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VARIABILITY OF QUANTITATIVE AND QUALITATIVE TRAITS OF COLOURED WINTER WHEAT

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The aim of research was to analyse winter wheat of different grain colour and to compare newly bred coloured genotypes from our breeding in grain yield and technological and nutritional quality. The set of seven purple, five blue and four yellow wheats of different origin, including seven newly bred genotypes from Vígľaš-Pstruša, was evaluated in the field experiments established by randomised complete block design in two replications in Piešťany, in the vegetations 2012/13 and 2013/14. In seven wheat varieties differing in grain colours (selected after two of each colour plus control red variety Ilona) anthocyanin composition was evaluated by HPLC analysis. Significant differences were between growing years and among colour groups in most analysed traits. Blue grain newly bred K 3575 699/3 showed the highest anthocyanin content (by 33.5% higher compared to blue grain registered variety Scorpion). However, blue grain genotypes showed negative agronomic traits combined with low number and grain weight per spike and high plant height. In new purple variety PS Karkulka, declared grain yield and its quality were confirmed and the highest mineral content (Fe, Zn, Cu, Mn) was found in selected set. Purple grain newly bred PS 5711 had lower anthocyanin content (by 17.7%), but in quality it was comparable to PS Karkulka. Varieties with yellow endosperm showed the highest number and weight of grains per spike, however it was significantly lower to Ilona. The breeding goal of coloured winter wheat is still to improve the grain yield as well as additional agronomics traits.

Key words: winter wheat, grain colour, grain yield, quality, HPLC, anthocyanin

In wheat breeding, in addition to obligate traits (grain yield, quality, and tolerance to biotic and abiotic stresses), new directions are aimed on increasing health promoting substances. The anthocyanins represent a new goal for wheat genetic improvement. In colour wheat anthocyanins are located either in a purple pericarp, or in blue aleurone and carotenoids in the endosperm. Renewed interest for wheat breeding with a high anthocyanins content is linked to various health benefits associated with anthocyanins from their natural sources. Studies have shown that anthocyanins have antioxidant (Reque *et al.* 2014, Ficco *et al.* 2014), anti-cancer (Fernandes *et al.* 2014), anti-obesity (Esposito *et al.* 2015, Johnson *et al.* 2016), and anti-inflammation effects (Esposito *et al.* 2014). However, it is unknown whether these health benefits are solely due to anthocyanins or the synergistic effect of diverse phytochemicals (Li *et al.* 2017).

Common wheat varieties, which are characterized by purple, blue or yellow grains are actually

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produced in small amounts, but growing interest has recently been shown in the genetic development of novel pigmented varieties (Jaafar *et al.* 2013, Martinek *et al.* 2013b). The winter wheat variety Scorpion with blue grain colour was registered in 2011 in Austria and in 2012 it was also registered in European list of cultivars (Martinek *et al.* 2013b). In 2013 in Slovakia, the first local winter wheat variety PS Karkulka with purple grain was registered (Hanková *et al.* 2014). Varieties Bona Dea and Bona Vita with yellow endosperm were bred and registered in Slovakia in 2006 and 2011, respectively. Varga *et al.* (2013) analysed the anthocyanin content of blue and purple wheat cultivars and their hybrids cultivated under Hungarian growing conditions. Jaafar *et al.* (2013) evaluated progeny from crosses between red, purple and blue grained wheat varieties selected over several cycles. The results showed that increasing anthocyanin content is possible by the combination of different genetic backgrounds for purple pericarp and blue aleurone. In fact, these unconventional varieties might be important sources of biologically active phytochemicals and as a result, they could be valuable as a raw materials for the production of functional foods (Ficco *et al.* 2016). Higher anthocyanin content of blue and purple wheat can be exploited to the anthocyanin content of bakery products if whole-meal flour or bran are used (Li *et al.* 2015). The content of yellow pigment is studied mainly in *T. durum* for producing superior pasta products (Lachman *et al.* 2017).

The aim of research was to evaluate the variability of quantitative and qualitative traits of different grain coloured winter wheat and to compare newly bred coloured genotypes originated from local breeding programmes.

MATERIAL AND METHODS

Evaluated set of winter wheats consisted of 17 varieties and genotypes (next variety) of different grain colour – seven purple samples (K 3517, K 3513, 994/3, PS Karkulka, PS 5711 from Research and Breeding Station at Vígľaš-Pstruša, Indigo (GB), Zernofialovetaja (unknown origin)), five blue (K 3575 699/3, 930/1 from Research and Breeding Station Vígľaš-Pstruša, Barevná 9, Barevná 25 (CZ), Scorpion (AT)), four yellow (Bona Dea, Bona Vita (SK), Luteus, Citronova (synonym Citrus) (DE)). As a control, local variety Ilona with standard red grain colour was used. Field experiments were established by randomized complete block design in two replications at the Research Institute in Piešťany (west part of Slovakia) in the vegetative years 2012/13 and 2013/14. Experimental unit consisted of a 1 m^2 plot. Locality is at an altitude of 163 m with a continental character of climate, long-time average annual precipitation is 608 mm and temperature 9.2°C. Soil type was Luvi-Haplic Chernozem; the locality belongs to a maize production type. In the Table 1 month precipitations and average temperatures are presented.

T a b l e 1

Precipitations and average temperature over two growing seasons (2012/13, 2013/14) at Piešťany, Slovakia

Month	10	11	12	1	2	3	4	5	6	7	Sum, mean
Normal* precipitations [mm]	40	52	46	32	33	28	40	66	72	59	468
Normal* temperature [°C]	9.7	4.2	–0.1	–2.0	0.4	4.5	9.6	14.5	17.4	18.9	7.9
2012/13											
Precipitations [mm]	63.4	15.8	26.2	37.4	68.8	70.6	9.8	40.8	102.4	3.0	438.2
Temperature [°C]	10.3	7.7	–1.1	–1.2	0.9	2.6	11.5	15.3	18.7	22.4	8.71
2013/14											
Precipitations [mm]	25.0	46.8	3.6	21.0	25.2	11.4	54.2	75.6	29.6	95.0	387.4
Temperature [°C]	12.1	6.7	2.7	3.0	3.2	8.5	11.8	15.2	19.2	21.7	10.4

*(1961–1990)

During the growing seasons standard cultivation practices were used. Within vegetations obligate traits were observed. In maturity, an average sample of 300 productive ears was collected from each plot and the number and weight of grains per ear and 1,000 grain weight (TGW) were determined. Protein, starch, gluten content and Zeleny test were assayed by the DA 7200 NIR analyser.

Extraction of anthocyanins from wheat grain bran and determination of total anthocyanins using the pH differential method were described in Žofajová *et al.* (2012).

Composition of anthocyanins, total ash and microelements (Fe, Zn, Cu, Mn) were determined in wheat varieties grown in 2013/14 (PS Karkulka, PS 5711, K 3575 699/3, Scorpion, Bona Vita, Luteus) selected after two of each colour group plus control (red) variety Ilona.

Composition of anthocyanins

The anthocyanins were extracted according to the method described by Abdel-Aal and Hucl (2003), with a modification according to Ficco *et al.* (2014). Homogenized cereal grain material (500 mg) was extracted twice by 8 ml of methanol acidified with 1.0 M HCl (85:15, v/v) at laboratory temperature for 30 minutes. Crude extracts were centrifuged at 9,000 RPM for 15 minutes. Separated supernatants were filtered through 0.45 μm cellulose syringe filters before HPLC analysis.

The Agilent 1200 Series HPLC System (Agilent Technologies, Santa Clara, CA, USA) used for analysis consists of a binary pump, the DAD SL detector, degasser, and column temperature controller. System control and data analysis were processed using the Agilent ChemStation software Rev. B.04.03 (Agilent Technologies, Santa Clara, CA, USA). The chromatographic separation was performed in Eclipse XD8-C18 column (3.5 μm, 3.0 × 100 mm) using water solution of formic acid (A; 4.5%, v/v) and methanol (B) as mobile phase at flow rate of 0.4 ml/min. The gradient program was set as follows: 0–30 min, 10–25% B; 30–40 min, 25-45% B; 40–42 min, 45–90% B; 42–45 min, 90% B. The chromatogram was monitored at a wavelength of 520 nm throughout the experiment. The column temperature was maintained at 30°C and the injection volume of each sample and standard solution was 10 μl. The HPLC mobile phase was prepared fresh daily, filtered through 0.45 μm membrane filter and then degassed before injection into the column.

Determination of total ash

For determination of total ash in wheat samples ashing furnace Carbolite AAF 1100 was used. The whole test of total ash was performed via STN ISO 2171. Each sample was prepared in duplicate.

Determination of microelements

All measurements were performed using an Agilent 4200 MP-AES with nitrogen plasma gas supplied via an Agilent 4107 Nitrogen Generator. The instrument operated in a fast sequential mode and featured a Peltier-cooled CCd detector.

Microwave digestion was used to prepare all wheat samples for total metal analysis of Cu, Zn, Mn and Fe by MP-AES. 7 mL of 65% HNO_3 and 1 mL of 30% H_2O_2 was added to 0.5 g of the sample. A preloaded method for the Milestone ETHOS 1 microwave system was used to digest the sample. Once cooled, the solution was diluted to 50 mL using ultrapure water. Each sample was prepared in triplicate and the quality of the MP-AES results was evaluated by comparing them with the values for reference material, strawberry leaf, Metranal 3.

The data were analysed by analysis of variance using Statgrafics Centurion X64.

RESULTS AND DISCUSSION

Effect of vegetative year (Table 2)

Significant differences were observed between vegetative years in all traits except grain number per ear. In seven evaluated traits (from eleven), higher average values were found in the vegetative year 2012/13 compared to subsequent one. The vegetation 2012/13 was in average by nine days exceed (not shown) and heading of varieties was by 10.9 days later, what was caused by later beginning of vegetation (average temperature in March 2013 was only 2.6°C) (Table 1). In analysed traits such as protein complex and Zeleny test higher results were observed in vegetation 2012/13 (from 13.6% for protein content to 18.9% for Zeleny test). The higher amount of precipitation (by 50.8 mm) and lower average temperature (by 1.7°C) during the growing season 2012/13 (Table 1) also positively influenced anthocyanin and ash content (increasing by 17.8% and 8.1%, respectively). Anthocyanin content is affected by environmental factors, e.g. weather conditions and soil type and quality, what was also expressed in significant interaction year × variety (not shown). Similarly, in spring wheat Abdel-Aal *et al.* (2016) found that genotype, year and location

T a b l e 2

Mean values of traits of 17 coloured winter wheat evaluated over two growing seasons (2012/13, 2013/14) at Piešťany, Slovakia

Trait	Growing season		Mean	$LSD_{0.05}$
	2012/13	2013/2014		
HEA	25.8[b]	14.9[a]	20.3	0.86
PH	101.7[a]	118.0[b]	109.9	3.07
TGW	42.4[a]	47.6[b]	45.0	1.74
GN	43.5	42.4	43.0	2.95
GW	1.85[a]	2.03[b]	1.94	0.45
PC	13.4[b]	11.8[a]	12.6	0.38
SC	61.3[a]	62.3[b]	61.8	0.34
GC	28.5[b]	24.9[a]	26.7	0.83
ZT	45.8[b]	38.5[a]	42.2	0.98
TAC	44.3[b]	37.6[a]	41.0	3.10
ASH	1.72[b]	1.59[a]	1.65	0.06

HEA – heading [number of days from May, 1]; PH – plant height [cm]; TGW – thousand grain weight [g]; GN – grain number per ear [piece]; GW – grain weight per ear [g]; PC – protein content [%]; SC – starch content [%]; GC – gluten content [%]; ZT – Zeleny test [ml]; TAC – total anthocyanin content [mg/kg]; ASH – ash content [%]
$LSD_{0.05}$ – least significant difference at the level $\alpha = 0.05$
Different letters indicate significant differences at $P < 0.05$

T a b l e 3

Descriptive statistics of traits of coloured winter wheat groups over two growing seasons (2012/13, 2013/14) at Piešťany, Slovakia

Trait	purple (n=7)		blue (n=5)		yellow (n=4)		control	$LSD_{0.05}$
	mean	range	mean	range	mean	range	mean	
HEA	19.8	5.0–26.0	23.7	5.0–37.0	18.8	3.0–35.0	9.5	4.91
PH	108.8	76.0–132.0	119.4	92.7–150.3	105.9	80.0–120.7	100.6	8.76
TGW	44.6	33.0–54.7	46.0	33.5–58.9	43.7	39.4–49.0	44.4	3.92
GN	40.9	27.4–57.0	37.6	23.8–55.2	49.3	30.6–69.5	55.2	5.02
GW	1.84	1.07–2.43	1.77	0.80–3.00	2.14	1.33–2.94	2.50	0.30
PC	12.2	10.3–13.8	13.4	10.5–17.9	12.7	11.2–15.8	12.4	0.83
SC	62.0	60.7–63.3	61.3	57.3–63.5	61.7	58.4–63.4	62.0	0.73
GC	25.9	20.5–30.2	28.4	22.8–38.4	26.9	23.6–33.7	25.7	1.88
ZT	38.8	27.0–48.0	44.3	33.5–57.0	45.3	37.5–53.0	44.8	3.30
TAC	48.2	7.8–93.4	61.0	21.6–120.2	12.7	2.87–28.8	15.5	13.02
ASH	1.74	1.58–1.93	1.57	1.43–1.78	1.69	1.571.81	1.57	0.11

Abbreviations see Table 2
$LSD_{0.05}$ – least significant difference at the level $\alpha = 0.05$

significantly influenced content and composition of anthocyanin pigments.

Higher precipitations in the period of intensive growth in the vegetation 2013/14 induced higher plant height (by 16.3 cm), grain weight and starch content (by 12.2% and 1.6%, respectively) compared to the previous vegetation.

Quantitative and qualitative traits among and within colour groups (Table 3, 4)

Significant differences were found among colour groups nearly in all evaluated traits (except heading, TGW and starch content). The earliest were varieties with yellow grains (heading – May, 18 to 19, on average), a day later purple ones and approximately 5 days later blue grain wheats. In each wheat group, high variability and varieties earlier compared to Ilona (average heading from May, 3 to 5) were found. The highest plant height had blue varieties (119.4 cm) and the lowest wheat varieties with yellow endosperm (105.9 cm). The highest number and weight of grains per spike were in varieties with yellow endosperm (49.3 pcs and 2.14 g, respectively) and the lowest results were determined for blue grain wheats (1.77 g and 37.6 pcs). Varieties with yellow endosperm showed lower weight and number of grains per ear compared to the control Ilona by 14.4% and 10.4%, respectively, and were comparable to Zeleny test. A valuable source of high grain weight per ear and TGW is the blue grain variety Scorpion (2.85 g and 57.2 g, respectively). These parameters were declared in the variety description presented by Martinek *et al.* (2013b). Variety Scorpion is suitable for baking bread, since intake of anthocyanins may play an important role in the prevention of human diseases (Bartl *et al.* 2015). Compared to control Ilona, the blue wheats showed good qualitative traits in term of protein as well as gluten content.

Our results are in agreement with other research finding and suggest that blue wheat varieties contain higher anthocyanin contents compared to purple seeds (Ficco *et al.* 2014; Žofajová *et al.* 2012 and others). The highest total anthocyanin content was observed in K 3575 699/3, what was by 33.5% higher compared to Scorpion. Purple wheats were rich in ash content, what was significantly higher compared to Ilona.

To compare grain yield traits of colour wheats (mainly purple and blue) to the red control variety Ilona we can confirm that the main objective in coloured wheat breeding is increasing the grain yield. Growing of colour wheats will depend on the grain yield and agronomic characters, comparable to commercial wheat varieties. In this direction, some progress has been achieved as reported Garg *et al.* (2016), who selected pigmented lines with commercial potential, having grain yield and thousand grain weight equivalent to the high yielding commercial cultivars. Anthocyanin rich lines adapted to local growing conditions were developed from low yielding exotic donor lines.

T a b l e 4

Average values of selected traits of coloured winter wheat over two growing seasons (2012/13, 2013/14) at Piešťany, Slovakia

Varieties	colour	TGW	GN	GW	PC	SC	GC	ZT	TAC	ASH
PS Karkulka	purple	48.4^{ab}	39.0^{a}	1.91^{a}	12.8	61.9	26.8	42.8	44.7^{abc}	1.83^{c}
PS 5711	purple	42.1^{a}	41.1^{ab}	1.73^{a}	12.4	61.5	26.6	41.7	36.8^{ab}	1.66^{ab}
K 3575 699/3	blue	54.4^{b}	35.2^{a}	1.92^{a}	13.0	61.8	28.1	46.6	76.1^{c}	1.61^{ab}
Scorpion	blue	57.2^{b}	50.2^{bc}	2.85^{b}	13.0	61.7	26.9	42.3	57.0^{bc}	1.54^{a}
Bona Vita	yellow	41.8^{a}	40.6^{a}	1.70^{a}	14.2	59.9	29.7	46.0	17.9^{a}	1.70^{bc}
Luteus	yellow	42.8^{a}	50.6^{c}	2.16^{a}	11.7	63.0	25.0	44.5	8.6^{a}	1.67^{ab}
Mean	–	47.8	42.8	2.05	13.0	61.7	27.2	44.0	40.2	1.67
$LSD_{0.05}$	–	8.85	9.47	0.57	1.72	1.36	3.98	6.18	38.40	0.15

Abbreviations see Table 2
$LSD_{0.05}$ – least significant difference at the level $\alpha = 0.05$
Different letters within the same column of each trait indicate significant differences at $P < 0.05$

Anthocyanin composition

Anthocyanin composition in selected wheat varieties differing in grain colours was evaluated by HPLC analysis. HPLC analysis is method for detailed description of differences between analysed varieties of wheat because photometric determination of total anthocyanins is not sensitive to differentiation of varietal specificities such as composition of anthocyanins, presence of other coloured compounds and effects of non-coloured compounds interfered during spectrophotometric determination. HPLC fingerprints in Figure 1 show composition of individual anthocyanins and other compounds (serotonin, melatonin and secoisolariciresinol diglucoside). Similar fingerprints have been also presented in wheat varieties by Hosseinian *et al.* (2007). These fingerprints prove that varieties Ilona (1), Luteus (2) and Bona Vita (3) do not contain anthocyanins whereas varieties Scorpion (4), K 3575 699/3 (5) (blue) and varieties PS 5711 (6) and PS Karkulka (7) (purple) contain some compounds with elution and chromogenic properties characteristic for anthocyanins. The peak areas of all these compounds expressed by percentage of total colour is described in Table 5. From the Table 5 it is evident that the colour of studied varieties is not caused only by presence of anthocyanins. Anthocyanins caused contribution to wheat colour in the range from 0 (Bona Vita) to 96% (PS 5711) of total colour which can be determined by classic methods based on spectrophotometric analysis (Table 4). The most common anthocyanin in purple wheat is cyanidin-3-O-glucoside, followed by peonidin-3-O-glucoside, whereas delphidin-3-0-glucoside is the most abundant anthocyanin in wheat (Abdel-Aal & Hucl 2003; Escribano-Bailón *et al.* 2004). On the base of described chromatographic method and spectral properties of separated compounds, anthocyanins were eluted from chromatographic column in retention time varied from 1.74 to 34.14 minutes. Compounds eluted out of this range can be included into groups of proteins, melatonins and serotonins (Hosseinian *et al.* 2007).

Grain minerals content (Table 6)

Concentration of mineral elements including Fe and Zn in wheat grains is important for human

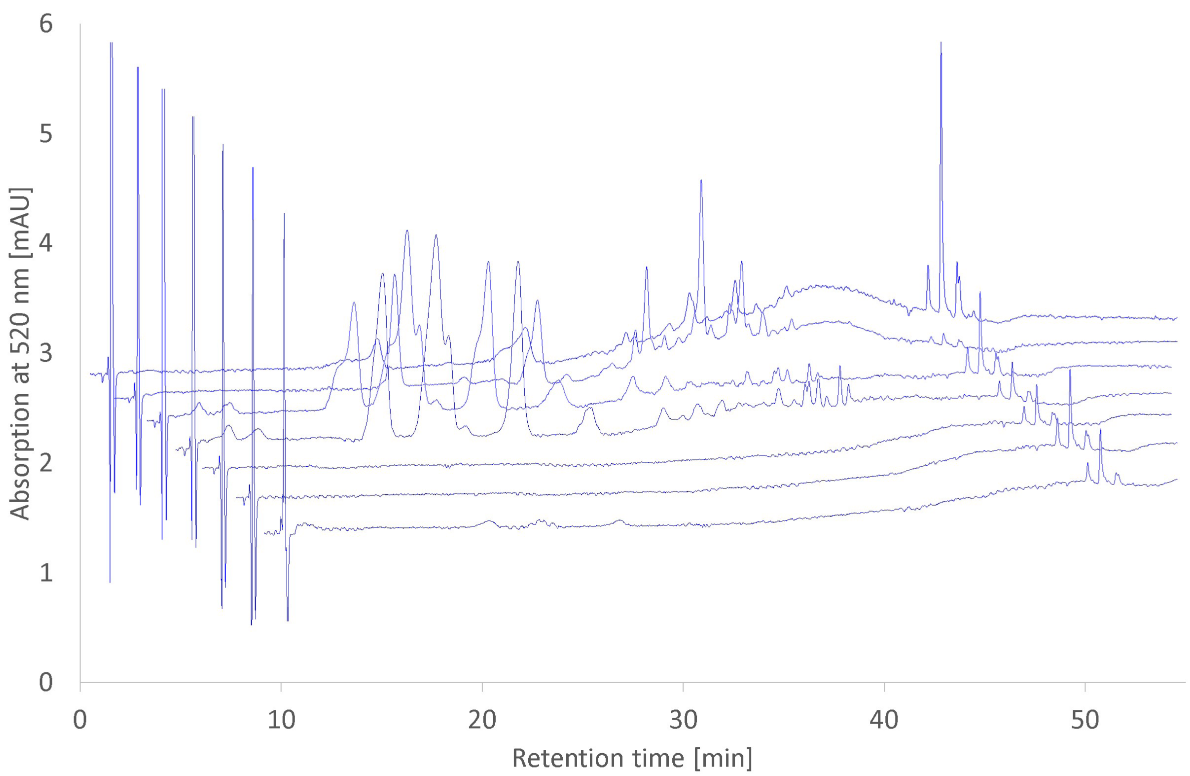

Figure 1. HPLC fingerprints of wheat extract determined at 520 nm; samples are in ascending order (upper is sample 7 and lower is sample 1) (1 – Ilona, 2 – Luteus, 3 – Bona Vita, 4 – Scorpion, 5 – K3575 699/3, 6 – PS 5711, 7 – PS Karkulka)

health. For deeper characterisation of grain coloured wheats, seven selected varieties were explored for minerals content. There were no significant differences among different colour winter wheat groups in Fe, Zn, Cu and Mn content (results not shown). The highest Fe in the grain showed the purple varieties in average (34.20 mg/kg) and the lowest varieties with yellow endosperm (32.09 mg/kg), which contrary showed the highest content of Zn and Mn (21.42 mg/kg and 29.72 mg/kg, respectively). In regard to small number of evaluated varieties and composition of file we could not confirm the results published by Ficco *et al.* (2014), who by evaluation of 76 colour wheats genotypes showed the highest content of Zn and Fe in blue grain wheat and in Cu and Mn he did not record any definite trend. On the

Table 5

The contribution of anthocyanins to colour of selected wheat varieties

Peak No.	Retention time [min]	Colourful contribution of anthocyanins [%]						
		Ilona	Luteus	Bona Vita	Scorpion	K3575 699/3	PS 5711	PS Karkulka
1	1.735	0	36.4	0	4.01	0	0	0
2	2.103	0	8.21	0	0	0	0	0
3	2.325	36.53	0	0	0	0	0	0
4	3.021	9.91	0	0	1.37	1.50	0	0
5	4.534	0	0	0	0	1.50	0	0
6	10.976	0	0	0	16.63	12.73	0	0
7	13.690	0	0	0	19.57	20.82	0	0
8	14.351	4.22	0	0	9.58	0	0	0
9	14.651	2.87	0	0	0	9.94	14.73	6.61
10	14.900	0	0	0	0.65	0	0	0
11	17.775	0	0	0	17.61	1.15	0	0
12	20.992	0	0	0	2.74	17.35	8.59	0
13	21.413	0	0	0	0	0	0	0
14	23.000	0	0	0	0	3.35	10.55	0
15	24.670	0	0	0	1.46	0	0.95	0
16	25.303	0	0	0	0	0	0	0
17	26.623	0	0	0	1.37	2.42	0.94	0
18	27.068	0	0	0	0	1.96	3.92	0
19	27.974	0	0	0	1.37	0	11.17	0
20	28.692	0	0	0	1.37	0.77	1.59	0
21	29.775	0	0	0	0	0	0.88	0
22	29.851	0	0	0	0	0.76	0	0
23	30.675	0	0	0	1.86	0	20.86	0
24	31.286	0	0	0	0.73	1.73	1.84	0
25	31.888	0	0	0	2.15	0	4.29	0
26	32.242	0	0	0	2.35	1.50	9.57	0
27	32.625	0	0	0	2.73	0	0	0
28	32.831	0	0	0	1.07	1.62	1.59	0
29	33.723	0	0	0	4.01	2.19	3.06	0
30	34.141	0	0	0	1.95	0	0	0

T a b l e 6

Grain minerals concentration of coloured winter wheat genotypes evaluated during the 2013/14 growing season at Piešťany, Slovakia

Varieties	Colour	Fe [mg/kg]	Zn [mg/kg]	Cu [mg/kg]	Mn [mg/kg]
PS Karkulka	purple	37.71[b]	22.84[d]	5.04	31.23[d]
PS 5711	purple	30.71[a]	18.80[a]	3.92	22.33[a]
K 3575 699/3	blue	32.83[a]	19.53[ab]	4.08	26.01[b]
Scorpion	blue	33.52[a]	20.25[abc]	4.19	30.25[cd]
Bona Vita	yellow	32.13[a]	21.82[cd]	4.68	30.47[cd]
Luteus	yellow	31.93[a]	21.03[bcd]	4.27	28.98[c]
Ilona	control (red)	30.85[a]	21.17[bcd]	4.70	28.87[c]
Mean	–	32.81	20.78	4.41	28.31
$LSD_{0.05}$	–	2.84	2.06	1.09	1.82

$LSD_{0.05}$ – least significant difference at the level $\alpha = 0.05$
Different letters within the same column of each trait indicate significant differences at $P < 0.05$

contrary, Guo *et al.* (2013) analysed nutrient composition in seven purple lines and found out 100% higher Fe content compared to control, white grain wheat.

Varieties with purple grain possessed the highest variability in all mineral elements. The registered variety PS Karkulka showed the highest mineral content and the lowest was observed in PS 5711. In grain mineral content instead of Mn, the newly bred blue genotype K 3575 699/3 was comparable with registered blue variety Scorpion. Among varieties, there were significant differences in Fe, Zn and Mn contents. The highest coefficient of variability (12.43%) was in Cu content and differences among varieties were not significant. The lowest coefficient of variability (1.90%) was in Mn content. Control variety Ilona was comparable in Zn and Mn content to the average value for coloured wheats and its grains showed more Cu (by 7.8%) and less Fe (by 6.9%). Variability in the content of mineral elements can be used in breeding for improved mineral availability in the end products. Information about the mineral content in the evaluated genotypes are within the range that published Ficco *et al.* (2014) and Zhang *et al.* (2010).

In Slovakia, there is an interest in coloured wheat observed especially in the production of extruded cereal products (puffed bread). Our assumption is to utilize coloured wheat grains in the production of baker's ware (Rückschloss *et al.* 2011). Martinek *et al.* (2013a) noticed that it will be necessary to know the extent of natural degradation of dyes during thermal processing of the wheat grain when during Maillard reaction chemical changes occur. The coating grain layers would be used for fortification of dairy products (for example yogurt), where not only the beneficial component of pigments, but also high content of dietary fibre will be used (Rückschloss *et al.* 2011).

CONCLUSIONS

Anthocyanin content in 17 colour wheat was influenced by weather conditions of experimental years and their interaction. The higher temperature and unequal distribution of precipitation caused reduction in anthocyanin content. Blue varieties contained higher anthocyanin content compared to purple ones. The highest total anthocyanin content showed K 3575 699/3 (blue grain newly bred), what was by 33.5% higher compared to blue registered variety Scorpion. K 3575 699/3 can be utilised in breeding programmes as a source of high anthocyanin content. Blue varieties (in average) were the highest in plant height and the lowest in number and weight of grain per spike, which may be negative for their commercial cultivation. However, the highest grain weight per ear and TGW were confirmed in the variety Scorpion. The registered purple variety

PS Karkulka showed the highest mineral content (Fe, Zn, Cu, Mn). Purple bred PS 5711 not reached the variety PS Karkulka in quantitative or qualitative traits. Varieties with yellow endosperm were the most yielding, but worse compared to the control Ilona.

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