Colour stability of the flowers of some rose varieties measured in $CIEDE_{2000}$

G. Boronkay[1], E. Jámbor-Benczúr[2], Á. Máthé[3]

[1]*Research Institute for Fruitgrowing and Ornamentals, Budapest, Hungary*
[2]*Department of Floriculture and Dendrology, Corvinus University of Budapest, Budapest, Hungary*
[3]*Faculty of Agriculture and Food Science, University of West Hungary, Mosonmagyaróvár, Hungary*

ABSTRACT: A variety trial has been carried out to study the colour stability of the flowers of some modern garden roses, especially of Hungarian varieties. 100 floribundas and polyanthas were observed. Colours of the petals were examined at three phenological stages of flowering: at bud opening and at the phenophase of young open flowers and aged open flowers. The colours were described in the 40° rotated CIE LCh model, and the differences were compared according to the $CIEDE_{2000}$ standard. Our work has demonstrated Hungarian varieties with excellent colour stability present in each studied class. It has also been verified that the Hungarian bred floribundas had a lower colour shift than the polyanthas or climbing roses. The best Hungarian floribundas were Pest and Reményik Sándor emléke. None of the Western-European roses excelled them in the colour stability. The majority of the best roses are red, orange-red or dark red, which might indicate that the colour stability is not independent of the main hue of flowers.

Keywords: rose; floribunda; polyantha; colour stability; CIE LCh; $CIEDE_{2000}$

In Hungary, the Research Institute for Fruitgrowing and Ornamentals has been maintaining the rose garden since the 1960's. The rich collection of nearly 1,500 varieties provides excellent opportunity for the evaluation of both Hungarian and well-known foreign rose varieties. Unlike the experiments by Palai et al. (2003), which concentrated on hybrid varieties and greenhouse production, we wanted to focus on the floribunda and polyantha classes.

The most impressive feature of the garden rose is flower. Good rose varieties must create solid, vivid patches of colour or sometimes even a multicoloured carpet. Therefore, the quality of the flower colour must be a very important factor in any variety evaluations. There are publications in which the main task was to determine the exact colours of the petals Zhenjiang et al. (2005). The main aim of their work was to specify the varieties as accurately as possible. Other works studied the environmental influences on the colour intensity, for example the effect of low light conditions and different sucrose levels (Uddin et al. 2001). In spite of the fact that the petal colour is the most prominent feature of the rose flower, the exact colour itself does not determine the value of variety, since it is a matter of taste. In the evaluation of garden roses, colour stability seems to be more important. Flowers in any colour can be valuable, but the best roses must have a good colour stability, the ageing petals are not supposed to be faded or spotted. It is true especially in public parks, because deadheading cannot always be carried out in such locations. Generally, individual growers can keep their plants in better quality, so their interest of colour stability is limited to the open and fully open flowering phases: it is essential that the colours of the young and matured petal suit each other. In view of these considerations, we have decided to study the colour stability of some new Hungarian varieties and foreign roses from our rose garden.

MATERIAL AND METHODS

The variety evaluation was carried out in Budapest, at the Budatétény Rose Garden, in 2003. The studied varieties were: 35 Hungarian bred floribundas and 18 polyanthas and 35 Western-European floribundas and 12 polyanthas from our collection. The only evaluated Czech variety was Čsl. Červený Kříž because the other Czech roses of our garden are grouped in the hybrid tea or lutea classes. The names and classifications of rose varieties are according to the American Rose Society (ARS) approved exhibition names (Cairns et al. 2000) and Hungarian lists of varieties (Rátkai 2001). The list of breeders of Hungarian variety candidates is based on Márk's compilation (2004).

Site of experiments

The experimental garden is situated in the southern part of Budapest, in Budatétény. It is located on the margin of the northwestern region of the Hungarian Great Plain, which is the most characteristic geographical part of the country. The typical climate of the Great Plain is continental, characterized by cold winters, frosty springs, and hot and dry summers. The rainiest months are May and June (Pécsi 1989).

Meteorological conditions

The weather in the experimental year was almost perfect for evaluating dry-climate tolerant varieties, because the temperature and precipitations were critical in that summer. In 2003, both spring and summer were extremely hot and arid, with unusually warm southern wind coming from Africa; in addition, as a consequence of the wind, the soil surface was continuously dry, and atmospheric drought could be observed as well throughout the whole season. In early summer and in autumn when mornings are rather chilly, a considerable colour deviation from the typical summer-colour of the roses may be observed, therefore the evaluation had to be performed in a limited period of time. According to our observations (Boronkay et al. 2007) the pink varieties get darker and more saturated in autumn than in summer; similarly red roses become slightly darker, and yellow ones slightly discoloured.

Care of plants

The varieties were planted in rows into the beds in 1993–1995; each row contained 8–10 stocks. During the experiment, the rose plantation received only the essential maintenance; for example, no irrigation was done in summer. The garden received as much pruning, weeding and plant-protection spraying as Hungarian parks usually do.

Evaluation of the discolouring

The question, which petal colour is the most decorative, is certainly a matter of taste, though any fading of flower is disadvantageous. Nonetheless, even a very strong shift in flower colour can be attractive sometimes. A good example of this may be for instance a well-known variety Masquerade (bred by Boerner in 1949).

The colours of the flower were measured between 2 and 9 July 2003. They were specified by means of the Pantone Formula Guide (2002–2003). Although this colour set is not supposed to be used in botany, it proved to be useful, because the physical parameters of each colour are determined, and the small cards are easy to handle.

The colour codes were recorded by comparing the Pantone colour cards with the petals in natural light in the open air, at sunny days. Afterwards, the colour data were converted to the standard CIE (Commission Internationale De L'eclairage) *L*a*b* system by means of Corel Photo-Paint 9 (version No. 9.397). Subsequently, each colour was computed into CIE LCh (Lightness-Chroma-hue) according to the formula in LOGICOL S.L.R. (2007) where the standard illumination is D65 "Daylight" and the standard observer is 10°. LCh proved to be the most suitable colour system, because its colour model ("colour space") is very close to the human colour perception. The CIE LCh is the variant of the CIE *L*a*b* colour space, and thus it is perceptually uniform (Uddin et al. 2001), which means that same distances in the colour space always show the same grades of colour differences. The 3 parameters of the CIE LCh model are the following:

L: Lightness, where 0 = black, 100 = white. (It is identical with "L" of the CIE *L*a*b* space.)

C: Chroma, where 0 = grey, higher value means brighter colour; this parameter is open, but the highest chroma is usually about 140. (It can be computed from "a" and "b" parameters of the CIE *L*a*b* space.)

h: Hue in degree from 0 to 359. (It can be computed from "a" and "b" parameters of the CIE *L*a*b* space, and rotated with 40° to get a position, where 0 is very close to red (255-0-0) in sRGB (standard red-green-blue) model.)

The total colour difference (ΔE_{00}) was measured with $CIEDE_{2000}$ Colour-difference formula (Central Bureau of the CIE 2001). The exact method and the used equations are described in the publication of Sharma et al. (2005) that basically follows the publication of Luo et al. (2001). The same test data were used as in Sharma's study to verify the correctness of our ΔE_{00} calculation (Boronkay 2007).

Originally, the flowers were determined by means of 6 colours; though the following 3 are sufficient to determine the discolouring:

(1) the petal colour of the opening bud, when the colour of the petals can be seen;

(2) the surface colour of the petal of the young, partly open flower;

(3) the surface colour of the aged petal, when the flower is the widest in diameter.

To describe the petal colour, splitting the petals into mono-colour segments, which is essential in variety recognition, was not necessary in our experiment (Zhenjiang et al. 2005). In each flower, the typical colour was identified by determining the overall colour of the flower. The exact location of the determinant colour depends on the flower type: in the single forms it was in the centre of the petal, while in the full or double flowers the determining colour was found at the edge of the petals. The other parts of the petals are usually invisible.

Change of lightness, chroma and hue. Between two phenophases the change of these parameters can be computed by a simple subtraction. In the LCh model the highest shift of lightness is 100, the highest shift of chroma is about 140, and that of the hue is 180°. If the evaluated phenological period contains more than two phenophases (for example: bud – opening flower – matured flower), the sum of absolute values of the changes has to be calculated.

The total colour difference models are appropriate tools for determining the colour change because they express it by only one value. The CIEDE$_{2000}$ method (Central Bureau of the CIE 2001) has been developed by members of the CIE Technical Committee 1–47, as an improved procedure for the computation of industrial colour differences (Sharma et al. 2005). It is much more accurate than the Euclidean model, and has a strong mathematical background, as it uses non-linear models and corrects the inaccuracies of the CIE *L*a*b* colour spaces. The symbol of the CIEDE$_{2000}$ colour difference is ΔE_{00}. Between absolute black and absolute white the ΔE_{00} value is 100, but it can be even higher between very bright colours.

(a) Range: change of colour, from the opening bud to the matured flower, through the young flower stage (3 stages). Colour shift was calculated according to the following method:

change of hue $\Delta h_a = |h_1 - h_2| + |h_2 - h_3|$,
change of lightness $\Delta L_a = |L_1 - L_2| + |L_2 - L_3|$,
change of saturation $\Delta C_a = |C_1 - C_2| + |C_2 - C_3|$,
where: 1 = bud stage, 2 = young and 3 = matured flower stage, so for example C_1 means saturation of the bud stage.

Since the variances of the three parameters are different and not to be directly compared – the highest possible change is 100 at lightness, but 180 at hue – the final results are expressed in the percentage of the mean value of Δh_a, ΔL_a and ΔC_a.

In this phenological range the cumulated total colour difference is $\Delta E_{00a} = \Delta E_{00}$ between the stages 1–2 + ΔE_{00} between the stages 2–3, where 1 = bud stage, 2 = young and 3 = matured flower stage.

(b) Range: change of colour from the young flower to the mature flower stage (2 stages). The method of calculating the colour shift is as follows:

change of hue $\Delta h_b = |h_2 - h_3|$,
change of lightness $\Delta L_b = |L_2 - L_3|$,
change of saturation $\Delta C_b = |C_2 - C_3|$,
where: 2 = young and 3 = matured flower stage.

The results are expressed in the percentage of the mean of Δh_b, ΔL_b and ΔC_b.

The total colour difference here is $\Delta E_{00b} = \Delta E_{00}$ between the stages 2–3, where 2 = young and 3 = matured flower stage.

It is to be noted that the bud colour corresponds to the back of the petals, because when the bud is opening, only the back of the petal can be seen through the sepals. In certain rose varieties the colour of the petal surface does not express the general colour of the flower, for example when the flower is full or rosette shaped. In these cases, the petals are curved, their back covers the upper side and the colours of the upper side and back surfaces blend, thus the colour of the flower is not same as the colour of the petal. In this case the general colour of the flower was measured. White roses were not studied.

RESULTS AND DISCUSSION

In the present study well visible differences in the colour stability were revealed in rose varieties. The colour shifts were much higher from the bud stadium, than from the opening flower, which is the shorter period, and in both ranges the chroma (saturation) was the most changeable parameter. The means of change at each parameter was following:

Range (a) (phenological stadiums 1 + 2 + 3): Δ Lightness: 19.0; Δ Chroma: 29.4; Δ Hue: 20.6°;

Range (b) (phenological stadiums of flower opening 2 + 3): Δ Lightness: 7.6; Δ Chroma: 11.2; Δ Hue: 8.8°.

The colour shift was much higher between the bud and the young opening flower stage, than during the blooming, as the second three values are only 1/3rd of the first values, although the first period (from bud to matured flower) is twice longer than

Table 1. Discolouring of flowers from bud to matured flower: five varieties, with the weakest, and the strongest cumulated colour change. The data are in percentage of the average change where 100%: ΔL_a = 19.0, ΔC_a = 29.4, Δh_a = 20.6

Variety	Class	ΔL_a (%)	ΔC_a (%)	Δh_a (%)	Average of ΔL_a, ΔC_a, Δh_a (%)
Reményik Sándor e.	fl	0	0	0	0
Pest	fl	25	33	4	21
Régen	po	30	40	12	27
Szabó Dezső emléke	fl	16	50	33	33
Poppy Flash	fl	34	27	38	33
Zirc	fl	344	214	97	218
Leila	po	118	156	440	238
Liu	fl	290	217	456	321
Minuette	fl	386	283	619	429
Dsida Jenő	fl	359	259	707	442

the second one (from young flower to aged flower). It is understandable, because the back of the petal determines the colour of the bud, whereas only the surface of the petal is visible after the opening.

Table 1 summarizes the results of observations on colour change (from the bud stage of the flower), whereas Table 2 shows data on the colour change from only the partly open flower stage. Only the most remarkable varieties are shown, the roses that have the strongest colour stability and the varieties with the strongest colour change. Remarkably, the way of change (for example lightening or darkening) cannot be specified because the colour-shift is not a simple process, for example the petals may first become darker, then lighter or in the case of polyanthas they turn from yellow to pink, then red and finally white.

According to the Table 1, only one non-fading variety was found, where the colour of the bud, the young and aged petals remained the same. This was the variety Reményik Sándor emléke, a Hungarian floribunda cultivar. The discolouring of the variety Pest was also very slight, its hue showed only a little change. The way of the change of the colours was not the same in individual varieties; although the roses with good

Table 2. Discolouring of flowers from opening flower to matured flower: varieties with the weakest, and the strongest colour change. The data are in percentage of the average change where 100%: ΔL_b = 7.6, ΔC_b = 11.2, Δh_b = 8.8

Variety	Class	ΔL_b (%)	ΔC_b (%)	Δh_b (%)	Average of ΔL_b, ΔC_b, Δh_b (%)
Reményik Sándor e.	po	0	0	0	0
Pest	fl	0	0	0	0
Régen	fl	0	0	0	0
Savaria	po	0	0	0	0
Fairy Damsel	fl	0	0	0	0
Szent László	po	0	0	0	0
Verecke	fl	223	320	59	201
Tihany	po	255	151	315	240
Dsida Jenő	fl	416	342	760	506
Minuette	fl	616	401	708	575
Liu	fl	674	331	1012	672

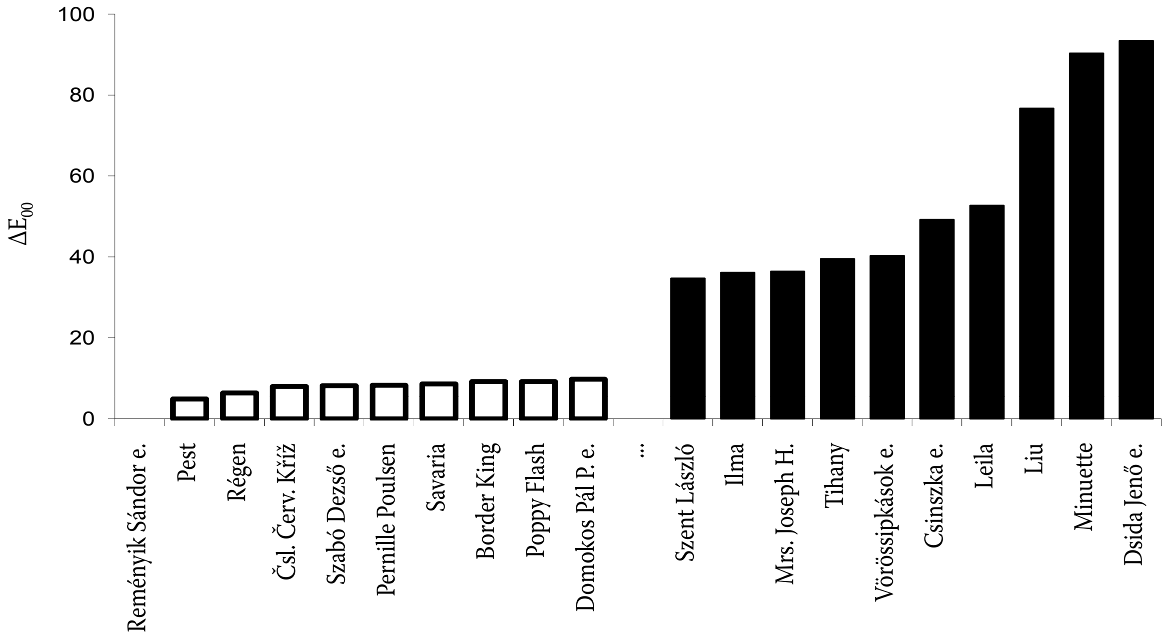

Fig. 1. Total colour difference (from bud to matured flower) according to the $CIEDE_{2000}$ method: ten varieties with the smallest and the greatest colour differences

colour stability had a low shift in their hue, the hue shift of the petals of Poppy Flash, Čsl. Červený Kříž was higher than the shift of their other parameters. Or in the colour change of the flower of Szabó Dezső emléke, the shift of the chroma was dominant, while in the case of Szaffi it was hue. Interestingly, in the colourful roses, like Minuette, Dsida Jenő emléke the most changing parameter was the hue whereas it was the least changing element in the varieties with good colour stability. Zirc was an exception, with the lightness of the flower being the least stabile.

If the bud stage is omitted (Table 2), a lot of varieties can be distinguished with good non-fading flowers. Fairy Damsel, Pest, Régen, Savaria and Szent

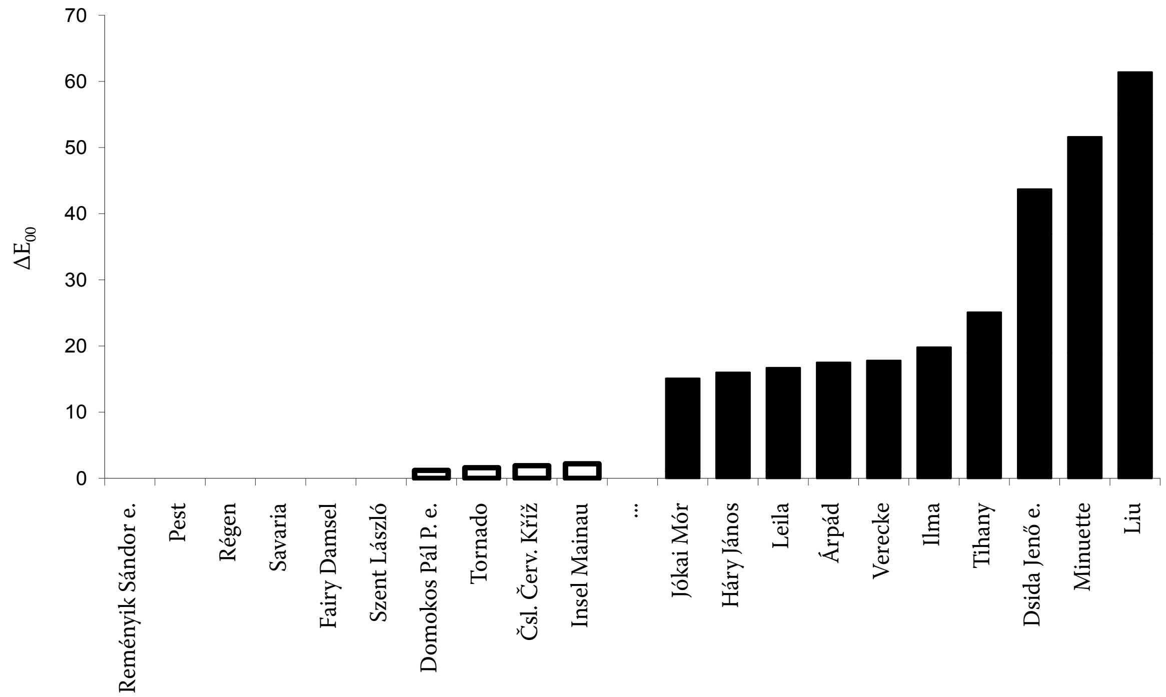

Fig. 2. Total colour difference (flower from opening to mature flower) according to the $CIEDE_{2000}$ method: ten varieties with the smallest and the greatest colour differences

Table 3. Roses with the highest colour stability at Budatétény, in 2003

Variety name (breeder, year, colour)	1	2	3	4	5	6	7	8
Pest (fl, Márk, 1993, carmine red)	×	×	×	×	×	×	×	×
Reményik Sándor emléke (fl, Márk, –, bright pink)	×	×	×	×	×	×	×	×
Régen (fl, Márk, 2000, blush)	×	×	×		×	×	×	×
Savaria (po, Márk, –, cherry red)	×	×				×	×	×
Čsl. Červený Kříž (po, Böhm, 1937, carmine red)	×	×	×	×				
Szent László (fl, Márk, 2002, carmine red)		×				×	×	×
Domokos Pál Péter emléke (po, Márk, 1998, salmon red)		×	×			×		
Szabó Dezső emléke (fl, Márk, 1989, bright red)	×		×					×
Border King (po, deRuiter, 1952, light red)	×						×	
Chic Parisien (fl, Delbard-Chabert, 1956, coral pink)					×	×		
Millecentenárium 96 (fl, Márk, 1996, light pink)			×		×			
Pernille Poulsen (fl, Poulsen, 1965, light pink)	×						×	
Poppy Flash (fl, Meilland, 1971, light red)	×				×			
Őrség (fl, Márk, –, carmine red and pink)					×	×		
Tornado (fl, Kordes, 1973, orange)		×				×		
Zágon (fl, Márk, –, salmon)							×	×

1 – smallest total colour difference from bud to matured flower, 2 – smallest total colour difference from opening to matured flower, 3 – smallest lightness difference from bud to matured flower, 4 – smallest lightness difference from opening to matured flower, 5 – smallest saturation difference from bud to matured flower, 6 – smallest saturation difference from opening to matured flower, 7 – smallest hue difference from bud to matured flower, 8 – smallest hue difference from opening to matured flower, × – the variety is among the best 10 varieties

László emléke proved to be practically non-fading, in addition to Reményik Sándor emléke. In this case 6 roses were not fading at all, changes of the hue of Liu was 10 times higher than the mean, and this value were 7 times higher at Minuette and Dsida Jenő emléke as well.

The most exact method of comparing the colour stability between two colours is using one parameter, i.e. the total colour difference. $CIDEDE_{2000}$ is the standard method for measuring the colour difference in CIE L^*a^*b and CIE LCh. Fig. 1 and Fig. 2 describe the varieties with the lowest and highest colour difference. The difference between the varieties with good and poor colour stability is higher during the second half of the flowering period, than from the bud. In both charts: Liu, Minuette and Dsida Jenő emléke were unquestionably the most colourful among all assessed varieties. When compared to these varieties, the ΔE_{00} is lower than 10 at the roses with the strongest colour stability in the phenological range (a), and lower than 5 in phenological range (b). It is 10% and 5% of the ΔE_{00} between black and white. The following roses had very low (lower than 5) colour change at the surface of the petal: Hungarian varieties Reményik Sándor emléke, Pest, Régen, Savaria, Szent László, Domokos Pál Péter emléke, Báthory István emléke, Szárazajta, Szabó Dezső emléke, Nagyvárad, Munkács, Millecentenárium, Zirc; the best non Hungarian roses were: Fairy Damsel, Tornado, Čsl. Červený Kříž, Insel Mainau, New Daily Mail, Lilli Marleen, Poppy Flash, Border King, La Sevillana, Pernille Poulsen, Elsbeth Meyer, Picasso, Garden Princess.

The majority of the good rose varieties are red, orange-red or dark red, which indicates that the colour stability is not independent of the main hue of the flowers. While the majority of the floribundas and polyanthas are pink, rose-pink, or blush, their colour stability is more moderate than that of the red types. While several light pink varieties have very dark buds, it is not typical in the red or yellow roses. In general, the colour stability of the pink or yellow roses (for example: Sunsprite or Domokos János emléke) is lower than the stability of the red ones.

The Hungarian polyanthas are highly colourful, not only the inner and the outer zone of the petals are different; almost all have a strong colour shift during the blooming process from butter yellow through blush and very vivid red to brick red and finally white. Dsida Jenő emléke is probably the most outstanding among them, but Tihany, Verecke, Árpád are very similar.

The majority of the varieties are double, and there are not enough data to compare the simple, semi-double, double and fully double flowers. Providing that the covered part of the petals had truly stronger colour stability, but the evaluation assessed only the visible colours, the colour change of the different types of flower was almost identical.

By summarizing our observations, a list of the most colourfast rose varieties was established (Table 3). This table does not list the colourful roses, because in the everyday practice the colour-stable roses are the most desirable.

The list shows that valuable Hungarian varieties can be found in both studied classes, however, more Hungarian bred floribundas had a good colour stability compared to polyanthas. The best Hungarian floribundas were Pest and Reményik Sándor emléke, although Régen was also fairly good. Only one non-Hungarian rose had excellent colour stability, the Čsl. Červený Kříž, which is a Czech variety. The lack of classical Western-European roses can be explained by the fact that these varieties were bred in the Atlantic climate and therefore are not perfectly suitable for the conditions of Hungarian long and hot summers.

References

BORONKAY G., 2007. Colour Conversion Centre. Available at: http://ccc.orgfree.com

BORONKAY G., JÁMBORNÉ BENCZÚR E., 2007. Magyar rózsafajták őszi és nyári virágszíne közötti eltérés Munsell-féle színrendszerben. In: XIII. Növénynemesítési Tudományos Napok, March 12. Budapest, Book of Abstracts: 171.

CAIRNS TH., YOUNG M., ADAMS J., EDBERG B., 2000. Modern Roses XI. The World Encyclopaedia of Roses. Shrevport, American Rose Society: 1–652.

Central Bureau of the CIE, 2001. Improvement to industrial colour-difference evaluation. CIE Publication 142–2001, Vienna.

LOGICOL S.L.R., 2007. Color Conversion Formulas. Available at: http://www.easyrgb.com/math.php?MATH=M9#text9

LUO M.R., CUI G., RIGG G., 2001. The development of the CIE 2000 colour difference formula: $CIEDE_{2000}$. Color Research & Application, *26*: 340–350.

MÁRK G., 2004. Magyar rózsák könyve. Budapest, Mezőgazda Kiadó.

PALAI S.K., MISHRA M., BHUYAN S., MISHRA H.N., 2003. Genetic variability in hybrid tea roses. Journal of Ornamental Horticulture (New Series), *6*: 29–33.

PANTONE, 2002–2003. Formula Guide Printer Edition, Coated Paper Printer Colour Management Kit, Product Code: PANT013, Manufacturers #: GP1201.

PÉCSI M., 1989. National Atlas of Hungary. Budapest, Mezőgazda Kiadó.

RÁTKAI J., 2001. National List of Varieties. Budapest, National Institute for Agricultural Quality Control.

SHARMA G., WU W., DALAL E.N., 2005. The $CIEDE_{2000}$ Color-Difference Formula: Implementation Notes. Supplementary Test Data and Mathematical Observations, Color Research and Application, *30*: 1. Available at: http://www.ece.rochester.edu/~gsharma/ciede2000/ciede2000noteCRNA.pdf

UDDIN A.F.M.J., HASHIMOTO F., KAKETANI M., SHIMIZU K., SAKATA Y., 2001. Analysis of light and sucrose potencies on petal coloration and pigmentation of lisianthus cultivars (*in vitro*). Scientia Horticulturae, *89*: 75–84.

ZHENJIANG M., GANDELIN M.H., BAOZONG Y., 2005. An OOPR-based rose variety recognition system. Engineering Applications of Artifical Intelligence, *19*: 79–101.

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Barevná stálost květů některých odrůd růží měřená podle $CIEDE_{2000}$

ABSTRAKT: V odrůdovém pokusu byla zjišťována barevná stálost květů u některých moderních zahradních růží – zejména maďarských odrůd. Bylo pozorováno 100 odrůd růží ze skupiny floribund a polyantek. Barvy květních plátků byly zkoumány ve třech fenologických stadiích kvetení: poupě, otvírající se květ, odkvétající květ. Barvy byly popsány v 40° rotujícím modelu CIE LCh a rozdíly byly porovnány podle standardu $CIEDE_{2000}$. Práce prokázala přítomnost maďarských odrůd růží s vynikající barevnou stálostí v každé hodnocené třídě. Bylo také ověřeno, že v Maďarsku šlechtěné floribundy mají menší změny barvy než polyantky a růže pnoucí. Nejlepší z maďarských floribund byly Pest a Reményik Sándor emléke. Žádná ze západoevropských růží je v barevné stálosti nepřekonala. Většina nejlepších růží jsou červené, oranžově červené a tmavě červené, což může indikovat, že barevná stálost růží není na hlavním odstínu květů nezávislá.

Klíčová slova: růže; floribunda; polyantka; barevná stálost; CIE LCh; $CIEDE_{2000}$

Corresponding author:

Gábor Boronkay, Ph.D., Research Institute for Fruitgrowing and Ornamentals, H-1223, Park utca 2, Budapest, Hungary
tel.: + 36 1 362 1596, fax: + 36 1 362 1573, e-mail: resinfru@hu.inter.net