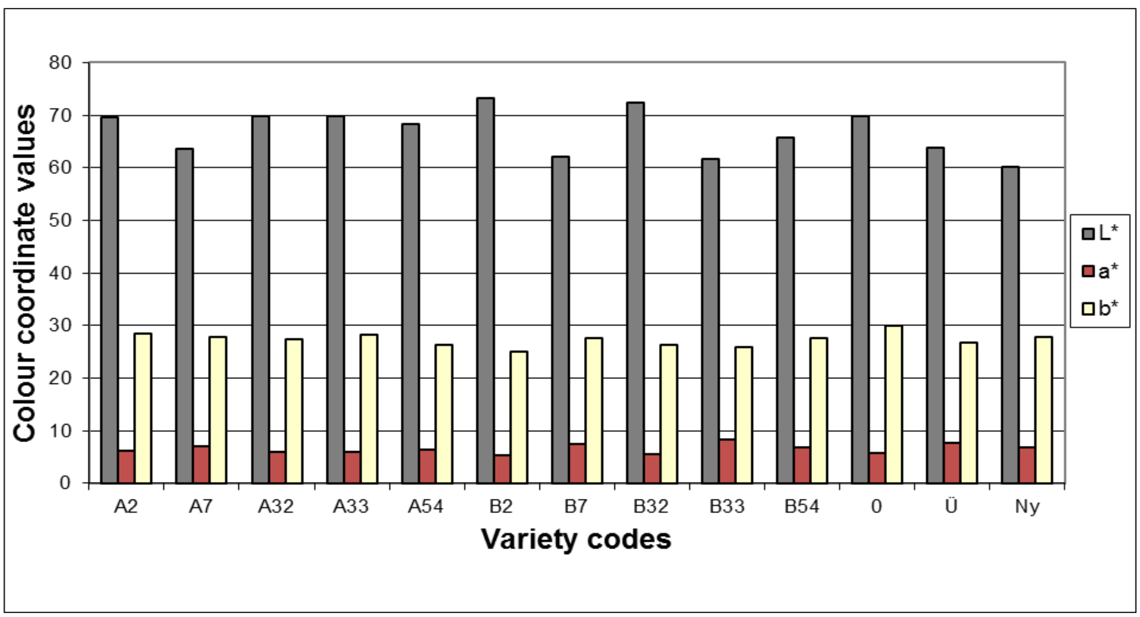


**Fig. 3.** Mean colour coordinate values of the investigated *Robinia* varieties in the heartwood

The mean values of the colour coordinates in the sapwood showed no significant differences between the investigated varieties as well (Fig. 4). In terms of the *L** coordinate, only the variety *B54* exhibited darker sapwood (73) compared to the other varieties (~85). Red hue (*a**) is very weak in the sapwood of *Robinia*, which is also indicated in the low values (generally between 0 and 1). The variety *B54* showed a small difference here as well, with the value of 3.5. The coordinate *a** turned in had values in case of the varieties *A32*, *A33* and *Ü*, which means the appearance of a very weak green hue (between -0.25 and -0.75). The mean values of the yellow hue in the sapwood (~30) showed no significant differences. Slightly higher values could be observed in case of the varieties A2 and NY (35 and 37, respectively).

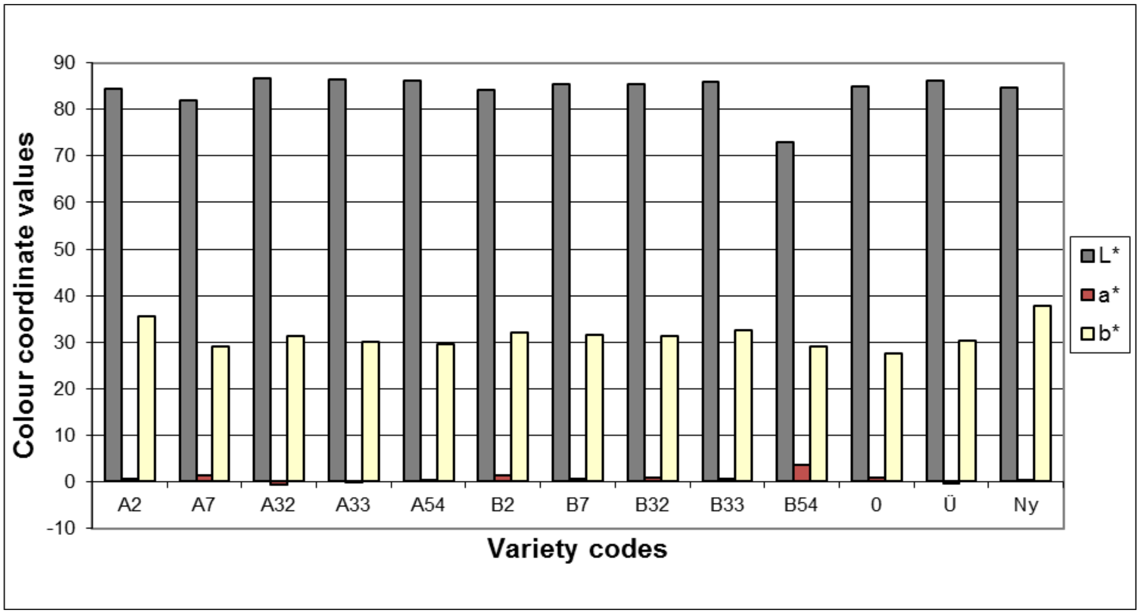


**Fig. 4.** Mean colour coordinate values of the investigated *Robinia* varieties in the sapwood

No significant tendencies could be found during the investigation of the mean values of *L** and *a** colour coordinates from the pith towards the sapwood in case of fast growing and non-fast growing *Robinia* varieties as well. In spite of that, in case of the colour coordinate *b** a significant growing tendency could be observed from the pith towards the sapwood, beside a similar variability as observed in the case of the other coordinates (Figs. 5a, b, and c.). These results show the colour diversity and stained appearance of the investigated *Robinia* varieties. The colour variability was high in the heartwood of all the investigated *Robinia* varieties (both the 10 fast growing and 3 control varieties). The colour variety was also represented well by the standard deviation (SD)-values.

SD-values of the colour coordinates for fast-growing varieties were, in general, higher than the control varieties (Figs. 6 to 8). SD-values of the lightness for almost all the fast-growing varieties were higher compared to the control varieties, except for the variety *A32*, which had similar SD to the control varieties. SD-values of the red hue for all the fast-growing varieties were higher as well, compared to the control varieties. However, there were two exceptions: Varieties *A32* and *B32* exhibited the same red hue SD-values as that of the control variety with the highest red hue SD (variety *O*). The same was observed in the case of the yellow hue SD-values, but the two exceptions were the varieties *A32* and *A54*. The results showed that the fast-growing variety *A32* had similar colour variability than the control varieties. This property makes it suitable for high-value applications, for example furniture or parquets.

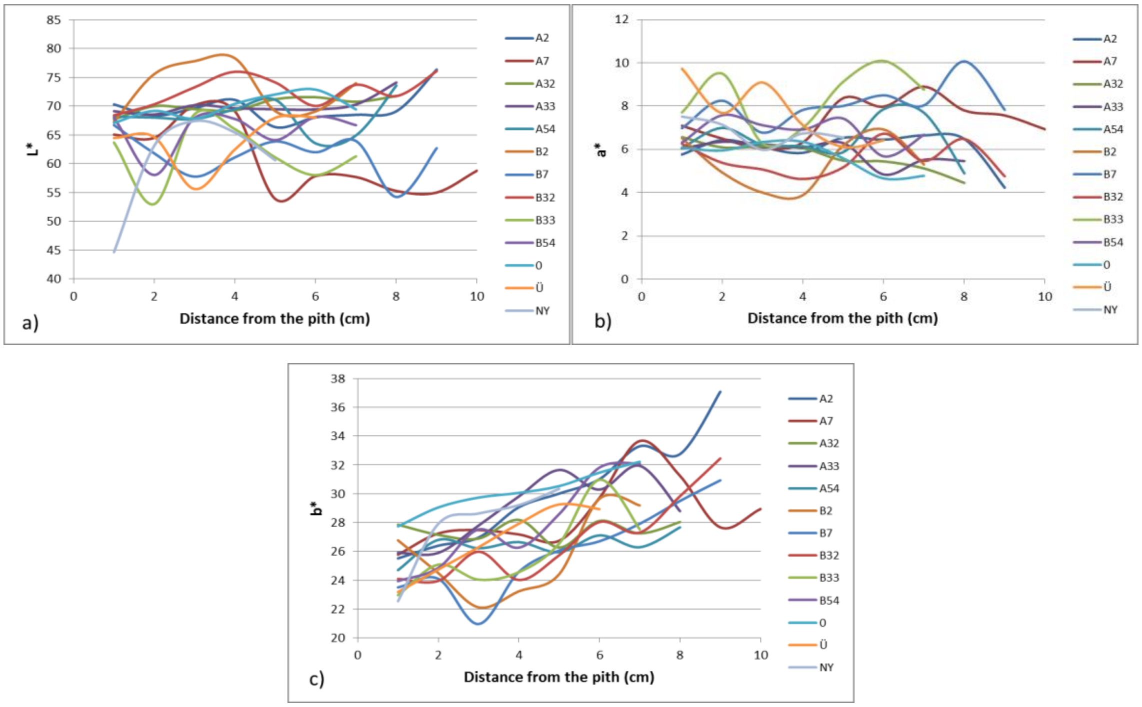


**Fig. 5.** L* (a), a* (b), and b*(c) colour values of the investigated *Robinia* varieties against the distance from the pith

On the other hand, in the case of fast-growing varieties, many outlier and extreme values of all colour coordinates could be observed which is not typical of the control (non-fast-growing) varieties (Figs. 4-6).

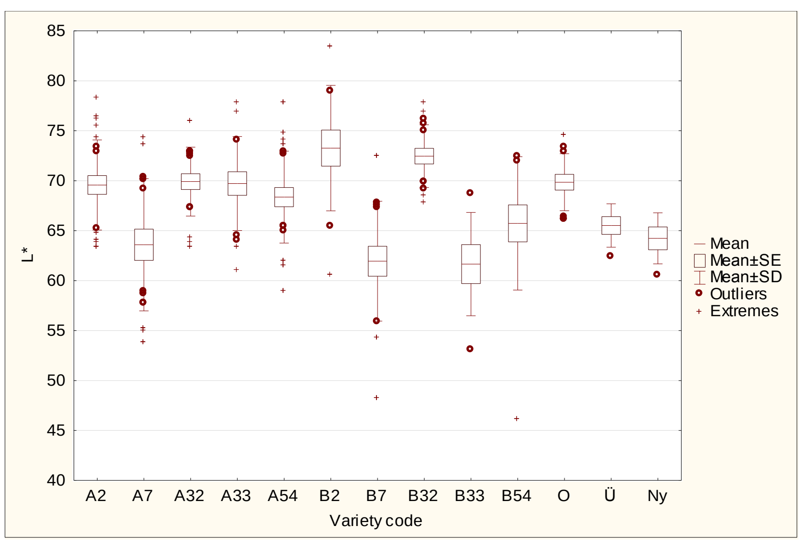


**Fig. 6.** Basic statistical values of *L** colour coordinate by the investigated *Robinia* varieties

Besides the high SD-values, this result also shows that the colour variability was higher for the selection of fast-growing varieties rather than non-fast-growing varieties. However, no correlation could be found between the mean annual ring width and the standard deviation of the colour coordinates. The correlation coefficient ($R^2$) was $2\times10^{-6}$, 0.126, and 0.166 for *L**, *a**, and *b** coordinates, respectively. Namely, the higher colour variability was not primarily due to the higher growing rate. The samples of the former mentioned fast-growing variety *A32* had originated from 3 different growing sites. The samples of the varieties *A33* and *A54* originated from the same sites, but they showed much higher SD-values; thus the effect of the growing site can be excluded as well. The colour variability or higher SD of the colour values is considered a varietal characteristic. The reason for that can be that the investigated varieties are actually clones propagated from the same root; thus the genetic diversity is very low among a variety. Therefore, it is suspected that the specimens that were selected for fast-growing already had the higher colour variability, independently from the growing rate. Thus, it is possible that this property has no correlation with the annual ring width.

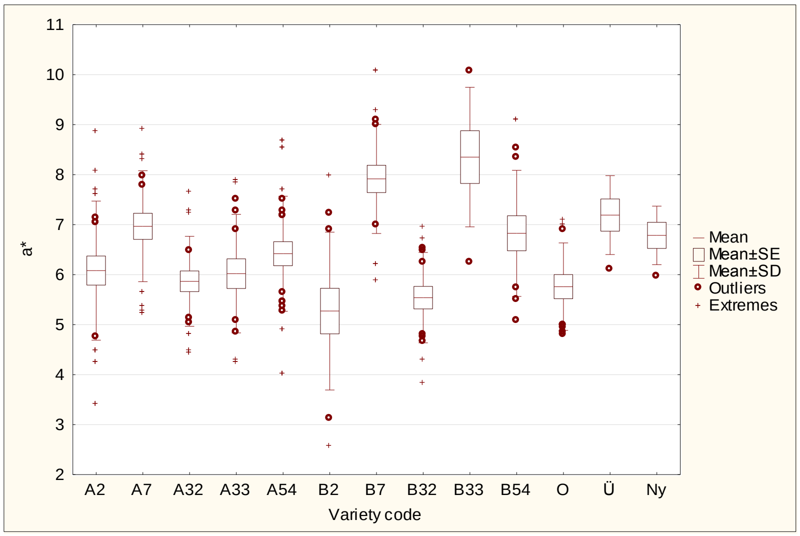


**Fig. 7.** Basic statistical values of a* colour coordinate by the investigated *Robinia* varieties

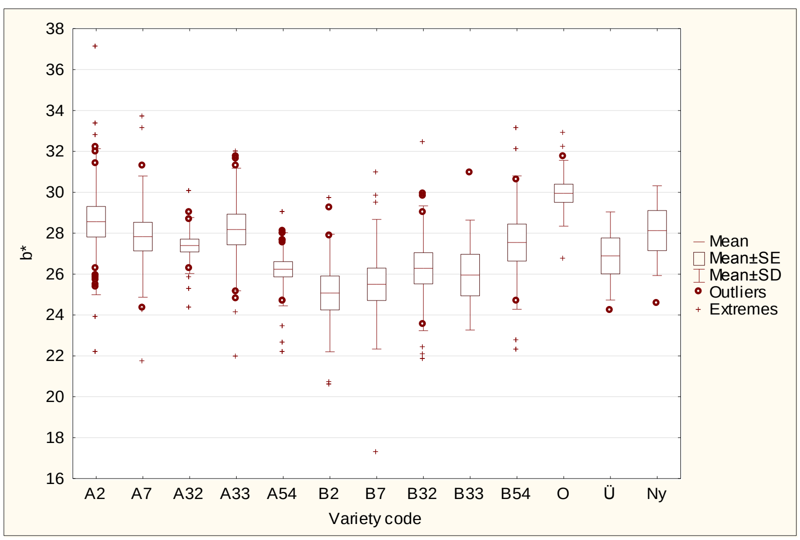


**Fig. 8.** Basic statistical values of *b** colour coordinate by the investigated *Robinia* varieties

The mean values of the color coordinates did not show the darker, brownish spotting of the heartwood which could be seen with the naked eye (Fig. 9). It means that it is not possible to determine the applicability of the *Robinia* wood according to the mean colour values of the heartwood or sapwood, from the point of view of the aesthetic aspects. It is necessary to investigate the standard deviation of the colour coordinates to show the color variability of the different varieties. *Robinia* is a ring-porous species; therefore the higher growth rate results in thicker latewood and higher latewood ratio (Kollmann 1941). Accordingly, the latewood will have more influence on the colour of the wood in the case of the fast-growing varieties, all the more so because latewood generally contains more extractives than earlywood.

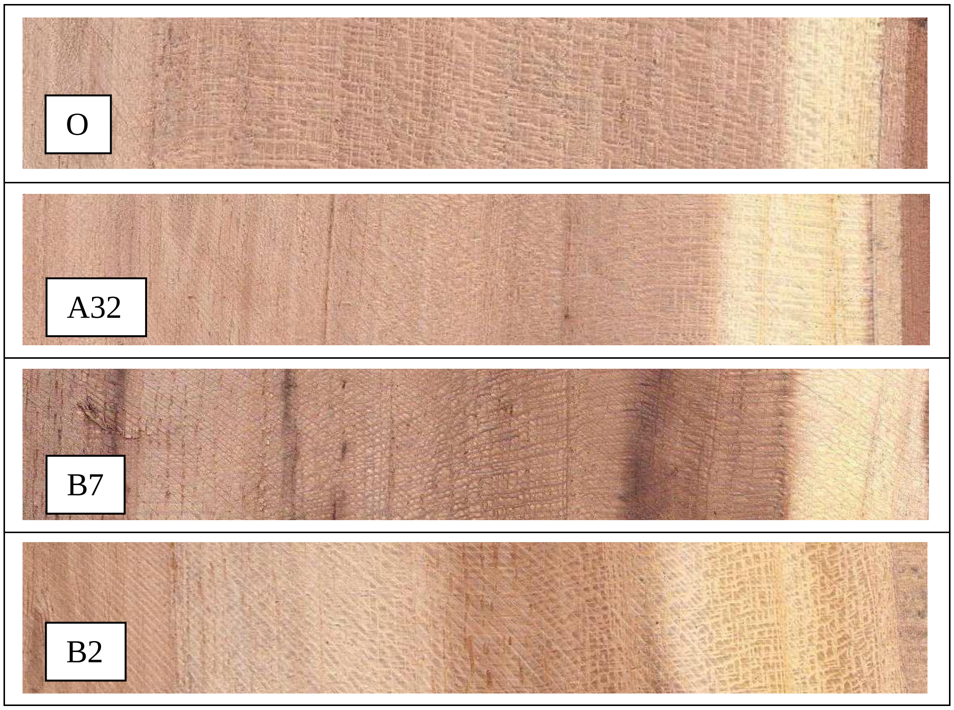


**Fig. 9.** Typical samples of a control (*O*), a fast growing variety with low colour variation (*A32*), and two samples of fast growing varieties with high colour variation (*B7* and *B2*)

## CONCLUSIONS

1. No significant tendencies were found for the mean values of $L^*$ and $a^*$ colour coordinates from the pith towards the sapwood for fast- growing and non-fast growing *Robinia* varieties. In spite of that, significant growing tendency was observed for the colour coordinate $b^*$ from the pith toward the sapwood, however the variability was similar as observed in the case of $L^*$ and $a^*$ colour coordinates.
2. Standard deviation of the colour coordinate values is, in general, higher for fast-growing varieties. In addition, many outliers and extreme values of all colour coordinates could be observed, which is not typical of the control (non-fast-growing) varieties. However, there was an exception among the fast-growing varieties (*A32*), in which case none of the color coordinates showed higher standard deviation compared to the non-fast-growing varieties.
3. There was no correlation between the mean annual ring width and the standard deviation of the colour coordinates. Namely, the higher colour variability is not

primarily due to the higher growing rate. It is considered that when comparing the color variability of the different varieties from the same growth sites, the higher standard deviation of the color coordinates by the fast-growing varieties is a varietal, genetic characteristic.

4. No significant differences were found among the different varieties in case of the mean color coordinates. It is not possible to determine the applicability of the *Robinia* wood according to the mean colour values of the heartwood or sapwood, from an aesthetics viewpoint. It is necessary to investigate the standard deviation of the colour coordinates to show the color variability and the applicability for aesthetical aspects of the different varieties.

## ACKNOWLEDGMENTS

This study was supported by the Environment Conscious Energy Efficient Building project (TAMOP-4.2.2.A–11/1/KONV-2012-0068) sponsored by the EU and the European Social Foundation.

## REFERENCES CITED

Amusant, N., Beauchene, J., Fournier, M., Janin, G., and Thevenon, M. F. (2004). "Decay resistance in *Dicorynia guianensis* Amsh.: Analysis of inter-tree and intra-tree variability and relations with wood colour," *Annals of Forest Science* 61(4), 373-380.

Bradbury, G., Potts, B. M., and Beadle, C. L. (2011a). "Genetic and environmental variation in wood properties of *Robinia melanoxylon*," *Annals of Forest Science* 68(8), 1363-1373.

Bradbury, G., Potts, B. M., Beadle, C. L., Dutkowski, G., and Hamilton, M. (2011b). "Genetic and environmental variation in heartwood colour of Australian blackwood (*Robinia melanoxylon* R.Br.)," *Holzforschung* 65(3), 349-359.

Buchelt, B., and Wagenführ, A. (2012). "Evaluation of colour differences on wood surfaces," *European Journal of Wood and Wood Products* 70(1-3), 389-391.

Defoirdt, N., Wuijtens, I., De Boever, L., Coppens, H., Van den Bulcke, J., and Van Acker, J. (2012). "A colour assessment methodology for oak wood," *Annals of Forest Science* 69(8), 939-946.

Dianiskova, M., Babiak, M., and Tolvaj, L. (2008). "Color homogenisation of cherrywood (*Cerasus avium* l.) and black locust (*Robinia pseudoaccacia* L.) during steaming," *Wood Research* 53(4), 45-58.

Drouin, M., Beauregard, R., and Duchesne, I. (2009). "Variability of wood colour in paper birch in Quebec," *Wood and Fiber Science* 41(4), 333-345.

Gierlinger, N., Jacques, D., Grabner, M., Wimmer, R., Schwanninger, M., Rozenberg, P., and Paques, L. (2004) "Colour of larch heartwood and relationships to extractives and brown-rot decay resistance," *Trees* 18, 102-108.

Grekin, M. (2007). "Colour and colour uniformity variation of Scots pine wood in the air-dry condition," *Wood and Fiber Science* 39(2), 279-290.

Katuscak, S., and Kucera, L. J. (2000). “CIE orthogonal and cylindrical colour parameters and the colour sequences of the temperate wood varieties,” *Drevarsky Vyskum* 45(3) 9-21.

Katuscak, S., Kucera, L. J., Varga, S., Vrska, M., Ceppan, M., Suty, S., and Jablonsky, M. (2002). “New method of recognition of wood varieties. Increasing of the effectiveness of colourimetric recognition of *Picea excelsa* and *Abies alba*,” *Drevarsky Vyskum* 47(1), 1-12.

Klumpers, J., and Janin, G. (1992). “Influence of age and annual ring width on the wood colour of oaks,” *Holz als Roh-Und Werkstoff* 50(4), 167-171.

Kollmann, F. (1941). *Die Esche und ihr Holz*. Springer, Berlin.

Molnár, S., and Bariska, M. (2005). *Wood Species of Hungary.* Szaktudás Kiadó Ház Rt, Budapest.

Montes, C. S., Hernández, R. E., Beaulieu, J., and Weber, J. C. (2008). “Genetic variation in wood color and its correlations with tree growth and wood density of *Calycophyllum spruceanum* at an early age in the Peruvian Amazon,” *New Forests* 35(1), 57-73.

Moya, R., and Berrocal, A. (2010). “Wood colour variation in sapwood and heartwood of young trees of *Tectona grandis* and its relationship with plantation characteristics, site, and decay resistance,” *Annals of Forest Science* 67(1), 109-117.

Moya, R., and Calvo-Alvarado, J. (2012). “Variation of wood colour parameters of *Tectona grandis* and its relationship with physical environmental factors,” *Annals of Forest Science* 69(8), 947-959.

Moya, R., Marin, J. D., Murillo, O., and Leandro, L. (2013). “Wood physical properties, color, decay resistance and stiffness in *Tectona grandis* clones with evidence of genetic control,” *Silvae Genetica* 62(3), 142-152.

Teischinger, A., Zukal, M. L., Meints, T., Hansmann, C., and Stingl, R. (2012). “Colour characterization of various hardwoods,” Proceedings of the 5$^{th}$ Conference on Hardwood Research and Utilisation in Europe 2012, 10-11, September 2012, Sopron, Hungary, 180-188.

Tolvaj, L., Molnár, S., Németh, R., and Varga, D. (2010). “Color modification of black locust depending on the steaming parameters,” *Wood Research* 55(2), 81-88.

Tolvaj, L., Persze, L., and Lang, E. (2013). “Correlation between hue angle and lightness of wood varieties grown in Hungary,” *Wood Research* 58(1), 141-146.

Varga, D., and Van der Zee, M. E. (2008). “Influence of steaming on selected wood properties of four hardwood species,” *Holz als Roh- und Werkstoff* 66(1), 11-18.

Article submitted: January 27, 2014; Peer review completed: May 7, 2014; Revised version received: October 3, 2014; Accepted: October 4, 2014; Published: October 9, 2014.