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## POUŽITIE GENETICKY MODIFIKOVANEJ KUKURICE V DIÉTACH KRÁLIKOV

### THE USE OF GENETICALLY MODIFIED MAIZE IN RABBITS DIETS

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The objective of this work was to determine the effect of selected maize varieties in diets on nutrient digestibility and growth performances, biochemical and mineral parameters in blood, characterization of meat quality, physical and chemical characteristics of meat in *Musculus longissimus dorsi* muscle substance, and caecal fermentation pattern of rabbits. Live weight growth, feed conversion and health of rabbits after feeding complete feed mixtures with 12 % proportion of Bt (MON 88017), isogenic maize and reference maize was tested by using 72 broiler rabbits (Hycole). Bt maize deteriorated neither the health of animals nor the production of animal proteins valuable for human nutrition compared with conventional maize. On the basis of our results we can summarize that genetically modified maize in rabbit nutrition did not have a negative influence on the health status of animals. Obtained results demonstrate minimal statistically insignificant differences of individual nutrients utilization and digestibility in tested mixtures. Application of Bt maize and isogenics maize to rabbits did not negatively influence the consumption of feed mixtures per unit of live weight growth. Insignificant differences of selected parameters of nutrients meat quality of the tested animals and on zootechnical parameters were obtained in all experimental groups. The concentration of biochemical and mineral parameters in blood was in the reference range and high value of cholesterol was detected in group with Bt maize. Total volatile fatty acids (VFA) in the caecal content of rabbits and molar concentrations of acetate ( $P < 0.01$ ) and propionate ( $P < 0.05$ ), however, were significantly higher and concentration of lactic acid lower ( $P < 0.01$ ) in the group with Bt maize in diet.

**Key words:** Bt maize, rabbit, meat, blood, caecum

In the year 2009, planting of genetically engineered crops was used by 14 million growers in 25 countries around the world; 90 % of them were small farmers. The most frequently cultivated crops are GM varieties of soya, maize, cotton and oilseed rape. In the year 2006, Slovakia, as 21<sup>st</sup> country in the world, ranked among growers of GM crops. In the European context, Slovakia ranks among the other 7 EU countries which have practical experience in Bt maize cultivation; they are: Spain, France, Romania, Portugal, Germany, the Czech Republic and Poland (Kříštková, 2010; Ervin et al., 2010). The majority of the GM crops grown worldwide is used as a feed for farm animals. The acceptance of GM crops in the European society is very low. Experimental data for feed safety assessment, including nutritional evaluation are absolutely necessary (Aulrich et al., 2001; Chrenková et al., 2007; Chrenková et al., 2008). Bt maize contains bacterial gene from the bacteria *Bacillus thuringiensis*. This gene codes the protein which is toxic for some insects. We assessed substantial equivalence in nutrient contents between isogenic and Bt maize by means of chemical analyses. The aim of the present experiment was to compare genetically tested maize (Bt maize MON 88017), isogenic maize (DKC 5143) and reference maize (PR 36D 79) in the balance and fattening experiments with rabbits.

### Material and methods

A total of 72 weaned rabbits (35<sup>th</sup> day of age, male sex, Hycole hybrid, housed individually in cages) were divided into 3 experimental groups:

- The rabbits in the 1<sup>st</sup> group were fed granulated mixture including 12% transgenic maize (MON 88017).

- The rabbits in the 2<sup>nd</sup> group were fed granulated mixture including 12% isogenic maize (DKC 5143).
- The rabbits in the 3<sup>rd</sup> group were fed granulated mixture including 12% reference maize (PR 36D 79).

The experiment lasted for 42 days. Rabbits were kept in standard cages (0.61 m × 0.34 m × 0.33 m), 2 animals per cage. Body weight and feed consumption were registered weekly. In fattening experiment the growth of live weight and consumption of feed mixtures per unit of live weight growth were studied. Between 65 and 70 days of age, 5 rabbits from each group were selected for digestibility tests using the balance method. The digestibility test was performed in accordance with the recommended methodology (Meertens and Lebas, 1989).

The samples of individual feeds were analyzed for content of nutrients (Table 1; Table 2) according the procedures of the AOAC (1995), and starch according to the alpha-amylloglucosidase method. Content of metabolised energy (ME) was calculated by the equation of Wiseman et al. (1992). Rabbits were fed *ad libitum* and they had free access to drinking water from nipple drinkers during the experiment. The diet formulation (complete granulated mixture, pellets of 3 mm diameter) for all groups is presented in Table 2.

Blood samples for biochemical and haematological analyses were obtained from the marginal ear vein (*Vena auricularis*) into dry non-heparinized glass tubes and blood serum was separated by centrifugation at 3 000 × g for 10 min. In blood serum, levels of proteins and lipids (g.l<sup>-1</sup>), cholesterol (mmol.l<sup>-1</sup>), glucose (mmol.l<sup>-1</sup>), calcium (mmol.l<sup>-1</sup>) were examined. Biochemical parameters were determined by an enzymatic colorimetric procedure using commercial set of Randox (United Kingdom). The activity of blood glutathione-peroxidase (GPx; U.ml<sup>-1</sup>) was determined by

**Table 1** Analysis of results of maize corn grown on allotment in PPRC Piešťany

Investigated parameters (1)	Unit (14)	1-transgenic maize MON 88017(15)	2-isogenic maize DKC 5143 (16)	3-reference maize PR 36D 79(17)
Dry matter (2)	g.kg <sup>-1</sup>	872.94	870.02	870.76
Crude protein (3)	g.kg <sup>-1</sup>	71.5	71.24	76.99
Crude fibre (4)	g.kg <sup>-1</sup>	17.17	17.96	22.38
Fat (5)	g.kg <sup>-1</sup>	33.08	36.10	30.94
Ash (6)	g.kg <sup>-1</sup>	11.82	12.22	11.91
N-Free Extract (7)	g.kg <sup>-1</sup>	739.38	732.5	728.53
Organic matter (8)	g.kg <sup>-1</sup>	861.12	857.71	858.85
Starch (9)	g.kg <sup>-1</sup>	645.66	641.12	636.30
Sugar total (10)	g.kg <sup>-1</sup>	20.50	20.74	16.99
Calcium (11)	g.kg <sup>-1</sup>	0.34	0.43	0.33
Phosphorus (12)	g.kg <sup>-1</sup>	2.28	2.32	2.37
ME (13)	MJ.kg <sup>-1</sup>	13.32	13.37	11.50

**Tabuľka 1** Analýza výsledkov kukuričného zrna dospelovaného na parcelách CVRV Piešťany

(1) sledované parametre, (2) sušina, (3) dusíkaté látky, (4) vláknina, (5) tuk, (6) popol, (7) BNLV, (8) organická hmota, (9) škrob, (10) celkový cukor, (11) vápnik, (12) fosfor, (13) metabolizovaná energia, (14) jednotka, (15) transgénna kukurica, (16) izogénna kukurica, (17) referenčná kukurica

**Table 2** Ingredients and chemical analysis of the experimental diets for rabbits

Feed ingredients (1)	in % (12)	Chemical analysis in g. kg <sup>-1</sup> (13)	Experimental group with maize (23)		
			1-transgenic MON 88017 (24)	2-isogenic DKC 5143 (25)	3-reference PR 36D 79 (26)
Lucerne meal (2)	41	dry matter (14)	901.8	895.8	895.6
Dried beet pulp (3)	10	crude protein (15)	172.8	168.1	171.4
Rape extr. meal (4)	20	crude fibre (16)	179.2	183.0	189.2
Wheat (5)	3	fat (17)	38.4	35.6	32.6
Apple pomace (6)	9	N free extract (18)	432.2	438.8	428.3
Maize (7)	12	organic matter (19)	822.6	821.6	821.5
Carob meal (8)	0.4	starch (20)	154.2	157.6	160.1
Mineral & Vitamins*(9)	3.2	calcium (21)	9.3	6.7	9.6
Rape oil (10)	1.0	phosphorus (22)	6.9	4.1	3.7
Limestone pulverized (11)	0.4	ME in MJ. kg <sup>-1</sup>	9.42	9.16	8.99

\* Provided per kg diet: vit. A 12000 IU; vit.D2 2500 IU; vit. E 20 mg; vit.B1 1.5 mg; vit. B2 7.5 mg; vit. B6 4.5 mg; vit.B 12 30 µg; vit.K 3 mg; nicotin acid 45 mg; folic acid 0.8 mg; biotin 0.08 mg ; Choline chloride 450 mg; Premix minerals (per kg diet) Ca 9.25 g; P 6.2 g; Na 1.6 g; Mg 1.0 g; K 10.8 g; Fe 327.5 mg; Mn 80 mg; Zn 0.7 mg

\* poskytuje pre kg diéty: vit. A 12000 IU; vit.D2 2500 IU; vit. E 20 mg; vit.B1 1.5 mg; vit. B2 7.5 mg; vit. B6 4.5 mg; vit.B 12 30 µg; vit.K 3 mg; nikotínová kys., 45 mg; listová kys., 0.8 mg; biotin 0.08 mg ; Cholín chlorid 450 mg; Premix minerálov (na kg diéty) Ca 9.25 g; P 6.2 g; Na 1.6 g; Mg 1.0 g; K 10.8 g; Fe 327.5 mg; Mn 80 mg; Zn 0.7 mg

**Tabuľka 2** Zložky a chemické analýzy experimentálnych diét pre králiky

(1) krmivové zložky, (2) lucernová múka, (3) sušené cukrovarské rezky, (4) repková extr. múka, (5) pšenica, (6) jablkové výlisky, (7) kukurica, (8) carobová múka, (9) minerál a vitamíny, (10) repkový olej, (11) vápenec mletý, (12) v %, (13) chemické analýzy v g. kg<sup>-1</sup>, (14) sušina, (15) N-látky, (16) vláknina, (17) tuk, (18) BNLV, (19) organická hmota, (20) škrob, (21) vápnik, (22) fosfor, (23) experimentálne skupiny s kukuricou, (24) transgénna kukurica, (25) izogénna kukurica, (26) referenčná kukurica

a RANSEL standard set from Randox (United Kingdom). Moreover, the phagocytic activity (PA) was monitored and expressed as percentage of bacteria ingested per phagocyte (100 neutrophils) during a limited period of incubation of particles suspension and phagocytes in serum (Hrubiško et al., 1981). Three animals from each group were slaughtered on 42<sup>nd</sup> day; they were stunned by electronarcosis (90 V for 5 s), immediately hung by the hind legs at the processing line and quickly bled by cutting the jugular veins and carotid arteries. After the bleeding, the *Musculus longissimus dorsi* (MLD) was separated by skin removal, chilled and stored 24 h at 4 °C until physico-chemical analysis (according STN 57 0185). Total water, protein and fat contents were estimated using an INFRATEC 1265 spectrometer and expressed in g/100g; from these values, the energy value was calculated [ $EV(kJ/100g) = 16.75 \times \text{Protein content} + 37.68 \times \text{Fat content}$ ]. Water holding capacity (WHC) was determined by compress method at constant pressure (Hašek and Palanská, 1976). The caecal samples from each of three slaughtered rabbits were collected for microbiological

analysis; pH, VFA, ammonia-N and lactic acid were determined. Caecal pH was measured immediately after sampling by using a digital pH meter; VFA concentration was determined using gas chromatography on a 1.8 m column with 10% SP1200 and 1% H<sub>3</sub>PO<sub>4</sub> on Chromosorbe WAW 80/100 mesh with isokaprylic acid as an internal standard (GC Carlo Erba). Ammonia-N concentration was measured by the microdiffusion method (Conway, 1967).

The results were quoted as mean ± standard deviation (SD); statistical evaluation of the results was performed by the one-way ANOVA and Tukey test.

## Results and discussion

The study was carried out in the Animal Production Research Centre, Nitra, in the Institute of Nutrition. The performance of feed conversion in three mixtures with 12% of transgenic maize,

**Table 3** Test results of complete feed mixture in feeding and balance experiments with rabbits

Investigated parameters (n = 24) (1)	Experimental group with maize (11)		
	1-MON 88017 transgenic (12)	2-DKC 5143 isogenic (13)	3-reference PR 36D 79 (14)
Daily weight gain in g.day <sup>-1</sup> (2)	36.88	36.95	39.0
Feed conversion ratio in g.g <sup>-1</sup> (3)	3.00	3.08	3.21
Carcass yield in % (4)	57.27	57.78	57.85
Coefficient of nutrients digestibility in % (n = 5) (5)			
Crude protein (6)	65.72 ± 2.35	63.97 ± 3.9	66.39 ± 1.04
Fat (7)	72.50 ± 8.45	78.22 ± 3.93A	76.30 ± 5.15
Crude fibre (8)	25.25 ± 0.56	25.29 ± 1.98	24.90 ± 1.76
Nitrogen-Free Extract (9)	75.57 ± 1.75	75.30 ± 2.03	75.88 ± 1.35
Organic matter (10)	61.34 ± 1.54	62.16 ± 1.79	62.06 ± 0.42

– differences between values in line marked by different letters (a, b, c) are significant on level  $P < 0.05$ ; (A B C) are significant on level  $P < 0.01$   
 – rozdiely medzi hodnotami v riadku označené rôznymi písmenami sú preukazné (a, b, c) pri hladine  $P < 0.05$ ; sú preukazné (A, B, C) pri hladine  $P < 0.01$

**Tabuľka 3** Výsledky testovania kompletnej kŕmnych zmesí v kŕmnych a bilančných experimentoch s králikmi  
 (1) sledované parametre, (2) denné váhové prírastky g.day<sup>-1</sup>, (3) konverzia krmiva v g.g<sup>-1</sup> prírastku, (4) jatočná výtažnosť v %, (5) koeficienty strávitelnosti živín v %, (6) N-látka, (7) tuk, (8) vlákna, (9) BNLV, (10) organická hmota, (11) Experimentálna skupina s kukuricou, (12) transgénna kukurica, (13) izogénna kukurica, (14) referenčná kukurica**Table 4** Meat quality traits of *longissimus dorsi* muscle (MLD) of rabbits 24 h post mortem

Investigated parameters in g.100 g <sup>-1</sup> MLD (1)	Experimental group with maize ( $\pm$ SD) (8)		
	1-MON 88017 transgenic (9)	2-DKC 5143 isogenic (10)	3-reference PR 36D 79 (11)
Content of water (2)	75.37 ± 0.06	75.6 ± 0.46	75.7 ± 0.38
Total proteins (3)	21.83 ± 0.15	21.9 ± 0.20	21.6 ± 0.11
Content of fat (4)	1.8 ± 0.10	1.47 ± 0.31	1.63 ± 0.32
Energetic value in kJ.100g <sup>-1</sup> (5)	433.53 ± 1.34	423.34 ± 14.86	423.90 ± 12.93
pH24	5.56 ± 0.02	5.57 ± 0.04	5.73 ± 0.03
Electrical conductivity in $\mu$ S (6)	0.96 ± 0.04	1.36 ± 0.83aC	0.55 ± 0.40
Water holding capacity (7)	29.49 ± 6.66	29.30 ± 5.94	30.81 ± 3.85

– differences between values in line marked by different letters (a, b, c) are significant on level  $P < 0.05$ ; (ABC) are significant on level  $P < 0.01$   
 – rozdiely medzi hodnotami v riadku označené rôznymi písmenami sú preukazné (a,b,c) pri hladine  $P < 0.05$ ; sú preukazné (A, B, C) pri hladine  $P < 0.01$

**Tabuľka 4** Ukazovateľy kvality mäsa svaloviny *longissimus dorsi* (MLD) králikov 24 h post mortem

(1) sledované parametre in g.100 g<sup>-1</sup> MLD), (2) obsah vody, (3) celkové biekoviny, (4) obsah tuku, (5) energetická hodnota in kJ.100 g<sup>-1</sup>, (6) elektrická vodivost, (7) volne viazaná voda, (8) experimentálna skupina s kukuricou, (9) transgénna kukurica, (10) izogénna kukurica, (11) referenčná kukurica

isogenic maize and reference maize intended for broiler rabbits was studied. After weaning at 35 days, the rabbits were fattened until they were 77 days old (granulated mixture, *ad libitum*). We did not find any significant differences among experimental groups in feed intake, body weight and carcass value in the fattening experiment (Table 3). The resulting digestibility coefficients for protein fell within the narrow range from 63.97 to 65.72 % and fat digestibility was within the interval from 72.50 to 78.22 %, which was similar to the data of Chraštinová et al. (2006). Feed mixtures differed regarding digestible energy content i.e. crude protein, crude fibre and fat. Physico-chemical properties of rabbit meat are presented in Table 4.

The protein and lipid contents of rabbit meat were measured in the range described by Dalle Zotte (2002), the water content slightly increased and the energy value decreased in comparison

**Table 5** Biochemical parameters in the blood of rabbits ( $\pm$ SD)

Investigated parameters (1) (n = 6)	Experimental group with maize (8)		
	1-MON 88017 transgenic (9)	2-DKC5143 isogenic (10)	3-reference PR 36D 79 (11)
Total proteins TP in g.l <sup>-1</sup> (2)	61.44 ± 3.87b	54.77 ± 3.80	62.28 ± 1.07b
Cholesterol CHOL in mmol.l <sup>-1</sup> (3)	2.08 ± 0.24bc	1.71 ± 0.29	1.56 ± 0.2
Triglycerides TRIGS in mmol.l <sup>-1</sup> (4)	1.10 ± 0.45	0.98 ± 0.35	0.84 ± 0.19
Glucose GLU in mmol.l <sup>-1</sup> (5)	8.10 ± 0.37	7.96 ± 0.36	7.93 ± 0.52
Alaninaminotransferaze ALT in U.l <sup>-1</sup> (6)	10.03 ± 2.78b	8.61 ± 1.47	10.13 ± 2.35b
Calcium Ca in mmol.l <sup>-1</sup> (7)	3.24 ± 0.14	3.07 ± 0.15	3.28 ± 0.06

– (Crumlin, UK) kits (TP 245, CH 200, AL 100, GL 2623, CA 590) a Bio-La-Test (Lachema Brno) TG L 250 S

– differences between values in line marked by different letters (a, b, c) are significant on level  $P < 0.05$

– rozdiely medzi hodnotami v riadku označené rôznymi písmenami sú preukazné (a, b, c) pri hladine  $P < 0.05$ ;

**Tabuľka 5** Biochemické parametre v krvi králikov ( $\pm$ SD)  
 (1) sledované parametre, (2) celkové biekoviny, (3) cholesterol CHOL, (4) triglyceridy TRIGS, (5) glukóza GLU, (6) alaninaminotransferáza ALT, (7) vápnik, (8) experimentálna skupina s kukuricou, (9) transgénna kukurica, (10) izogénna kukurica, (11) referenčná kukurica

with presented data by the above-mentioned author. It is well known that muscle fat content, pH and water holding capacity (WHC) are related. There is a positive correlation between intramuscular fat content and WHC as well as between ultimate pH and WHC (Dalle Zotte, 2002; Hernández et al., 2000); these findings were confirmed also by us.

The values of blood parameters were changed in the framework of the physiological level (Post Graduate Committee in Veterinary Science). Some authors presented a wide range of blood parameters, mainly of cholesterol (Canzi et al., 2000). Increased levels of the biochemical parameters in blood serum could be explained as a result of better resorption and utilization of these nutrients from the gastrointestinal tract, which was also described in our previous studies (Aulrich et al., 2001; Sommer et al., 2004; Chraštinová et al., 2006; Chrenková et al., 2007; Pogány Simonová et al., 2009).

At day 42, immunostimulative effect of maize was noted in both experimental groups. Phagocytic activity was measured in

**Table 6** The value of PA and IPA in rabbit blood and the activity of blood GPx ( $\pm$  SD)

Experimental group with maize (1)	Phagocytic activity in % (5)	Index PA (6)	The activity of blood enzyme glutathione peroxidase GPx (U/g Hb) (7)
1-MON 88017 (2)	43.7 $\pm$ 0.5	1.8 $\pm$ 0.05	125.34 $\pm$ 31.58c
2-DKC5143 (3)	44.8 $\pm$ 0.8	1.8 $\pm$ 0.06	121.54 $\pm$ 24.89c
3-PR 36D 79 (4)	45.5 $\pm$ 0.6	1.8 $\pm$ 0.06	107.83 $\pm$ 34.44

– differences between values in line marked by different letters (c) are significant on level  $P < 0.05$

– štatisticky preukazný rozdiel medzi pokusnými skupinami a referenčou skupinou na hladine významnosti  $P < 0.05$

**Tabuľka 6** Hodnoty PA a IPA v krvi králikov a aktívita krvnej GPx

(1) experimentálna skupina s kukuricou, (2) transgénna kukurica, (3) izogénna kukurica, (4) referenčná kukurica, (5) fagocytárna aktivita, (6) index PA, (7) aktívita enzymu glutation peroxidázy GPx (U/g Hb) v krvi

**Table 7** Qualitative parameters in caecum

Investigated parameters (1)	Experimental group with maize ( $\pm$ SD) (7)		
	1-MON 88017 (8)	2-DKC5143 (9)	3-PR 36D 79 (10)
pH	6.14 $\pm$ 0.35	6.12 $\pm$ 0.29	6.57 $\pm$ 0.34
N-NH <sub>3</sub> in mmol.l <sup>-1</sup>	11.62 $\pm$ 5.76	11.46 $\pm$ 7.03	17.75 $\pm$ 5.57AB
Acetic a. in mmol.100 g <sup>-1</sup> (2)	3.990 $\pm$ 0.48C	3.154 $\pm$ 0.55	2.944 $\pm$ 0.08
Propionic a. in mmol.100 g <sup>-1</sup> (3)	0.263 $\pm$ 0.07 b,c	0.192 $\pm$ 0.05	0.210 $\pm$ 0.06
Butyric a. in mmol.100 g <sup>-1</sup> (4)	0.775 $\pm$ 0.15	0.735 $\pm$ 0.09	0.364 $\pm$ 0.01AB
Other VFA in mmol.100 g <sup>-1</sup> (5)	0.105 $\pm$ 0.01b,c	0.092 $\pm$ 0.01	0.092 $\pm$ 0.01
Lactic acid in g.100 g <sup>-1</sup> (6)	0.036 $\pm$ 0.001	0.036 $\pm$ 0.001	0.068 $\pm$ 0.002AB

– differences between values in line marked by different letters (a, b, c) are significant on level  $P < 0.05$ ; (ABC) are significant on level  $P < 0.01$

– rozdiely medzi hodnotami označenými rozdielnymi písmenami (a, b, c) sú štatisticky významné na hladine  $P < 0.05$ ; (A, B, C) sú štatisticky významné na hladine  $P < 0.01$

**Tabuľka 7** Kvalitatívne parametre v slepom čreve

(1) sledované parametre, (2) octová k., (3) propiónová k., (4) maslová k., (5) Iné UMK, (6) mliečna k., (7) experimentálna skupina s kukuricou, (8) transgénna kukurica, (9) izogénna kukurica, (10) referenčná kukurica

the range between 43.7 and 45.5 % (Table 6). Measurement of the low activity of GPx in experimental groups as well as the evidently good health of rabbits indicated that no oxidative stress was evoked during the experiment. Concentration of observed VFA shows that the most intensive process was in caecum of rabbits in experimental group 1 (Table 7) and lower concentration of ammonia – N affects pH value. High concentration of acetic acid, propionic acid, butyric acid and lactic acid were in the caecum of rabbits with the supplemented reference maize PR 36D 79, which arose over the period of maize starch production by biochemical and fermentative processes. Low fibre diets resulted in decrease of acetates and increase of propionates and butyrates.

Feeding of genetically modified maize to rabbits did not influence biochemical and zootechnical parameters, as well as it had no negative effect on growth performance of rabbits.

### Conclusion

On the basis of our results we can summarize that genetically modified maize in rabbit nutrition did not have a negative influence on the health status of the animals. Feeding of genetically modified Bt maize and isogenic maize to rabbits did not negatively influence the feed conversion, digestibility of nutrients, meat quality of the tested animals and zootechnical parameters and biochemical and mineral parameters in blood and caecum. It had no negative effect on growth performance of rabbits and influence on body weight as well.

ké a minerálové parametre v krvi, charakteristiky kvality mäsa, fyzikálne a chemické charakteristiky pre mäso v MLD svaile, a fermentačný model v slepom čreve králikov. Rast živej hmotnosti, konverziu krmiva a zdravie králikov po skrmovaní kompletných zmesí s 12 % podielom Bt kukurice (MON 88017), izogénnej kukurice a referenčnej kukurice boli skúšané na 72 brojlerových králikoch (Hycola). Bt kukurica nezhoršovala vôbec zdravie zvierat ani výrobu živočíšnych proteínov cenných pre ľudskú výživu v porovnaní s bežnou kukuricou. Na základe našich výsledkov môžeme zhŕnúť, že geneticky modifikovaná kukurica vo výžive králikov nemala negatívny vplyv na zdravotný stav zvierat. Získané výsledky ukazujú minimálne, štatisticky nevýznamné rozdiely vo využívaní individuálnych živín a v stráviteľnosti skúšaných zmesí. Po použití Bt kukurice a izogénnej kukurice pre králikov záporne neovplyvnili spotrebú kŕmnych zmesí na jednotku prírastku živej hmotnosti. Neboli získané významné rozdiely vo vybraných parametroch kvality mäsa skúšaných zvierat a zootechnických parametroch vo všetkých skúšobných skupinách. Koncentrácia biochemických a minerálnych parametrov v krvi boli v referenčnom rozsahu a vysoké hladiny cholesterolu boli objavené v skupine s Bt kukuricou. V skupine s Bt kukuricou v diéte boli v obsahu slepého čreva králikov významne vyššie celkové unikáve mastné kyseliny (VFA) a molárne koncentrácie octanu ( $P < 0.01$ ) a propionátu ( $P < 0.05$ ), ale koncentrácia kyseliny mliečnej bola nižšia ( $P < 0.01$ ).

**Klúčové slová:** Bt kukurica; králik; mäso; krv; slepé črevo

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### Súhrn

Cieľom tejto práce bolo zistiť efekt vybraných odrôd kukurice v diétach na stráviteľnosť živín a rastovú úžitkovosť, biochemic-

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## THE EFFECT OF CULTIVAR AND STAND DENSITIY ON YIELD COMPONENTS AND YIELD OF POT MARIGOLD

### VPLYV ODRODY A HUSTOTY PORASTU NA ÚRODOTVORNÉ PRVKY A ÚRODU NECHTÍKA LEKÁRSKEHO

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Field trial with Pot Marigold (*Calendula officinalis* L.) was conducted in 2008 at experimental field of Institute of Field and Vegetable Crops at Rimski Šančevi ( $\phi$  45° 20 N,  $\lambda$  19° 51 E), Novi Sad, Serbia. The experimental design was a split-plot arrangement, where the main plots were cultivars and the sub-plot stand densities. There were 4 cultivars: "Bački Petrovac-BP", "Orange King-OK", "Plamen-P" and "Plamen Plus-PP" and 4 densities: 20, 30, 40 and 50 plants per square meter. Dry matter content of receptacle, petiole and whole flower was significantly the highest in BP and the lowest in PP. Fresh/dry ratio was in opposite position for receptacle 5.4 and 6.0, for petiole 6.4 and 7.2 and for flower 5.7 and 6.6 respectively. Plant density does not influence dry matter and fresh/dry ratio. Fresh and dry flower yield was the highest in all cultivars at density of 40 plants per square meter. There is no difference between cultivars in fresh; while in dry flower yield of BP cultivar was the highest (1 299 kg·ha<sup>-1</sup>) and P cultivar the lowest (1 082 kg·ha<sup>-1</sup>). Fresh and dry ratio of petal/flower was the highest in PP (50 and 45%) and the lowest in P (37 and 33 %). Those ratios regularly increase with increasing of stand density.

**Key words:** pot marigold, stand density, cultivar, yield, dry matter

*Calendula officinalis* L. – Pot Marigold is a native of the Mediterranean area but is grown widely across Europe as ornamental or for medicinal and even culinary purposes. It produces large numbers of yellow-orange flowers over a long period. In Serbia and Vojvodina province pot marigold is used as a traditional medicinal plant – floral drug.

Use of „natural“ products has dramatically increased interest in medicinal and aromatic plants as food preservatives, pharmaceutical compounds, seasonings, and flavorings (Craker, 1999), among them is calendula, whose production is also increasing. Like other medical plants, crop management of marigold is not studied enough so further agronomic research is needed to ensure that validated crop management guidelines are available to growers if and when large-scale calendula production occurs (Martin and Deo, 2000). It was feasible according to Wilen et al. (2004) and Habán et al. (2010) cultivation of Calendula as a dual purpose for seed and flower yield. Accomplished results from commercial production of calendula in Vojvodina, point out to the great possibilities for successful and profitable cultivation of this crop. For those reasons, we chose to research two main cultural practices: plant density and cultivars. The effects of plant density at two widely spread cultivars in Vojvodina and two new cultivars from Czech Republic were investigated. According to the results of Kišgeci (2002) optimal row spacing for marigold is 40 – 50 cm, while Šilješ et al. (1992) as optimal row spacing quote 0.50 – 60 m. According to Martin and Deo (2000) recommended row spacing with commercial seed drills is 0.12 – 25 m, although wider, 0.50 m rows are used for mechanical weeding systems and optimal populations for flower yield was around 46 plants/m<sup>2</sup>. Flower and seed yield were the highest at the maximum investigated 25 plants/m<sup>2</sup> (Seghatoleslami and Mousavi, 2009). Gomes et al. (2007) quote that yields of fresh and dried mass of capitula were not

influenced by densities from 6 – 12 plants per m<sup>2</sup>. Like optimal for oilseed production Smith et al. (1997) suggested a population of 50 – 60 plants per m<sup>2</sup> and Cromack and Smith (1998) and Froment et al. (2002) about 40 plants per m<sup>2</sup>. The aim of this research was to find the best adapted variety and optimal row spacing, concerning petal yield, as the most important medical raw material of marigold. These researches will contribute the optimal cultural practices for marigold in Vojvodina province and will also be the beginning of variety specific cultural practice of marigold.

### Material and methods

Field trial with calendula or pot marigold (*Calendula officinalis* L.) was conducted in 2008 at experimental field of Institute of Field and Vegetable Crops at Rimski Šančevi ( $\phi$  45° 20 N,  $\lambda$  19° 51 E), Novi Sad, Serbia. The experiment was on calcareous Chernozem soil type, with good soil properties and followed a crop of sunflower. On autumn (under plough), was applied 100 kg·ha<sup>-1</sup> NPK nutrients (15 : 15 : 15) and in spring (before sowing) 100 kg·ha<sup>-1</sup> of Urea (46% N). The experimental design was a randomized complete block with split-plot arrangement, where the main plots were cultivars and the sub-plot stand densities. There were 4 cultivars: "Bački Petrovac-BP", "Orange King-OK", "Plamen-P" and "Plamen Plus-PP" and 4 densities: 20, 30, 40 and 50 plants per square meter. Row distances were 50 cm for all densities. There were three replicates, and plots sizes were 10 m<sup>2</sup>.

Sowing was manually at depth of 2 – 3 cm, with 2 – 3 seeds per hill and in the stage of 3 – 5 leaves were thinned to the single plant. Weed control was by hand weeding. Fully opened flowers in the sampling length (two rows x 3 m) were plucked by

hand, 7 times during vegetation, once a week. In this paper totals of all harvests are shown. Dry matter content, fresh and air dry yield and fresh/dry ratio of receptacle, petiole and whole flower were measured. Analysis of variance of two factor randomized complete block design with split plot done by Mstat C statistical package.

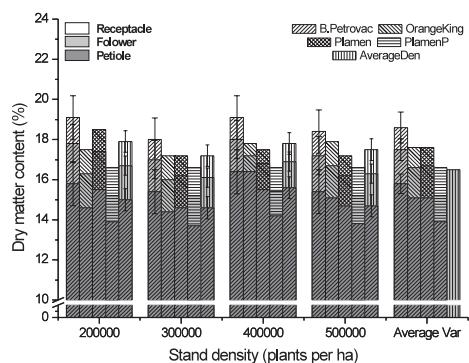
## Results and discussion

Dry matter content (DM) was the highest in receptacle (17.6%) and lowest in petiole (15.0%). At each density and in average for variety in receptacle, petiole and whole flower, DM were significantly the highest in BP and the lowest in PP, while between OK and P there are not differences (Figure 1). Stand densities do not influence DM.

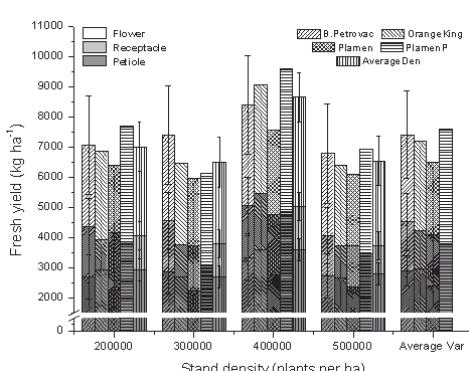
There are no significant differences between varieties in fresh yield of flower and receptacle, but in petiole variety PP had significantly the highest yield. That is because only PP have higher yield of petiole than receptacle, at each density. On an average and at each variety, significantly the highest yield of fresh flower, petiole and receptacle were at density of 40 plants per square meter, while between other densities there were not significant differences (Figure 2).

There are no significant differences between varieties in air dry yield of flower and petiole, but the highest flower yield had variety BP ( $1\ 299\ kg\cdot ha^{-1}$ ) and the highest petiole yield variety PP (526.4  $kg\cdot ha^{-1}$ ). The only significantly lower yield of

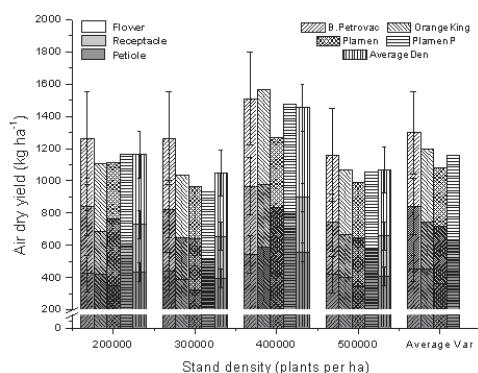
receptacle had variety PP. On average for variety, significantly the highest yield of air dry flower, petiole and receptacle were at density of 40 plants per square meter, while between other densities there were not significant differences (Figure 3). It corresponds with results of Kišceci (2002) for row distance and with results of Martin and Deo (2000), Gomes et al. (2007) and Seghatolslami and Mousavi (2009) concerning plant number per square meter. Flowers yield of varieties OK and PP were significantly the highest at density of 40 plants while between other densities there aren't significant differences. Variety BP



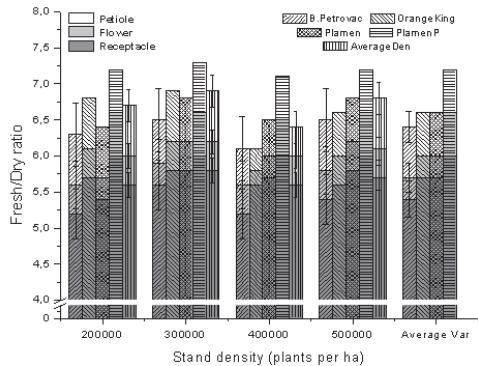
**Figure 1** The effect of variety and stand density on dry matter content of calendula  
**Obrázok 1** Vplyv odrody a hustoty porastu na obsah suchej hmoty nechtičky



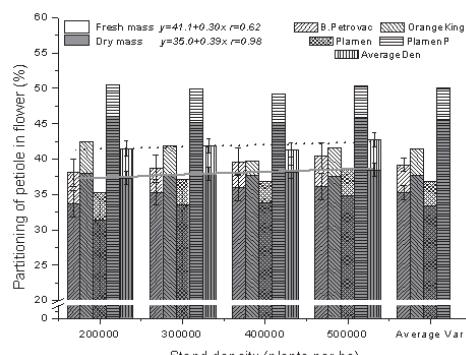
**Figure 2** The effect of variety and stand density on fresh yield of calendula  
**Obrázok 2** Vplyv odrody a hustoty porastu na úrodu čerstvej hmoty nechtička



**Figure 3** The effect of variety and stand density on air dry yield of calendula  
**Obrázok 3** Vplyv odrody a hustoty porastu na úrodu vzduchom sušeného nechtička



**Figure 4** The effect of variety and stand density on fresh/dry ratio of calendula  
**Obrázok 4** Vplyv odrody a hustoty porastu na pomer čerstvej/suchej hmoty nechtička



**Figure 5** The effect of variety and stand density on petiole flower ratio of calendula  
**Obrázok 5** Vplyv odrody a hustoty porastu na podiel jazykovitých kvetov na úbere

had only significant lower flower yield at density of 50 plants, while in variety P there were no significant differences. Similarly to flower yield, stand densities and varieties influenced air dry yield of receptacle and petiole.

Fresh/dry ratio present quantity of fresh mass to one weight unit of air dry mass and it mainly depends on dry matter content. Significantly the lowest fresh dry ratio of receptacle, flower and petiole had variety BP, 5.4, 5.7 and 6.4 respectively. Variety PP had significantly the highest ratio of 6.0, 6.6 and 7.2 respectively. Ratio of other two varieties was ranged in this value. On density average only ratio of flower was significantly lower at density of 40 plants. In interaction variety\*density significant difference was in flower fresh dry ratio only, where variety BP had significantly lower ratio at density of 40 plants (Figure 4).

Fresh and dry ratio of petal/flower was significantly the highest in variety PP (50 and 45%) and significantly the lowest in P (37 and 33 %) between them were varieties BP and OK with significant differences too. In average for densities in fresh and dry ratio there were significant differences only between 20 and 50 plants, but those ratios regularly increased with increasing stand density,  $r = 0.62$  and  $0.98$  respectively. Only significant differences of interaction variety\*density was between the lowest and highest densities of fresh and dry petiole/flower ratio of varieties BP and P (Figure 5).

### Conclusions

According to results next conclusions could be made:

- Dry matter content was the highest in receptacle (17.6%) and lowest in petiole (15.0%).
- Dry matter content in receptacle, petiole and whole flower highly influenced by variety (the highest in BP and the lowest in PP) and not by stand density.
- There is no significant difference in fresh and dry flower yield between cultivars, although BP had the highest ( $1\ 299\ kg.ha^{-1}$ ) and P the lowest ( $1082\ kg.ha^{-1}$ ) dry yield.
- Fresh and dry flower yield was the highest in all cultivars at 40 plants per square meter.
- Fresh dry ratio of receptacle, flower and petiole was the lowest in variety BP; 5.4, 5.7 and 6.4 respectively and the highest in variety PP; 6.0, 6.6 and 7.2 respectively. Plant density doesn't influence this trait.
- Fresh and dry ratio of petal/flower was the highest in PP (50 and 45%) and the lowest in P (37 and 33 %). Those ratios regularly increase with increasing stand density.

### Súhrn

Poľný pokus s nechtíkom lekárskym bol uskutočnený v roku 2008 na experimentálnej ploche Inštitútu poľných a záhradných plodín v lokalite Rimski Šančevi ( $\varphi 45^{\circ} 20' N$ ,  $\lambda 19^{\circ} 51' E$ ), v Novom Sade v Srbsku. Pokus bol založený metódou delených dielcov, pričom odrôda bola považovaná za hlavnú parcelku a faktor hustota porastu bol hodnotený v podparcelkách. Hodnotili sa štyri odrôdy: „Bački Petrovac“, „Orange King“, „Plamen“ a „Plamen Plus“ a štyri hustoty porastu pri 20, 30, 40 a 50 rastlinach na meter štvorcový. Suchá hmota kvetného lôžka, okvetných lístkov a celého kvetu bola preukazne vyššia pri odrôde Bački Petrovac a najnižšia pri odrôde Plamen Plus. Protichodne bol pomer čerstvá/suchá hmota pre kvetné lôžko v pomere 5,4 a 6,0, pri okvetných lístoch 6,4 a 7,2, pri kvetoch 5,7 a 6,6. Hustota porastu neovplyvnila produkciu suchej hmoty a pomer čerstvá hmota/suchá hmota. Najvyššia produkcia čerstvej a suchej hmoty kvetov

bola pri hustote porastu 40 rastlín na  $m^2$ . Nebol zistený rozdiel v produkcií čerstvej hmoty kvetov medzi odrôdami, ale úroda suchej hmoty kvetov pri odrôde Bački Petrovac bola preukazne najvyššia  $1\ 299\ kg.ha^{-1}$  a pri odrôde Plamen najnižšia ( $1\ 082\ kg.ha^{-1}$ ). Pomer čerstvej a suchej hmoty jazykovitých kvetov úborov bol najvyšší pri odrôde Plamen Plus (50 a 45%) a najnižší pri odrôde Plamen (37 a 33 %). Tieto pomery pravidelne narastali s narastajúcou hustotou porastu.

**Kľúčové slová:** nechtík lekársky, hustota porastu, odrôda, úroda, suchá hmota

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## THE YIELD AND QUALITY OF MILK THISTLE [*SILYBUM MARIANUM* (L.) GAERTN.] SEED OIL FROM THE PERSPECTIVE OF ENVIRONMENT AND GENOTYPE – A PILOT STUDY

### VÝNOS A KVALITA OLEJE PLODŮ OSTROPESTŘCE MARIÁNSKÉHO [*SILYBUM MARIANUM* (L.) GAERTN.] Z POHLEDU PROSTŘEDÍ A GENOTYPU – PILOTNÍ STUDIE

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During the years 2007 – 2008, samples of Milk thistle [*Silybum Marianum* (L.) Gaertn.] variety Silyb (silybene type, CZE) from five Czech growing regions were assessed for seed oil content (%) and neutralization number. The second part included six different genotypes with the evaluation of oil content (%), the spectrum of main fatty acids, neutralization number (NN). The analyses showed highly significant differences in the seed oil content for environment and year conditions. The highest average oil content had the sample from cereal region 2 (21.28 %), the lowest value was in potato region 2 (18.97 %). In 2007, the oil content was 20.30 %, in 2008 – 19.59 %. The NN was significantly affected also by both factors. Regarding the genotypes, the highest oil content had variety Silyb – silybene type (21.6 %), followed by the variety Mirel (21.0 %). The lowest content of oil was recorded in Rosa Canina and Leros samples (17.5 % and 18.1 %). The neutralization number (NN) varied highly in the samples (4.3 – 33.0). For all samples dominant fatty acid (FA) was linoleic, followed by oleic, palmitic and stearic acid and another minor FA (0.03 till 0.7 %). The highest amount of linoleic acid was recorded in variety Mirel (66.4 %), the lowest content had Serbian sample (50.6 %).

**Key words:** milk thistle, *Silybum Marianum*, seed oil, fatty acids, environment

Milk thistle [*Silybum Marianum* (L.) Gaertn.], a medicinal plant from Apiaceae (*Umbelliferae*) family, is cultivated for the seeds, achenes, which contain flavonolignans, known as silymarin complex. This substance is used in therapy for its hepatoprotective activity (Habán et al., 2009). Milk thistle is also an alternative oil crop while the side product of seed pressing is fatty oil with high content of polyunsaturated fatty acids. Among them, linoleic acid prevails (Buchta et al., 2010). The oil is used in animal nutrition, cosmetology, dermatology for its specific properties (Součková, 2011). It is suitable for the production of environmental friendly organic coatings together with the interesting price (Středa, 2003).

The area of milk thistle varies from 700 to 4500 ha. There are two varieties in the Czech Republic, one is registered with the Plant Variety Rights (PVR), second has the PVR only. Variety Silyb was registered for the isolation of silymarin complex in pharmaceutical industry. Mirel variety was applied to PVR for seed oil content and fatty acids composition but was not spread last year (Součková, 2011; ÚKZÚZ, 2011). Milk thistle production is interested for a lot of farmers and agricultural companies but the certified seed material is not available on the market. The aim of the work was to assess oil content and neutralization number of milk thistle fruits from different localities in the Czech Republic during two years. In the second part, we have tested the oil content and fatty acids spectrum in different genotypes or provenances.

#### Material and methods

In the first part of the experiments, the samples from five growing regions in the years 2007 – 2008 were assessed for seed oil content (%) and neutralization number. These samples

from silybene type seeds of variety Silyb were sampled from the production plots in amount of 1.5 kg. Localities covered two potatoes growing regions (P1, P2), two cereals growing regions (C1, C2) and one sugar beet growing region (S). All analyses were performed six months after the harvest.

The second part of the research covered six samples of different genotypes of Milk thistle obtained from companies, gene banks and from the food supplement market. The samples were from the years 2009 – 2010, but the year was not a factor of the interest in this part of assessment. Varieties Silyb (silybene and silydianine type) and Mirel were grown in the Czech Republic. The samples from Czech Republic (CZE1 and CZE2) were from the market. As we found out by the questionnaire, they were Czech origin, but without the description of the variety and locality. Serbian genotype had no description. The aim of this part was to evaluate the oil content (%), the spectrum of main fatty acids in the oil (% ratio) and neutralization number (NN).

The total oil content was evaluated by the gravimetric method in %. 20.0 g of oil seed and was mixed with 500.0 mL of petroleum ether in evaporation flask. This mixture was stirred in water bath (40 °C) for 2 hours. The mixture was filtered and the filtrate was distilled under vacuum. After distillation of majority of the mixture, petroleum ether was spilled over and the distillation under vacuum was continued. The flask with the rest of seed oil was weighted. The neutralization number was tested by the method of Ph. Eur. VI. (2008). The sample were subjected to titration by the alcoholic solution of potassium hydroxide on phenolphthalein till to mild pink colour.

In the extracted oil samples fatty acids profiles were evaluated by gas chromatography with flame-ionization detector (GC/FID). Extracted oil (40 – 60 mg) was dissolved in isoctane and homogenized by ultrasound. After that sodium methanolate was added and the mixture was boiled under

reverse condenser. BF3 was added, after that, isoctane and saturated solution of NaCl was mixed with hot liquid. Methyl esters of fatty acids (FAMES) were shortly and intensively shaken out into isoctane. Organic and water phase were separated and FAMES were analyzed by GC on HP4890 with capillary column DB-23, in temperature program from 100 °C \* 3 min \* 10 °C/min \* 170 °C \* 0 min \* 4 °C/min \* 230 °C \* 8 min \* 5 °C/min \* 250 °C \* 15 min, temperature of the injector 270 °C, temperature of the detector 280 °C. The injection volume was 2 ml, the carrier gas was nitrogen. The flame-ionization detector was connected to the column output. Final data were processed in CSW Station software (version 1.7, Data Apex).

The results in the first part were evaluated by the analyses of variance for two factors (year, locality) in STATISTICA CZ 8.0 software, on the level of significance  $\alpha = 0.95$ . The parameters in the second experiment related to the genotypes were the average values from two assessments. Because of the lack of the data, we could not provide any further statistical analyses except the descriptive statistics.

## Results and discussion

### The effect of growing locality and the year on the oil content and neutralization number

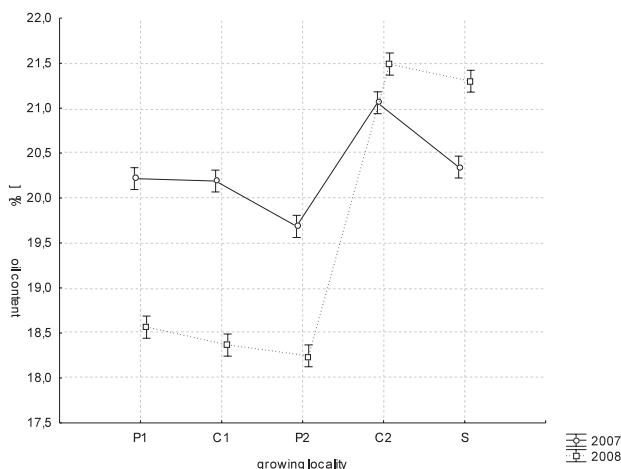
Analyzed data showed statistically highly significant differences in the seed oil content among the growing localities. The average values of oil content are presented in the Figure 1. The highest average oil content was recorded in the sample from C2 region (21.28 %) and the lowest value was in P2 region (18.97 %). The differences between the years 2007 (20.30 %) and 2008 (19.59 %) were also statistically highly significant. The oil content is affected by the genotype, the year and the environment mainly and also by their interactions (Baranyk et al., 2007). We confirmed this common known fact. The reaction to the conditions in both potato regions and both cereal regions were similar in both years, but the effect of the year was dominant as it can be seen from the Figure 1. The contents of the oil in the samples from all of localities and from both years were of 20 % lower in average than is mentioned in Czech experiments or literary sources. According to Buchta et al. (2010), the average oil content in the achenes varied between

25 – 35 % in the Czech Republic. Baranyk et al. (1995) found out the average value 24.5 % for the locality of central Bohemia. This region includes cereal growing region (C) and sugar beet growing region (S). Their results were very variable and were caused by the heterogeneity in the ripeness of the achenes, which is strongly influenced by the weather conditions during that period.

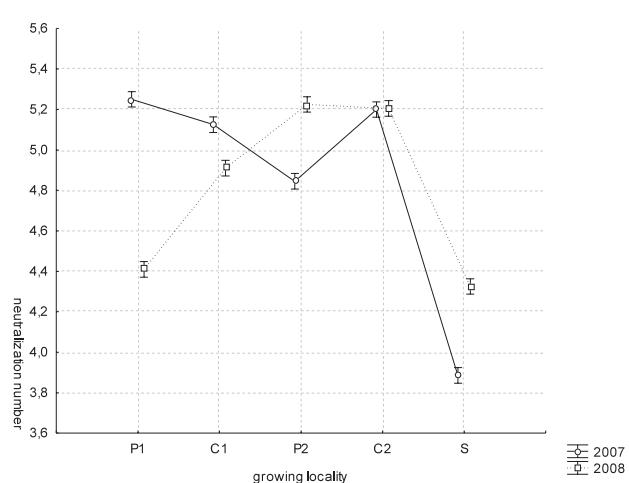
The neutralization number (NN) is statistically significantly affected by both factors, environment and year conditions. The highest NN was found out in the sample from C2 region (5.2), the lowest value was in S region (4.11). The NN in 2007 was 4.86, in 2008, it was 4.82. The values are shown in Figure 2. Surprisingly, the same values of NN were found in the different environment. The sample from sugar beet region differed from the others of the highest value. All the samples corresponded with the limit given by the Specification of the product (2008), where the NN should be lower than 10 mg KOH per g. The assessment was performed till 6 months after the harvest, so even we know that the production was processed in one company, we can not confirm the quality of oil from the point of view of the storage conditions in this organization. The values could be affected by the growing environment or storing by agricultural producers. Generally, the quality of oil seed is influenced by the period of the storage, the temperature and also there are the differences among the varieties (Ghasemnezhad and Honermeier, 2009).

### The effect of genotype on the oil content, neutralization number and fatty acids profile

Seed oil contents in the assessed genotypes are shown in the Figure 3. The highest oil content had sample of variety Silyb – silybire type from the holder of PVR (21.6 %), followed by the variety Mirel, also from the holder of PVR (21.0 %). According to the DUS tests, Mirel has declared 21.6 % of oil in average (ÚKZÚZ, 2011). The lowest content of oil was recorded in two samples from pharmaceutical and food companies (17.5 %, 18.1 %). The level of oil content in our genotypes was lower than is mentioned in literature, for example in Hosnedl et al. (1998) and in Buchta et al. (2010). Generally, the content of oil in our genotypes was lower than for example in the samples from Iran – 25.0 % (Hasanloo et al., 2008) or 26 – 31 % (Fathi-Achachlouei and Azadmard-Damirchi, 2009). Because we have limited number of the results in one year and low



**Figure 1** Effect of the locality and the year on oil content  
Obrázok 1 Efekt lokality a ročníka na obsah oleja



**Figure 2** Effect of the locality and the year on the neutralization number  
Obrázok 2 Efekt lokality a ročníka na číslo neutralizácie

**Table 1** Fatty acid ratio (%) in the oils of various genotypes. SAT total saturated FA, MUFA total monounsaturated FA, PUFA total polyunsaturated FA

Fatty acids	Czech Republic 1 (CZE)	Czech Republic 2 (CZE)	Mirel (CZE)	Silyb (silydianine, CZE)	Silyb (silybine, CZE)	Serbia
C14:0	0.075	0.067	0.072	0.076	0.071	0.081
C15:0 IS	0.023	0.018	0.021	0.022	0.019	0.019
C16:0	7.826	7.561	7.249	8.480	7.697	9.209
C16:1n7c	0.054	0.056	0.049	0.071	0.056	0.070
C18:0	4.677	4.843	3.568	5.285	5.329	5.925
C18:1n9c	19.191	21.201	16.263	21.339	22.887	25.447
C18:1n7c	0.440	0.438	0.393	0.520	0.443	0.497
C18:2n6c	60.527	58.920	66.401	56.955	55.906	50.589
C18:3n3c	0.290	0.200	0.266	0.278	0.188	0.226
C20:0	2.730	2.790	2.090	2.978	3.269	3.450
C20:1n9c	0.990	0.935	1.066	0.929	0.916	0.915
C22:0	2.253	2.239	1.894	2.335	2.454	2.760
C22:1n9c	0.216	0.038	0.049	0.045	0.036	0.082
C24:0	0.653	0.657	0.555	0.648	0.695	0.700
C24:1n9c	0.055	0.037	0.064	0.039	0.034	0.030
SAT	18.237	18.175	15.449	19.824	19.480	22.144
MUFA	20.946	22.705	17.884	22.943	24.372	27.041
PUFA	60.817	59.120	66.667	57.233	56.148	50.815

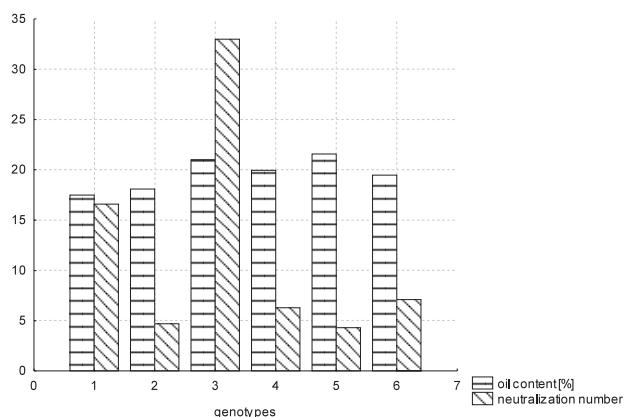
**Tabuľka 1** Obsah mastných kyselín v oleji, rôznych genotypov v %. SAT celkové nasýtené mastné kyseliny, MUFA celkové nenasýtené mastné kyseliny, PUFA celkové polo nasýtené mastné kyseliny

number of the genotypes, we can not strictly judge why the oil content in Czech samples were lower. It was probably caused by the influence of the year condition and genotype, as stated by Černý et al. (2010). Even the Milk thistle oil is chemically similar to sunflower oil; it is not suitable to compare the influence of sunflower genotypes on oil content and quality because of lack of the literature and serious scientific backgrounds in Milk thistle genotypes chemical description.

The neutralization number (NN) varied highly in the samples, the highest value was at variety Mirel (33), and the lowest NN was at variety Silyb – silybine type (4.3). When the maximal limit for this parameter is 10 mg of KOH.g<sup>-1</sup>

(Specification of the product, 2008), also the sample from food producers (CZE1) was out of the limit (16.6). High values of this parameter can be caused by totally inadequate way of storing of the seeds. The other samples corresponded with the standard requirements (Figure 3).

The Table 1 shows the ratios of fatty acids detected in the samples. Dominant fatty acid (FA) is linoleic for all the samples, followed by oleic acid, palmitic and stearic acid. Beside these main fatty acids, another minor FA was detected in the oil samples in amounts from 0.03 till 0.7 %. The highest amount of linoleic acid was recorded in the oil from variety Mirel (66.4 %), the lowest content had the sample from Serbia (50.6 %, without the description of variety). According to the DUS tests of the Central Institute of testing and Controlling in Agriculture, for Mirel, it is declared 8.5 % of palmitic acid, 22.5 % of oleic acid and 57.9 % of linoleic acid (ÚKZÚZ, 2009). Buchta et al. (2010) have evaluated the main FA in Milk thistle oil, linoleic acid ranged from 55.0 % to 72.0 %, 15.0 – 20.0 % of oleic acid and 8.0 – 14.0 % of saturated FA. Even there is lack of the literature about the individual FA profiles in the different genotypes of Milk thistle of the globe; there is some information about the seed oil quality from the other countries. Pakistani samples had 26 – 39 % of oil, with 23 – 47 % of oleic acid, 9 – 58 % of linoleic acid, 12 – 34 % of palmitic acid and 6 – 15 % of stearic acid. Higher contents of oleic (26.38 %) and linoleic acids (64.4 %) were also found (Khan et al., 2007). On the other hand, Iranian samples showed lower content of linoleic acid (45.36 %), but higher content of oleic acid (31.58 %) (Hasanloo et al., 2008). Regarding the absence of relevant literature, an interesting composition had ground defatted Milk thistle fruit, declared as Milk thistle flour (Botanic Oil Innovations, USA), where the content of the oil was 7.5 %, linoleic acid 4.6 %, oleic acid 37.1 %, palmitic acid 27.4 %, stearic acid 17.7 % (Parry et al., 2008). This product has surprisingly high content of saturated FA. Iranian authors

**Figure 3** Content of oil in Milk thistle genotypes and their neutralization numbers  
1 – Czech Republic 1, 2 – Czech Republic 2, 3 – Mirel, 4 – Silyb (silydianine type), 5 – Silyb (silybine type), 6 – Serbia**Obrázok 3** Obsah oleja a číslo neutralizácie v genotypoch pestreca mařínskeho  
1 – Czech Republic 1, 2 – Czech Republic 2, 3 – Mirel, 4 – pestrec (silydianine typ), 5 – pestrec (silybine typ), 6 – Srbsko

have performed the experiments regarding influence of the water conditions on the fatty acids composition in the oil. They included two foreign varieties – Budakalaszi (Hungary) and CN-seed (England), and two native varieties (Khoreslo, Babak Castle) using dryland and irrigated farming conditions. The type of farming did not influence the fatty acids composition. Native varieties had different levels of saturated and monounsaturated FA, but no differences in polyunsaturated FA were observed (Fathi-Achachlouei and Azadmard-Damirchi, 2009).

### Conclusions

The seed oil content in Milk thistle is affected by the environment in the frame of the dominant effect of the year conditions. It is called for better regionalization of this crop to the suitable regions. Another important factor influencing the seed oil content is a genotype, so there is the evidence of the interactions of three important factors. Nutrition quality of the oil is given mainly by the spectrum of unsaturated fatty acids. The samples of Milk thistle of various origins had predominant content of linoleic acid, followed by oleic acid. The oil of Milk thistle can be considered as nutritionally valuable, similar to sunflower oil as it was confirmed in previous published results. According to our search, majority of the processing companies are not interested in the origin of the raw material. They have no information about the variety, the region of production. The processing companies have to determine the origin of Milk thistle variety and implement appropriate technology in given environment.

### Súhrn

Vzorky nažek ostropestřce mariánského [*Silybum Marianum* (L.) Gaertn.], odrůdy Silyb (silybinový typ, ČR) z 5 výrobních oblastí České republiky byly během let 2007 – 2008 testovány na obsah oleje (%) a číslo kyselosti. Ve druhé části bylo hodnoceno 6 genotypů z hlediska obsahu oleje (%), spektra mastných kyselin a čísla kyselosti. Výsledky prokázaly statisticky průkazný vliv lokality a ročníku na obsah oleje. Nejvyšší obsah oleje měl vzorek z obilnářské výrobní oblasti 2 (21,28 %), nejnižší hodnoty byly zjištěny v bramborářské výrobní oblasti 2 (18,97 %). Obsah oleje byl v roce 2007 20,30 %, v roce 2008 19,59 %. Číslo kyselosti bylo rovněž statisticky průkazně ovlivněno oběma faktory. Co se týká genotypů, nejvyšší obsah oleje měla odrůda Silyb – silybinový typ (21,6 %), následovaný odrůdou Mirel (21,0 %). Nejnižší obsah měly vzorky z produkce CZE1 a CZE2 (17,5 % a 18,1 %). Číslo kyselosti bylo velmi variabilní, dosahovalo hodnot od 4,3 do 33,0. Dominantní mastnou kyselinou ve všech vzorcích byla linolová, dále olejová, palmitová a stearová a také některé minoritní MK (0,03 – 0,7 %). Nejvyšší obsah k. linolové měla odrůda Mirel (66,4 %), nejnižší obsah byl stanoven u srbského genotypu (50,6 %).

**Klíčová slova:** ostropestřec mariánský, *Silybum Marianum*, olej, mastné kyseliny, prostředí

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## ANTIOXIDANT ACTIVITY AND TOTAL PHENOLIC CONTENT OF FRACTIONS FROM SELECTED BULGARIAN MEDICINAL PLANTS

### ANTIOXIDAČNÁ AKTIVITA A CELKOVÝ OBSAH FRAKCIÍ FENOLOV VO VYBRANÝCH LIEČIVÝCH RASTLINÁCH BULHARSKA

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The antioxidant activities (AOA) of crude methanolic extracts (CME) and its ethyl acetate (EAF), butanol (BF), petroleum ether (PEF), chloroform (CF) and water fractions (WF) of eight Bulgarian medicinal plants were analyzed using the ABTS cation radical decolorization assay. The presence of compounds possessing antioxidant activity was identified in three fractions: in EAF of *Fragaria vesca*, *Rheum officinale* and *Melissa officinalis*, in BF of *Cydonia vulgaris*, *Hypericum perforatum* and *Origanum vulgare* and in CME of *Arctostaphylos uva-ursi*. Total phenolic content (TPC) was also determined for each extract/fractions. EAF contained the highest TPC as compared to the other fractions for all species followed by the BF for *Arctostaphylos uva-ursi*, *Fragaria vesca*, *Hypericum perforatum*, *Melissa officinalis* and *Origanum vulgare* and by CME for *Alchemilla vulgaris*, *Cydonia vulgaris* and *Rheum officinale*. AOA correlated positively to TPC of CME, BF and EAF, all of them showing a potential value as a source of natural antioxidants.

**Key words:** Bulgarian medicinal plants, antioxidant activity, total polyphenol content, fractions

Since ancient times plants have been used to prepare teas and beverages, and spices and herbs have been added to different type of food to improve quality, taste and flavor. Recently many plants and plant products have been recognized for their antioxidant properties (Kähkönen et al., 1999; Choi et al., 2002; Cai et al., 2004; Djerdane et al., 2006; Pourmorad et al., 2006; Wong et al., 2006). Plant phenolic compounds (flavonoids, phenolic acids and tannins) are the substances thought to contribute to a great extend to the antioxidant potential of plants (Nijveldt et al., 2001; Higdon et al., 2003; Scalbert et al., 2005). The antioxidant activity (AOA) and total phenolic content (TPC) of aqueous and aqueous-alcoholic extracts of over 50 Bulgarian medicinal plants have been extensively studied (Ivanov 2007; Ivanova et al., 2005, Ivanova et al., 2009, Kiselova et al., 2004; Kiselova et al., 2006), and plants with high TPC correlating to their antioxidant potential were identified. However, there are no relevant studies on the fractions containing highest amount of antioxidants from these plants. The aim of this work was to examine phenolic compounds of extracts of eight Bulgarian plants and their fractions and to evaluate their AOA.

### Material and methods

#### Plant material

Plant material was collected in different regions in Bulgaria. The species were identified and voucher specimens were deposited at the Department of Biology and Pharmaceutical Sciences, Faculty of Pharmacy, Medical University of Varna.

#### Extraction and fractionation

5 g powdered dry material was extracted for 30 min with 100 ml methanol at room temperature in ultrasound chamber. The

extract was filtered and the plant material was extracted another two times using the same procedure. All filtrates were combined and the crude methanolic extract was evaporated to

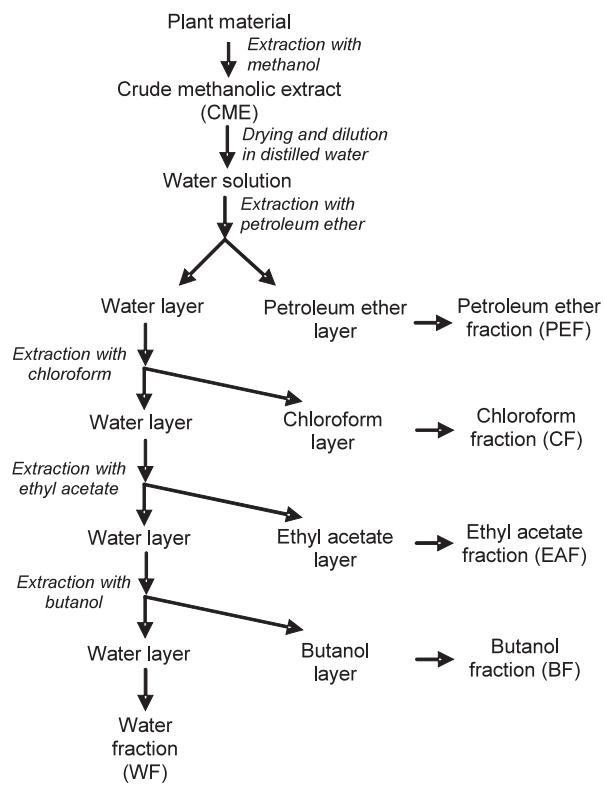


Figure 1 Extraction and fractionation procedure  
Obrázok 1 Proces extrakcie a frakcionácie

dryness under vacuum. The residual was dissolved in 50 ml distilled water and the solution was further consecutively extracted with petroleum ether, chloroform, ethyl acetate and butanol (fig. 1).

For measuring the AOA and the TPC of fractions 10 mg fractionated dry material was dissolved in 1 ml of appropriate solvent: chloroform for petroleum ether (PEF) and chloroform (CF) fractions; absolute ethanol for crude methanolic extract (CME), ethyl acetate (EAF) and butanol (BF) fractions and distilled water for water fraction (WF).

**Antioxidant activity** was measured using the ABTS (2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid)) cations radical decolorization assay (Re et al., 1999). The method is based on the consumption of preformed in the presence of potassium persulfate ABTS radical (ABTS<sup>+</sup>). Addition of antioxidants to ABTS<sup>+</sup> reduces it to ABTS. Absorption was measured at 734 nm. Uric acid was used as a standard. The antioxidant activity is presented as mmol/L Uric Acid Equivalents (UAE). The results are presented as means  $\pm$  S.D. Each measurement was performed at least in triplicate on Synergy 2 plate reader.

**Total phenolic content** was measured using the Folin-Ciocalteu reagent as described by Singleton and Rossi (1965). Absorption was measured at 760 nm. TPC was expressed as mmol/L Quercetin Equivalents (QE). Results are presented as means  $\pm$  S.D. Each measurement was performed at least in triplicate on Synergy 2 plate reader.

### Statistical analysis

All results are presented as means  $\pm$  standard deviation of three determinations and all were averaged. Statistical analysis was performed by employing GraphPad Prism 3.0 statistical software. TPC was plotted against AOA and the correlations were analyzed by calculating the r correlation coefficient.

## Results and discussion

Eight Bulgarian medicinal plants (*Alchemilla vulgaris*, *Arctostaphylos uva-ursi*, *Cydonia vulgaris*, *Fragaria vesca*, *Hypericum perforatum*, *Melissa officinalis*, *Origanum vulgare* and *Rheum officinale*) were selected for fractioning based on their AOA and TPC of water and water-alcoholic extracts AOA and TPC of each fraction from all eight plants were measured (fig. 2).

The highest AOA for the CME was measured for *Arctostaphylos uva-ursi* ( $63.23 \pm 2.97$  mmol/L), for the PEF – for *Cydonia vulgaris* ( $23.75 \pm 0.1$  mmol/L), for CF – for *Hypericum perforatum* ( $6.51 \pm 0.01$  mmol/L) and *Arctostaphylos uva-ursi* ( $6.02 \pm 0.4$  mmol/L), for EAF – for *Fragaria vesca* ( $98.42 \pm 7.43$  mmol/L), for BF – for *Fragaria vesca* ( $60.27 \pm 0.93$  mmol/L) and *Arctostaphylos uva-ursi* ( $59.91 \pm 1.23$  mmol/L) and for WF – for *Fragaria vesca* ( $22.49 \pm 0.15$  mmol/L).

Highest TPC for the CME was determined for *Alchemilla vulgaris* ( $12.26 \pm 0.29$  mmol/L), for the PEF and CF – for *Rheum officinale* ( $2.38 \pm 0.05$  mmol/L and  $2.91 \pm 0.04$  mmol/L, respectively), for EAF – for *Fragaria vesca* ( $16.78 \pm 0.47$  mmol/L), for BF – for *Hypericum perforatum* ( $9.76 \pm 0.13$  mmol/L) and for the WF – for *Melissa officinalis* ( $6.3 \pm 0.11$  mmol/L), *Fragaria vesca* ( $5.63 \pm 0.22$  mmol/L) and *Origanum vulgare* ( $5.6 \pm 0.31$  mmol/L).

With the aim of establishing a quantitative relationship between the AOA and the content of phenolic compounds correlation study was carried out (Fig. 3). A high positive correlation ( $r = 0.87$ ) was established for the EAF; ( $r = 0.83$ ) for BF and for the CME ( $r = 0.71$ ). The other fractions did not exhibit this quantitative relationship – the r values or the PEF CF and WF were  $r = 0.19$ ,  $r = -0.13$  and  $r = 0.21$ , respectively. These results indicate that the phenolic compounds were extracted

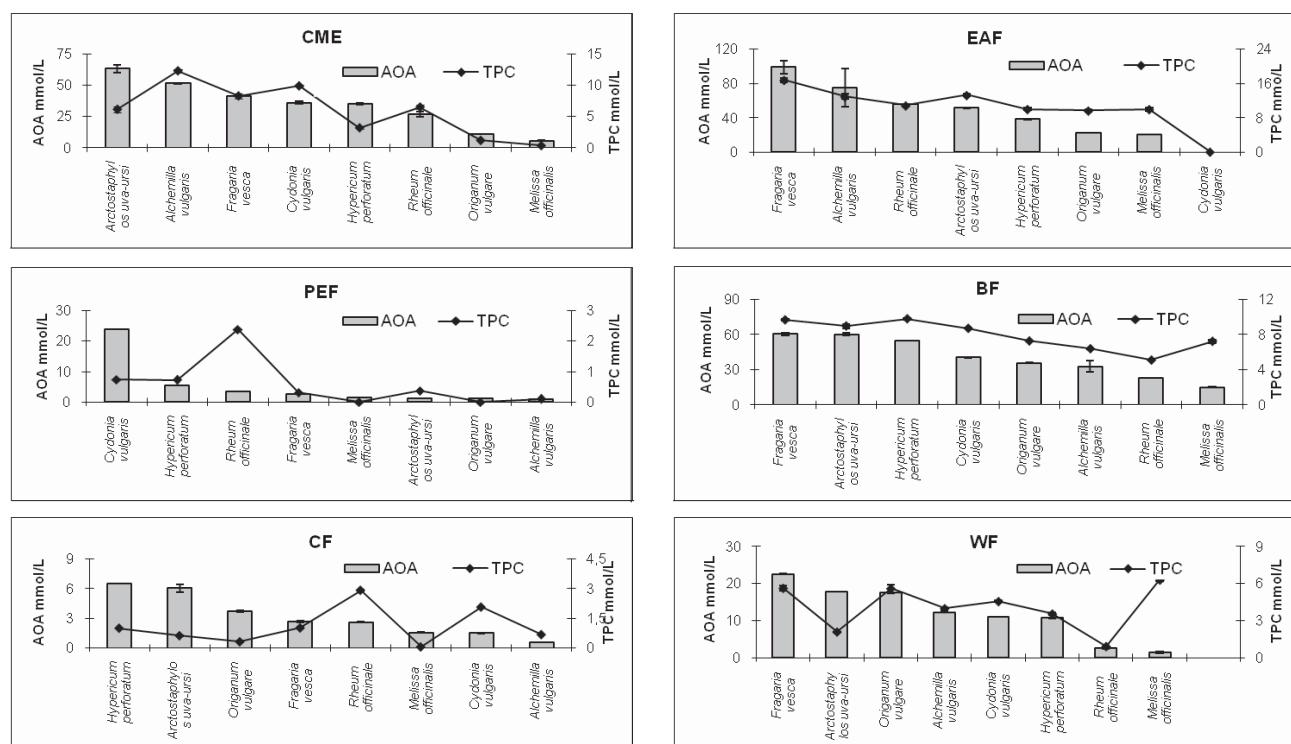
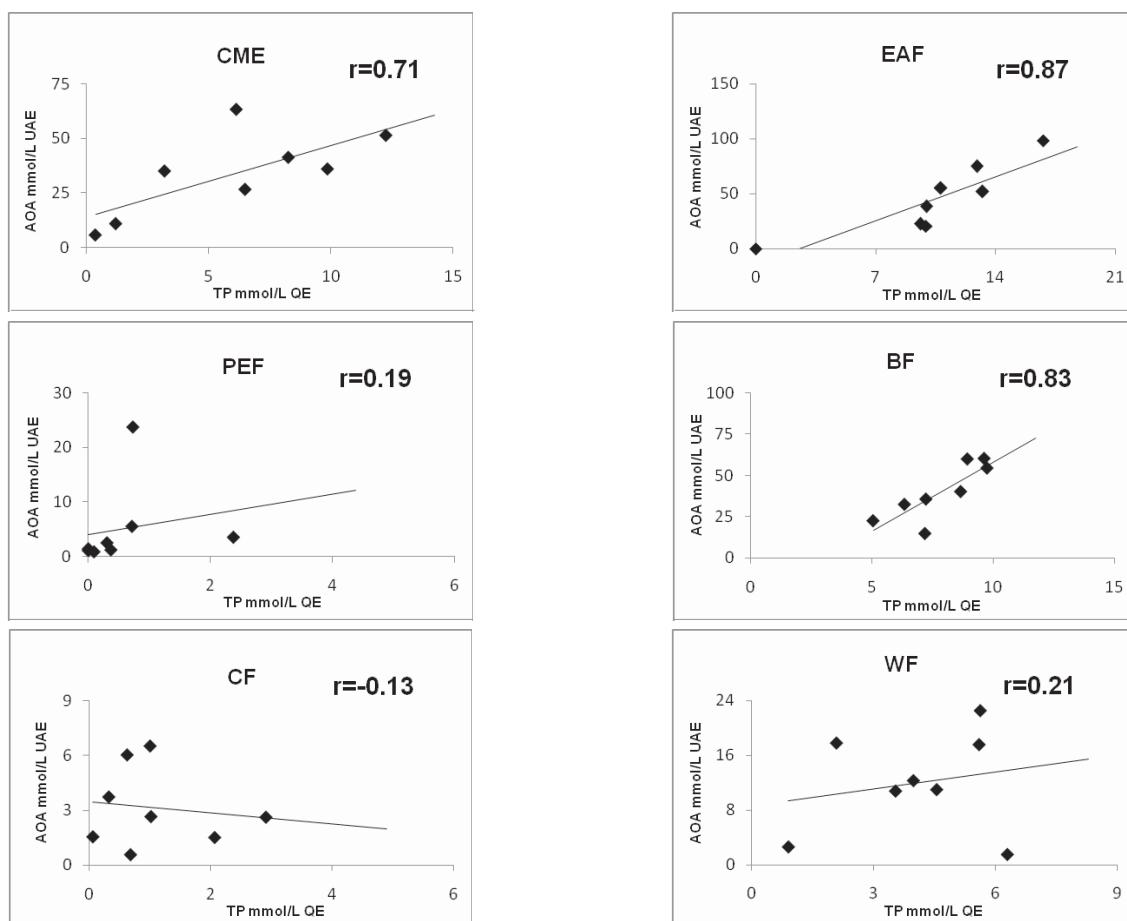
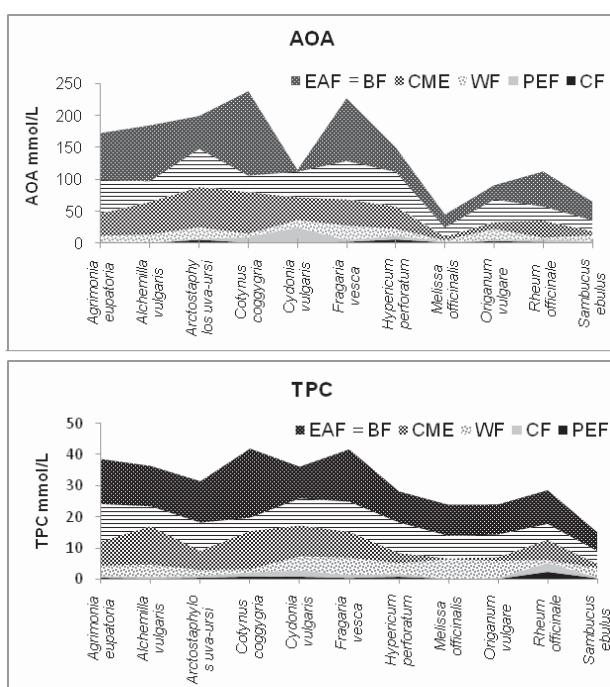


Figure 2 Antioxidants activity and total phenolic content of extracts/fractions of selected Bulgarian medicinal plants  
Obrázok 2 Antioxidačná aktivita a celkový obsah fenolov v extraktoch/frakciách vybraných bulharských liečivých rastlín



**Figure 3** Correlation between antioxidant activity and total phenolic content in extracts/fractions  
**Obrázok 3** Korelácia medzi antioxiдаčnou aktivitou a celkovým obsahom fenolov v extraktoch/frakciách



**Figure 4** Quantitative comparison between antioxidant activity and total phenolic content in extracts/fractions  
**Obrázok 4** Kvantitatívne porovnanie antioxiдаčnej aktivity a obsahu celkových fenolov v extraktoch/frakciách

predominantly into the CME and in the EAF and BF fractions. The absence of significant correlation indicates that the low but still present AOA measured in PEF, CF and WF could be contributed to other extracted compounds different from phenolics. A correlation between AOA and TPC has been reported for methanolic extracts from different plants (Jeetendra et al., 2011; Alali et al., 2007).

AOA analyses of plant fractions indicated that *Alchemilla vulgaris*, *Fragaria vesca*, *Rheum officinale* and *Melissa officinalis* exhibited highest AOA of their EAF; *Cydonia vulgaris*, *Hypericum perforatum* and *Origanum vulgare* – of their BF. Only *Arctostaphylos uva-ursi* had most active CME against the pre-formed ABTS radical.

Highest TPC was measured for all species in the EAF followed by the BF for *Arctostaphylos uva-ursi*, *Fragaria vesca*, *Hypericum perforatum*, *Melissa officinalis* and *Origanum vulgare* and further by CME for *Alchemilla vulgaris*, *Cotinus coggygria*, *Cydonia vulgaris* and *Rheum officinale*.

Comparison between the extract/fractions indicated that EAF had generally highest AOA and concentration of total polyphenols followed by the BF and CME, while the WF, PEF and CF exhibited low AOA and total phenolics concentration (fig. 4).

## Conclusions

This investigation identified the presence of compounds possessing antioxidant activity in three fractions: in EAF of *F. vesca*, *R. officinale*, and *M. officinalis*, in BF of *C. vulgaris*, *H. perforatum* and *O. vulgare* and in CME of *A. uva-ursi*.

The TPC of EAF was highest as compared to the other fractions for all species followed by the BF for *A. uva-ursi*, *F. vesca*, *H. perforatum*, *M. officinalis* and *O. vulgare* and by CME for *A. vulgaris*, *C. vulgaris* and *R. officinale*. AOA correlated positively to TPC of CME, BF and EAF, all of them showing a potential value as a source of natural antioxidants. These results represent a good basis for further analyses of selected plants to the discovery of new natural food additives.

## Súhrn

Antioxiadačná aktívita (AOA) hrubého metanolového extraktu (CME) a jeho etyl acetátu (EAF), butanolu (BF), benzénu (PEF), chloroformu (CF) a vodnej frakcie (WF) deviatich liečivých rastlín Bulharska bola analyzovaná použitím ABTS katiónovej radikálovej dekolorizačnej analýzy. Prítomnosť zlúčenín s antioxiadačnou aktivitou bola identifikovaná v troch frakciách: v EAF pri *Fragaria vesca*, *Rheum officinale* a *Melissa officinalis*, v BF frakcii pri *Cydonia vulgaris*, *Hypericum perforatum* a *Origanum vulgare* a v CME frakcii pri *Arctostaphylos uva-ursi*. Pre každý extrakt/frakciu bol zistovaný celkový obsah fenolov (TPC). Najvyšší obsah TPC, v porovnaní s ostatnými frakciami, obsahovala frakcia EAF, potom nasledovala frakcia BF pri *Arctostaphylos uva-ursi*, *Fragaria vesca*, *Hypericum perforatum*, *Melissa officinalis* a *Origanum vulgare* potom frakcia CME pri *Alchemilla vulgaris*, *Cydonia vulgaris* a *Rheum officinale*. AOA mala pozitívnu koreláciu s TPC pri CME, BF a EAF. Všetky uvedené frakcie majú potenciálnu hodnotu ako zdroje prírodných antioxidantov.

**Kľúčové slová:** liečivé rastliny Bulharska, antioxiadačná aktívita, celkový obsah polyfenolov, frakcie

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## THE YIELD FORMATION OF SUNFLOWER INFLUENCED BY TEMPERATURE AND MOISTURE CONDITIONS OF EXPERIMENTAL FIELD

### TVORBA ÚRODY SLNEČNICE ROČNEJ VPLYVOM TEPLOTNÝCH A VLHKOSTNÝCH PODMIENOK PESTOVATEĽSKEJ LOKALITY

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Slovak University of Agriculture in Nitra, Slovak Republic

Field polyfactorial experiments with sunflower (conventional, medium-late hybrids: NK Brio, Alexandra PR, NK Ferti, NK Alego) were realized on the experimental base of Center of Biology and Ecology of Plants FAFR SUA in Nitra Dolná Malanta. Experimental area is located in corn production region, characterized as warm and slightly dry with mild winter and long sunshine, in altitude 250 m, with brown soil. The influence of both temperature and moisture conditions of experimental area on sunflower yield of achenes (conventional, medium-late hybrids: NK Brio, Alexandra PR, NK Ferti, NK Alego) was observed. Fore crop of sunflower (*Helianthus annuus* L.) was wheat (*Triticum aestivum* L.). Technological system of sunflower cultivation was realized in accordance with conventional technology of cultivation. The basic fertilization was made by balance method on the base of agrochemical soil analysis for expected yield 3 t ha<sup>-1</sup>. During experimental years the change of inner energy ( $\Delta U$ ) was evaluated for thermodynamic characteristic analysis (security of the temperature and moisture) and the impact of changes on yield forming with maximal yield ( $Y_{\max}$  in 2008) and minimal yield ( $Y_{\min}$  in 2009). Achieved value of yield from thermal and precipitation energy introduces concrete energy amount, which is available in given period for concrete amount of yield. From the results follow that the sunflower has got critical thermodynamic phase in the period of months July and August. For the yield formation it is necessary, that input power of precipitation prevailed over the thermal during the months July and August. Achieved results confirmed statistically high significant dependence of the yield on weather conditions. It is necessary to consider potential change of agro technological measures in sunflower cultivation because of large annual variations in climate characteristics.

**Key words:** sunflower, thermodynamic conditions, yield of achenes

The process of yield formation of field crops is significantly affected by presence and abundance of many factors. Where agro ecological factors are dominant, their mutual interaction influences respectively. The yield variability and final production of crops is influenced mainly by the weather conditions. The influence of weather conditions is decisive in the yield creation process of oilseeds and other crops. Their interaction leads to regulation of particular growth phase, due to its forming quantity and quality of yield-forming elements (Brandt et al., 2003; Macák et al. 2007; Fecák et al. 2009).

According to Kudrna (1985) the inner energy ( $\Delta U$ ) as the criterion reviewing the influence of basic agro-climatic conditions (temperature, water, radiation, etc.) during the field crops vegetation in system solar radiation energy → phytocenosis energy, introduces this part of cell structures energy, which keeps the transformation processes on the move.

The evaluation of the effect of basic climatic quantity (temperature and water) on yield formation of field crops is very complicated. Water from biologic and physiologic (Švhra, 1984; Passioura, 2002, 2007; Chaves et al., 2003) aspects and point of view of agro climatic regionalization (Fischer and Turner, 1978; Špánik et al., 2002) is irreplaceable factor of life on the Earth. The water regime is considered to be a main indicator of environment production performance (Passioura, 2002).

Aiken (2006) and Švelucha (1982) consider water demand as a determining factor for yield creation of field crops. The sunflower grades the requirements on the water during the vegetation period. Therefore, the disproportion between physiological requirements to the water and real precipitation in

season can get to the status, which we evaluate as water deficient.

The growth of sunflower is significantly limited under drought (Murillo, 1998). The plant consumes (of total water demand) approximately 23 % to the formation of head, 60 % from establishment to fertilization and 17 % to the full maturity. Water stress of plants affects not only reduction of yield but participates in the decrease of total oil content and oil composition in the sunflower achenes (Hussain, 2008).

Brandt et al. (2003) consider also the air temperature a decisive climatic factor beside water. The soil temperature and temperature of soil solution depends on it.

In the optimal agroecological regions the sum of active temperatures should be more than 10 °C for sunflower cultivation during growing season 120 – 150 days (Fábry, 1992). The sunflower increases demands on the temperature from growth stage of flowering to maturation of achenes. Therefore the average temperature should not be less than 18 °C at night and average daily temperature less than 24 °C during the season from July to half August. Sunflower requires average temperature more than 15 °C at night and daily more than 20 °C in the end of August and in September (Beard and Geng, 1982).

Global changes relating to precipitation decrease and rising of temperatures involved from climatic system analysis (Repa and Špánik, 1999) and from respecting of sunflower temperature and moisture demands for medium geographic areas. However, both finding and consciousness of these facts can have significant impact on decreasing of yield and quality of sunflower production (Loomis and Connor, 1992).

**Table 1** Agrochemical soil analysis

Parameters (1)	Year (2)			
	2008	2009	2010	
N <sub>an</sub> (by Kjeldahl method) (3)	mg.kg <sup>-1</sup> of soil (9)	7.2	8.7	11.4
P (by Mehlich III method) (4)	mg.kg <sup>-1</sup> of soil (9)	45.30	38.00	61.20
K (by Mehlich III method) (5)	mg.kg <sup>-1</sup> of soil (9)	421.00	395.00	433.00
Humus (by Tjurin method) (6)	%	1.05	0.35	2.19
Carbonates (7)	%	0.87	1.51	0.36
pH/KCl (8)		6.25	6.34	6.20

**Tabuľka 1** Agrochemický rozbor pôdy

(1) parametre, (2) rok, (3) N<sub>an</sub> (Kjeldahl metóda), (4) P (Mehlich III metóda), (5) K (Mehlich III metóda), (6) humus (Tjurin metóda), (7) uhličitany, (8) pH/KCl, (9) mg.kg<sup>-1</sup> pôdy

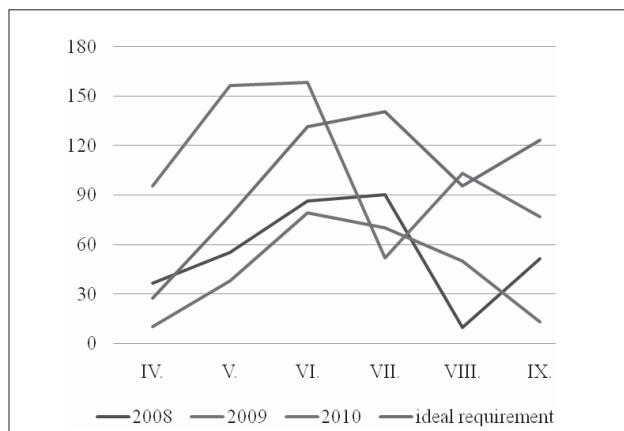
The aim of contribution is to point out, from results of experimental years 2008 – 2010, an impact of temperature and moisture conditions of experimental area on amount of yield of sunflower achenes ( $Y$ ).

## Material and method

Field polyfactorial experiments with sunflower (conventional, medium-late hybrids: NK Brio, Alexandra PR, NK Ferti, NK Alego) were realized on the experimental base of Center Biology and Ecology of Plants FAFR SUA in Nitra Dolná Malanta. Experimental area is located in corn production area, characterized as warm and slightly dry with mild winter and long sunshine. The trials were carried out on brown soil.

The fore crop of sunflower (*Helianthus annuus* L.) was winter wheat (*Triticum aestivum* L.). Basic fertilization was made using the balance method on the base of agrochemical soil analysis for amount of yield 3 tons per hectare.

Tillage (stubble ploughed under, deep autumn plowing), the way of setting up of sunflower (sowing date II. decade of April, interline distance 0.70 m, distance in row 0.22 m), treatment during the vegetation (preemergent herbicide application, double application of fungicides) and harvesting 2008 ( $Y_{\max}$ ) – III. decade of September, 2009 ( $Y_{\min}$ ) – I. decade of October, non-desiccated canopy, were made by conventional technology of sunflower cultivation.

**Figure 2** The process of water conditions in mm in experimental years in comparison with ideal requirement**Obrázok 2** Priebeh vlhkostných podmienok v mm experimentálnych rokov v porovnaní s ideálou potrebou

Basic meteorological data (monthly precipitation in mm, average daily temperature in °C) were obtained from Horticulture and Landscape Engineering Faculty at Slovak University of Agriculture (Fig. 1 – 2).

Experiments were carried out by the split plot design with randomized complete blocks base design (Ehrenbergerová, 1995). Statistical evaluation of the experimental factors was processed by the multifactor analysis of variance.

Using form to review the influence of climatic conditions is value of internal energy ( $\Delta U$ ).

The amount of transformed kinetic energy into potential energy is expressed:

$$T = \frac{Y_{prod}}{t_c} \quad S = \frac{Y_{prod}}{h_s}$$

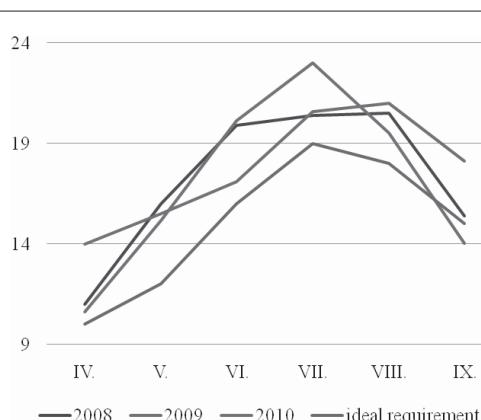
where:

- $T$  – temperature coefficient
- $S$  – precipitation coefficient

$$Y_t = T \cdot t_{cn} \quad Y_h = S \cdot h_s$$

where:

- $Y_t$  – term energy for yield formation
- $Y_{hs}$  – precipitation energy for yield formation
- $Y_{prod}$  – productive yield ( $t.ha^{-1}$ )
- $h_s$  – month precipitation sum per crop vegetation (mm)
- $h_{sn}$  – precipitation in monitored period (e.g. month, decade, pentade, etc.) (mm)

**Figure 1** The process of temperature conditions in °C in experimental years in comparison with ideal requirement**Obrázok 1** Priebeh teplotných podmienok v °C experimentálnych rokov v porovnaní s ideálou potrebou

- $t_c$  – month temperature sum per crop vegetation ( $^{\circ}\text{C}$ )  
 $t_{cn}$  – temperature in monitored period (e.g. month, decade, pentade, etc.) ( $^{\circ}\text{C}$ )

The yield value  $Y_t$  or  $Y_{hs}$  represents the energy quantum in system solar radiation energy – phytocenosis energy (Kudrna, 1989), which is defined time available for yield, so for change of total inner energy system ( $\Delta U$ ). The total inner energy system change ( $\Delta U$ ) is next formulated as:

$$\Delta U = \frac{Y}{t_c} t_{cn} - \frac{Y}{hs} h_{sn} = T \cdot cn - S \cdot h_{sn} = Y_t - Y_{hs}$$

## Results and discussion

The formation of sunflower yield is significantly affected by both temperature and moisture requirements during the vegetation. Thermodynamic conditions of individual experimental years were differentiated by temperature and moisture conditions (Figure 1 – 2, table 2). In year 2008, when the yield of achenes was highest ( $Y_{\max} = 3.88 \text{ t ha}^{-1}$ ), the process of weather conditions was most favourable for formation of sunflower yield during individual growth seasons (precipitation per vegetation was 329.3 mm; average temperature was  $17.2^{\circ}\text{C}$ ). In year 2009, when the lowest yield was achieved ( $Y_{\min} = 2.67 \text{ t ha}^{-1}$ ), the tendency of weather conditions in comparison with physiological ones was less responding (precipitation per vegetation is 260.0 mm; average temperature is  $17.7^{\circ}\text{C}$ ). The differences show statistically high significant dependence on

the weather conditions in the achene yield ( $Y_{\max}$  and  $Y_{\min}$   $1.21 \text{ t ha}^{-1}$ ) in years 2008 – 2010.

Increasing of achene yield is influenced not only by total precipitations but also by their uniform distribution during vegetation period, i.e. during growth stages, when the crop uses them effectively. The sunflower requires higher precipitation during the formation of assimilatory apparatus with maximum in growth stage of flowering and formation of heads, i.e. during July in our region. Deficit of precipitation influenced metabolism process deregulatory in the season of increased physiological moisture requirement, what increased differences between potential and real yield of achenes (Crithley, Siegert and Chapman, 2003).

The differences between achene yields were significantly influenced not only by precipitation but also by temperatures. Higher values in comparison with long-term normal (1961 – 1990) are caused by increased transpiration and evapotranspiration, it impacts on total nutrient intakes and performance of assimilation. For optimal process of yield formation it is decisive, that precipitation increases with rising daily temperatures for appropriate conditions to growth and development. On the other hand, in the end of vegetation period, gradual decline of average temperatures and precipitations is appropriate (Fábry, 1982), which partially confirmed our results.

Kudrna (1985) presents that maximum yields of many crops are reached in conditions of maximum growth intensity and high stability between biological processes and climatic factors. The optimal running of the biological processes in the plant cells needs concrete thermo-dynamic conditions in various

**Table 2** The thermal and moisture conditions for formation of sunflower inner energy in years with maximum and minimum yield

Month (1)	Normal (n) 1961 – 1990 (2)		Ideal requirement (5)		$Y_{\max}$ (6) $3.88 \text{ t.ha}^{-1}$ (2008)		$Y_{\min}$ (7) $2.67 \text{ t.ha}^{-1}$ (2009)	
	$\sum \text{mm}$ (3)	$X_{td}^{\circ}\text{C}$ (4)	$\sum \text{mm}$ (3)	$X_{td}^{\circ}\text{C}$ (4)	$\sum \text{mm}$ (3)	$X_{td}^{\circ}\text{C}$ (4)	$\sum \text{mm}$ (3)	$X_{td}^{\circ}\text{C}$ (4)
IV.	39.0	10.4	27.5	10.0	36.4	11.0	10.0	14.0
V.	58.0	15.1	77.6	12.0	55.4	16.0	38.0	15.5
VI.	66.0	18.0	131.6	16.0	86.2	19.9	79.0	17.1
VII.	52.0	19.8	140.6	19.0	90.0	20.4	70.0	20.6
VIII.	61.0	19.3	95.4	18.0	9.8	20.5	50.0	21.0
IX.	40.0	15.6	123.2	15.0	51.5	15.4	13.0	18.0

**Tabuľka 2** Teplotné a vlahové podmienky pre tvorbu vnútornnej energie slnečnice ročnej v rokoch s minimálnou a maximálnou úrodou

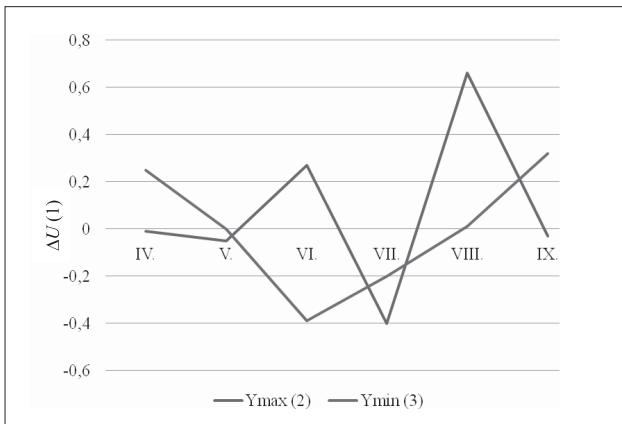
(3) sum of precipitation, (4) average daily temperature, (6) maximum yield in  $\text{t.ha}^{-1}$ , (7) minimum yield in  $\text{t.ha}^{-1}$   
(1) mesiac, (2) klimatický normál, (3) suma zrážok, (4) priemerná denná teplota, (5) ideálna potreba, (6) maximálna úroda v  $\text{t.ha}^{-1}$ , (7) minimálna úroda v  $\text{t.ha}^{-1}$

**Table 3** Changes of inner energy for  $\Delta U$  for sunflower

Month (1)	$Y_{\max}$ $3.88 \text{ t.ha}^{-1}$ (2008) (2)			$Y_{\min}$ $2.67 \text{ t.ha}^{-1}$ (2009) (3)		
	$Y_t$	$Y_{hs}$	$\Delta U$ (6)	$Y_t$	$Y_{hs}$	$\Delta U$ (6)
IV.	0.41	0.42	-0.01	0.35	0.10	+0.25
V.	0.60	0.65	-0.05	0.38	0.38	0.00
VI.	0.74	1.01	0.27	0.42	0.81	-0.39
VII.	0.76	1.06	-0.40	0.51	0.71	-0.20
VIII.	0.77	0.11	+0.66	0.52	0.51	+0.01
IX.	0.57	0.60	-0.03	0.45	0.13	+0.32

**Tabuľka 3** Zmeny vnútornej energie pre slnečnicu ročnú

(2) maximum yield of achenes, (3) minimum yield of achenes, (4) temperature energy needed for yield formation, (5) rainfall energy needed for yield formation, (6) change of inner energy  
(1) mesiac, (2) maximálna úroda v  $\text{t.ha}^{-1}$ , (3) minimálna úroda v  $\text{t.ha}^{-1}$ , (4) energia teploty potrebnej na formovanie úrody, (5) energia zrážok potrebnej na formovanie úrody, (6) zmena vnútornej energie



**Figure 3** Characteristic thermodynamic curve line of inner energy for maximum and minimum yield of sunflower

(1)  $\Delta U$  – values of internal energy, (2)  $Y_{\max}$  – maximum yield,  
(3)  $Y_{\min}$  – minimum yield

**Obrázok 3** Charakteristická termodynamická krivka vnútornnej energie pre maximálnu a minimálnu úrodu slnečnice ročnej

(1)  $\Delta U$  – hodnoty vnútornnej energie, (2)  $Y_{\max}$  – maximálna úroda,  
(3)  $Y_{\min}$  – minimálna úroda

phases of growth and development. Maximum dry matter accumulation is defined by maximum accumulation of inner energy of systems. Metabolic activity as an aspect of inner energy of systems is deactivated under deficit of precipitation in conditions without irrigation what results in sunflower yield decrease. Kudrna (1985) considers the change of an inner energy ( $\Delta U$ ) as a basic criterion of energy transformation of thermodynamic characteristics. From the point of maximum yield of achenes formation it is important that the values of inner energy should be negative during the critical thermo-dynamic growth. That means that it predominates the energy input from precipitation ( $Y_{hs}$ ) over the energy from temperatures ( $Y_t$ ) during formation of achenes. Balance changes between both temperatures and precipitation cause the disproportion in reached yields.

Critical period of growing and development of the sunflower shows a maximum intensity of growing heads and achenes. For achievement of maximum yield it is necessary to reach maximum change of inner energy ( $\Delta U$ ) by both maximum temperatures and maximum precipitations. The course of characteristic curves in individual months of vegetation period confirms that critical periods with lowest values of inner energy are united with intensive growth of field crops. This period is predestined to temperature gradients, when the plant grows intensively. Calculated changes of the level of  $\Delta U$  and their influences on yield formation are given in Table 3 and in Figure 1 by thermodynamic curve lines

Analyzed data show the real situation of inner energy on axis of coordinates for vegetation period of sunflower, where prevails the influence of precipitation over temperatures by achievement  $Y_{\max}$ , resp.  $Y_{\min}$ . For formation of the maximal yield, more significant influence of precipitation in July and August was found. On the other hand, values of inner energy relating to the minimum yield formation show shift of period with prevailing influence of precipitation over the temperatures in May and June and dominance of temperatures in August, what we consider important from this analysis.

### Conclusions

From the point of yield formation, the analysis of thermodynamic locality conditions represents one of

alternatives for study of production process forming the field crops. The aim of work is to show an impact of both temperature and moisture conditions on sunflower yield of achenes from experiment results of years 2008 – 2010 ( $Y$ ).

From analysis of thermodynamic conditions of sunflower cultivation it is proved that maximum yield of achenes ( $Y_{\max}$ ) was achieved in the year 2008, where the precipitation was 329.3 mm during the vegetation period and average temperature was 17.2 °C. The lowest yield ( $Y_{\min}$ ) was reached in the year 2009, where the precipitation was only 260.0 mm and average temperature was 17.7 °C. The difference between the precipitations in experimental years was 69.3 mm and between yields of achenes 1.21 t ha<sup>-1</sup> (statistically highly significant).

The value of inner energy was negative for the formation of maximum yield (2008) in critical growth periods. On the other hand, the input power of thermal energy dominated over precipitation formed of minimum yield. In year with maximum yield the sunflower showed higher requirements on moisture in July and August, however, in the year with minimum yield the highest requirements were in May and June.

### Súhrn

Poľné polyfaktorové pokusy boli realizované v rokoch 2008 – 2010 na experimentálnych pozemkoch Strediska biológie a ekológie rastlín FAPZ SPU v Nitre Dolná Malanta. Záujmové územie je lokalizované v kukuričnej výrobnej oblasti (klimatická oblasť: teplá; klimatická podoblasť: suchá; klimatický okrsok: teplý, suchý s miernou zimou a dlhým slnečným svitom) pri nadmorskej výške 250 m, na hnedozemi kultízemejnej. V experimentoch bol sledovaný vplyv teplotných a vlakových podmienok experimentálneho stanovišta na výšku úrody nažiek slnečnice ročnej (konvenčné, stredne neskoré hybrydy: NK Brio, Alexandra PR, NK Ferti, NK Alego). Predplodinou slnečnice ročnej bola pšenica letná forma ozimná (*Triticum aestivum* L.). Technologický systém pestovania slnečnice ročnej bol realizovaný v súlade so zásadami konvenčnej technológie pestovania. Základné hnojenie bolo uskutočnené bilančnou metódou na základe agrochemického rozboru pôdy na predpokladanú výšku úrody 3 t.ha<sup>-1</sup>. Základné meteorologické údaje boli získané z Fakulty záhradníctva a krajinného inžinierstva Slovenskej poľnohospodárskej univerzity. V priebehu pokusných rokov bola pre analýzu termodynamických charakteristik (teplotná a vlaková zabezpečenosť) hodnotená zmena vnútornnej energie ( $\Delta U$ ) a vplyv sledovaných zmien na formovanie úrody v rokoch s úrodou maximálnou ( $Y_{\max}$ : 2008) a úrodou minimálnou ( $Y_{\min}$ : 2009). Získanú hodnotu úrody z energie tepla alebo zrázok predstavuje konkrétné množstvo energie, ktoré je v určitom danom období k dispozícii pre určitú výšku úrody. Z výsledkov vyplýva, že slnečnica ročná má vo vegetačnom období kritickú termodynamickú fázu v období mesiacov júl – august. Z hľadiska tvorby úrody je preto potrebné, aby v uvedených mesiacoch vegetačného obdobia prevládal príkon energie zo zrázok nad teplotami. Dosiahnuté výsledky potvrdili štatisticky vysokú závislosť úrody na priebehu poveternostných podmienok ročníka. Pre značné medziročné rozdiely v klimatických charakteristikách je potrebné uvažovať o potenciálnej úprave agrotechnických opatrení technologického systému pestovania slnečnice ročnej.

**Kľúčové slová:** slnečnica ročná, termodynamické podmienky, úroda nažiek

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## ZHODNOTENIE UTVÁRANIA KRANIOLOGICKÝCH MIER A PAROŽIA SRNCÍCH TROFEJÍ V POĽOVNEJ OBLASTI TRIBEČ

### ANALYSIS OF CRANIOMETRICAL AND ANTLER DEVELOPMENT OF *CAPREOLUS C. CAPREOLUS* C. CAPREOLUS FROM HUNTING REGION TRIBEC

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The Aim of the study was to evaluate craniometry and trophy development of Capreolus c. capreolus in hunting region Tribeč as a preposition of successful management and selection. Measurement of 14 craniometrical characteristics and CIC evaluation results were included into dataset. In total 153 trophies were evaluated (years 2003 – 2007) in districts of Nitra, Topoľčany, Partizánske, Zlaté Moravce. Comparison was made according to trophies presented on National hunting trophy exhibition in year 2005. Craniometry of roe-buck in hunting region Tribeč doesn't reach values of roe-buck in Slovakia and differences in length of right stem, length of left stem, average length of stems, trophy weight, trophy volume and trophy span were of high statistical significance. CIC evaluation resulted in higher values of trophies in Slovakia. Based on CIC evaluation in hunting region Tribeč, most important on total trophy value had trophy volume ( $R^2 = 90.46\%$ ) and trophy span ( $R^2 = 74.37\%$ ) respectively. Trophy span could be a parameter, considered before hunting as selection criterion. Most significant correlations were observed between minimum pedicle width and stem length ( $r_{xy} = 0.759 - 0.834$ ) and trophy weight (0.892) respectively.

**Key words:** *Capreolus c. capreolus*, Roe-buck, craniometry, trophy quality, selection

Srncia zver patrí medzi našu najrozšírenejšiu raticovú zver, ktorá sa vyskytuje takmer vo všetkých poľovných revíroch Slovenska. Je veľmi populárna a významne prispieva k vytváraniu príležitostí poľovania pre stále zväčšujúci sa počet poľovníkov. Vďaka tomu zostáva veľmi perspektívnym druhom aj pri čoraz viac sa zvyšujúcim tlaku civilizačných faktorov na životné prostredie zveri. Chov a lov srncie zveri je významne ovplyvňovaný rôznymi okolnostami. Populácie sú nadmerne zmladené a pomery pohlaví je v nich silne narušený v prospech samičej zveri. Kvalitu populácie je možné kvantifikovať napr. kraniometrickými hodnotami alebo trofejovými hodnotami (Vajner a Hromas, 1988). Ako ďalej uvádzajú Hell a Holý (1988) len na základe vedeckých podkladov akými sú predovšetkým preštudovanie rastu parožkov v závislosti od veku srncov je možné vypracovať objektívne kritéria pre negatívnu selekcii pre každú poľovnú oblasť, ak tieto majú pôsobiť progresívne. Pelabon a van Breukelen (1998) vyhodnotili asymetriu v utváraní ľavého a pravého kmeňa ako indikátora úrovne populácie. Zároveň poukazujú na negatívny vplyv vysokej hustoty srncie zveri na živú hmotnosť jedincov ako aj trofejovú hodnotu vyjadrenú zvýšenou asymetriou parožia. Pokorný et al. (2004) naopak použili analýzu srncieho parožia ako indikátor historickej záťaže prostredia ťažkými kovmi.

#### Materiál a metódy

Poľovná oblasť J-XXXIII Tribeč sa viaže na orografické celky Tribeč a Pohronský Inovec. Tribeč je geomorfologický celok patriaci do Fatransko-tatranskej oblasti, ohraničenej na juhu a západe Nitrianskou nivou a pahorkatinou, na severe Hornonitrianskou kotlínou a Vtáčnikom, na východe Pohronským Inovcom a na juhovýchode Žitavskou pahorkatinou. Na juhu je ohraničený Hronskou pahorkatinou, na západe Žitavskou pahorkatinou a pohorím Tribeč, na severe Vtáčnikom a východe

Štiavnickými vrchmi. Je sopečného pôvodu, zložený predovšetkým z andezitov a ryolitov. Poľovná oblasť Tribeč sa v súčasnosti nachádza na území piatich okresov a troch krajov. Poľovná oblasť sa vyznačuje lesnatou centrálnou časťou s výraznou hranicou pole – les a náhlym prechodom do poľného, husto obývaného okraja. Centrálna časť má viac ako 90 % lesnatosť. Značnú časť Tribeča a Pohronského Inovca pokrývajú listnaté dubovo-hrabové lesy s prímesou buka. Medzi najrozšírenejšie skupiny lesných typov patria bukové – dubiny, menej holé bučiny a dubové bučiny. Rozsiahla centrálna časť pohoria je neobývaná a tvorí ucelený a pomerne zachovalý prírodný komplex v plnej mieri vyhovujúci jelenej zveri. Okrajové časti pohoria, a tým aj poľovnej oblasti, sú pomerne husto osídlené s poľnohospodársky obrábanou krajinou poľného charakteru. Tu nachádza vhodné životné podmienky najmä malá a srncia zver.

Databázu vstupných údajov tvorili údaje o 14 kraniologických mierach srncích trofí a ich bodovom hodnotení metodou podľa CIC. Celkovo bolo do databázy zaradených 153 srncích trofí z okresov Nitra, Topoľčany, Partizánske a Zlaté Moravce, na území ktorých sa rozkladá poľovná oblasť Tribeč. Na zistenie základných variačno-štatistických charakteristík a grafické znázornenie trendov a tendencií bol použitý program MS Excel. Dižkové charakteristiky boli posuvným meradlom v centimetroch s presnosťou na 1 mm ( $I_1$  a  $M_1$  s presnosťou na 0,1 mm). Zistené údaje boli štatisticky vyhodnotené vzhľadom na vek srncov odhadnutý na chovateľskej prehliadke.

Zistovanie rozmerov parožia srncov bolo vykonávané pásmovým meradlom a hmotnosť parožkov bola zisťovaná pomocou digitálnej váhy. Jednotlivé parametre boli merané v cm s presnosťou na 0,5 cm, hmotnosť v g. Hodnotené trofje boli rozdelené do 10 vekových stupňov (1- až 10-ročné srnce). Pri jednoročných srncoch sa zo sledovaných charakteristík parožia hodnotil iba jeden znak a to dĺžka kmeňov. Údaje o jednotlivých parametroch parožia podielajúcich sa na bodovej hodnote boli získané na chovateľských prehliadkach bodovaním srncích tro-

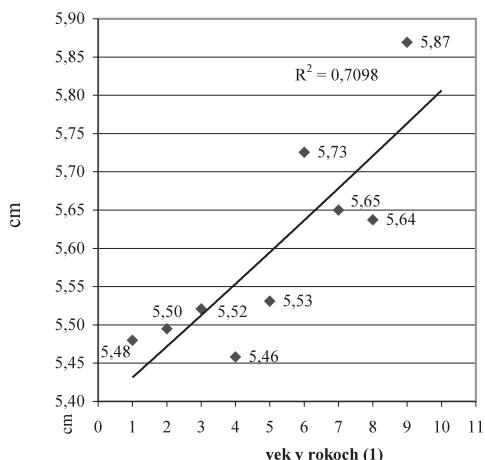
fejí metódou CIC. Údaje boli zapisované do štandardizovanej tabuľky na hodnotenie srnčích parožkov CIC. Tabuľka a popis techniky merania a hodnotenia srnčích parožkov sú uvedené vo Vyhláške MP SR č. 368/1997 o chovateľských prehliadkach polovníckych trofiej. Meranie a hodnotenie srnčích trofiej bolo vykonané v spolupráci s členmi hodnotiteľskej komisie OkO SPZ Zlaté Moravce, Nitra, Partizánske a Topoľčany.

Cieľom práce bolo zhodnotenie utvárania kraniologických mier a parožia srnčích trofiej v poľovnej oblasti Tribeč v rokoch 2003 – 2007 ako predpoklad úspešného manažmentu a selekcie srnčej zveri.

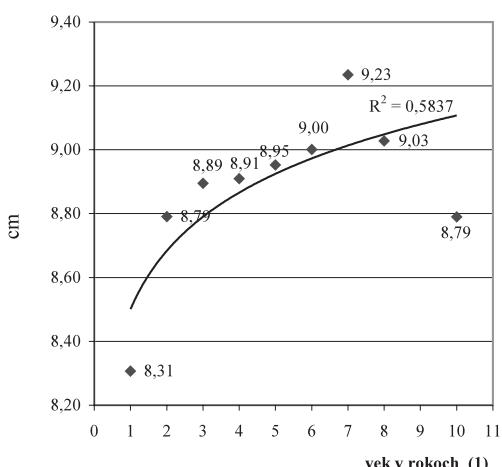
## Výsledky a diskusia

### Zhodnotenie intenzity rastu kraniometrických mier

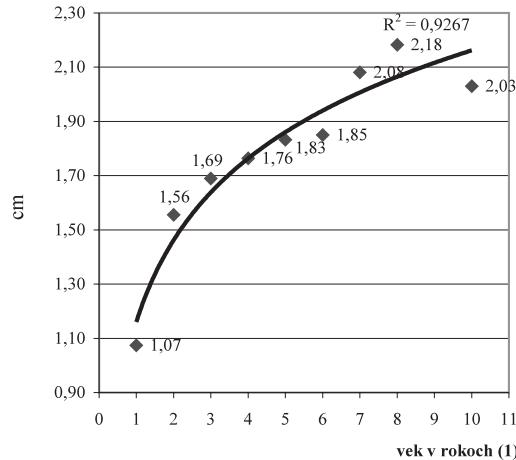
V predmetnej problematike je len obmedzené množstvo aktuálnych literárnych zdrojov, ktoré sa priamo zaoberajú kraniometriou a skôr skúmajú utváranie parožia v kontexte populáčnych a prírodných podmienok srnčej zveri. V danom štatistickom súbore bola regresnou analýzou hodnotená miera závislosti rozmerov le-



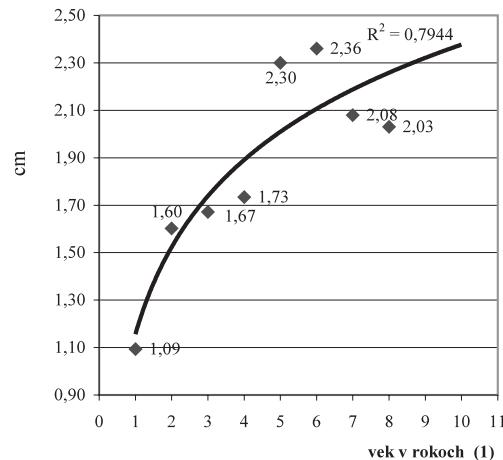
Obrázok 1 Závislosť dĺžky horného radu zubov srncov od veku  
Figure 1 Dependency of length of top cheektooth row from age  
(1) age in years



Obrázok 2 Závislosť šírky lebky srncov v orbitách od veku  
Figure 2 Dependency of maximum width of cheek from orbit from age  
(1) age in years



Obrázok 3 Závislosť minimálnej šírky pravej pučnice od veku srnca  
Figure 3 Dependency of right pedicle minimum width from age  
(1) age in years



Obrázok 4 Závislosť minimálnej šírky ľavej pučnice od veku srnca  
Figure 4 Dependency left pedicle minimum width from orbit from age  
(1) age in years

biek od veku. Vychádzali sme z predpokladu, že rast prebieha exponenciálne, t. j. v prvej fáze je možné sledovať prudký rast, ktorý sa vekom spomaľuje do dosiahnutia telesnej dospelosti.

Rast dĺžkových rozmerov lebiek srncov v nami hodnotenom súbore mal nelineárny priebeh v závislosti od vekového stupňa. Vek determinoval intenzitu rastu dĺžkových mier v rozsahu od 38,23 % (dĺžka rostra od P1) do 70,98 % (dĺžka horného radu zubov, obr. 1). Najvyššiu intenzitu rastu dĺžkových mier je možné pozorovať v rozmedzí štvrtého až šiesteho vekového stupňa. Pri starších jedincoch je dĺžkový rast len pozvoľný do dosiahnutia telesnej dospelosti.

Rast šírkových rozmerov lebiek srncov mal nelineárny priebeh v závislosti od vekového stupňa, pričom vek determinoval rast šírkových rozmerov od  $R^2 = 25,41\%$  (zadná zygomatická šírka) do  $R^2 = 58,37\%$  (šírka lebky v orbitách, obr. 2). Rast šírkových mier kulminoval medzi 6. a 7. vekovým stupňom.

Najvyššie koeficienty determinácie boli odhadnuté pre minimálnu šírku pravej (92,67 %, obr. 3) resp. ľavej pučnice (79,44 %, obr. 4). Rôzni autori (Fik, 2005; Beke, 2008; Hell, 1979; Hell a Holý, 1988; Vach, 1999) popisujú úzky vzťah medzi šírkou pučnice a kvalitou srnčej trofeje. Graficky sú znázornené kraniometrické miery s najvyššími koeficientmi determinácie v závislosti od

**Tabuľka 1** Základné variačno-štatistické ukazovatele kranilogických mier srnca lesného v poľovnej oblasti Tribeč v rokoch 2003 – 2007

Rozmer (15)	n (16)	n <sub>miss.</sub> (17)	$\bar{x}$ v cm	$\sigma_p$	$x_{\min.}$	$x_{\max.}$	R <sup>2</sup> v % (18)
CDL (1)	142	11	17,70	7,22	15,4	22,20	46,53
KBDL (2)	141	12	18,10	2,06	16,4	19,85	41,24
BDL (3)	141	12	16,48	1,16	14,58	18,40	53,50
DHRZ (4)	153	0	5,69	0,85	4,86	6,20	79,57
DRP1 (5)	146	7	5,48	0,40	4,22	6,80	38,23
DLO (6)	140	13	9,56	0,54	9,17	10,10	66,98
DMO (7)	150	3	11,41	0,41	9,45	11,97	74,72
MDN (8)	152	1	5,78	0,57	4,74	8,60	55,42
MSLO (9)	151	2	8,77	0,55	5,76	9,90	58,37
POS (10)	152	1	5,68	0,94	4,12	7,00	47,41
ZZMS (11)	150	3	5,87	0,49	5,2	6,90	25,41
MSPP (12)	153	0	1,59	0,46	0,7	2,80	92,67
MSLP (13)	153	0	1,61	0,47	0,55	2,90	79,44
MSM (14)	153	0	6,00	0,48	3,37	8,72	26,77

**Table 1** Basic statistical craniometrical characteristic of *Capreolus c. capreolus* from hunting region Tribec in years 2003 – 2007

(1) total length of cranium, (2) condylobasal length of cranium, (3) basal length of cranium, (4) length of top cheektooth row, (5) rostrum length from P1, (6) cheek length from orbit, (7) length of neurocranium from orbit, (8) maximum length of nasalia, (9) maximum width of cheek from orbit, (10) postorbital width, (11) caudal zygomatic maximum width, (12) right pedicle minimum width, (13) left pedicle minimum width, (14) maximum width of neurocranium, (15) measure, (16) number of obs., (17) missing obs., (18) coefficient of determination

vekového stupňa. Nami odhadnuté rastové krivky majú eksponenciálny (obr. 1) resp. logaritmický priebeh (obr. 2 – 4). Rozšírením údajovej bázy a rozšírením analýz by tieto mohli prispieť perspektívne k spresneniu odhadu veku a určeniu vekovej triedy a tým k posúdeniu správnosti odstrelu diskutabilných jedincov.

Pre zhodnotenie kvality srncov v poľovnej oblasti Tribeč a jej porovnanie s vývojom na Slovensku sme použili výsledky kraniometrického hodnotenia a hodnotenia trofejí na celoslo-

venskej výstave trofejí „Poľovníctvo a príroda 2005“. Na výstave bolo celkom hodnotených 70 trofejí srncov 4. až 8. vekového stupňa (tabuľka 2). Preukaznosť rozdielov v sledovaných súboroch srncov (tabuľka 3) sme vyhodnotili t-testom.

Ako vyplýva zo základných variačno-štatistických ukazovateľov, súbor srncov z poľovnej oblasti Tribeč vykazoval vyššiu mieru variability, vyjadrenú smerodajnou odchýlkou ako súbor trofejí z celoslovenskej výstavy v roku 2005. Vyššia miera variability trofejí v súbore srncov poľovnej oblasti Tribeč bola spôsobená širším zastúpením vekových stupňov a tým, že na chovateľských prehliadkach boli prezentované trofeje po selektívnom odstrele ako výsledok konkrétneho chovateľského roka. Súbor trofejí z celoslovenskej výstavy bol predselektovaný a predstavoval výber trofejí reprezentujúcich jednotlivé re-

**Tabuľka 2** Základné variačno-štatistické ukazovatele kranilogických mier srnca lesného prezentovaných v roku 2005 na celoslovenskej výstave trofejí

Rozmer (15)	n (16)	$\bar{x}$ v cm	$\sigma_p$	$x_{\min.}$	$x_{\max.}$
CDL (1)	70	20,351	0,376	19,53	21,49
KBDL (2)	70	19,203	0,361	18,26	19,90
BDL (3)	70	17,49	0,355	15,35	18,12
DHRZ (4)	70	5,775	0,539	5,12	8,64
DRP1 (5)	70	5,929	0,921	5,12	8,86
DLO (6)	70	10,200	0,367	9,14	10,94
DMO (7)	70	11,101	0,366	10,14	11,68
MDN (8)	70	6,518	0,947	4,95	8,76
MSLO (9)	70	9,352	0,402	6,83	9,98
POS (10)	70	6,155	0,268	5,15	6,92
ZZMS (11)	70	6,137	0,374	5,52	6,87
MSPP (12)	70	2,291	0,150	2,06	2,61
MSLP (13)	70	2,272	0,147	2,06	2,64
MSM (14)	70	6,317	0,175	6,04	6,80

+ P > 0,05; ++P > 0,001

**Table 2** Basic statistical craniometrical characteristic of *Capreolus c. capreolus* presented at National hunting trophy exhibition in year 2005

(1) total length of cranium, (2) condylobasal length of cranium, (3) basal length of cranium, (4) length of top cheektooth row, (5) rostrum length from P1, (6) cheek length from orbit, (7) length of neurocranium from orbit, (8) maximum length of nasalia, (9) maximum width of cheek from orbit, (10) postorbital width, (11) caudal zygomatic maximum width, (12) right pedicle minimum width, (13) left pedicle minimum width, (14) maximum width of neurocranium, (15) measure, (16) number of obs.

**Tabuľka 3** Testovanie preukaznosti rozdielov kranilogických mier srnca lesného v chovateľskej oblasti Tribeč a SR

Rozmer (1)	Rozdiel (2)	Preukaznosť (3)
CDL	-2,651	++
KBDL	-1,103	++
BDL	-1,01	++
DHRZ	-0,085	-
DRP1	-0,449	++
DLO	-2,74	++
DMO	0,309	-
MDN	-0,738	++
MSLO	-0,582	++
POS	-0,475	++
ZZMS	-0,267	++
MSPP	-0,701	++
MSLP	-0,662	++
MSM	-0,317	++

+ P > 0,05; ++P > 0,001

**Table 3** Results of statistical differences testing of craniometrical characteristic of *Capreolus c. capreolus* of hunting region Tribeč and Slovak republic

(1) measure, (2) difference, (3) significance

gióny, vykazoval súbor podstatne nižšiu variabilitu v porovnaní s rozmermi trofejí v chovateľskej oblasti Tribeč, čo spolu s užším rozpätím vekových stupňov ovplyvnilo variabilitu v súbore.

Pri porovnaní priemerných hodnôt kraniometrických ukazovateľov, je možné konštatovať zhodu s hodnotami, ktoré vo svojej práci uvádzali Hell a Holý (1988) srncov za Slovensko, resp. Vach (1999) v Českej republike. Možno súhlasí s autormi, že srnce s vyššími šírkovými mierami majú vyšší predpoklad pre utváranie trofejí s vyššími bodovými hodnotami.

Ako vyplýva z výsledkov testovania štatistickej významnosti, kraniometrické miery srncov poľovnej oblasti Tribeč nedosahujú priemerné hodnoty mier srncov z celoslovenskej výstavy. Zistené rozdiely boli štatisticky vysoko signifikantné. Rozdiely sú najvýznamnejšie v celkovej, bazálnej resp. kondylobazálnej dĺžke lebky (tabuľka 3). Tieto rozdiely boli vysoko štatisticky preukazné. Najnižší rozdiel bol zistený v dĺžke horného radu zubov (0,102 v prospech súboru za Slovensko), tento ale neboli štatisticky významný. Rozdiely dĺžky horného radu zubov, resp. dĺžky mozgovne v orbitách neboli štatisticky významné.

### Trofejová kvalita

V sledovanom súbore trofejí poľovnej oblasti Tribeč bola zistená vysoká variabilita vybraných mier trofejí parožia, ktoré vplývajú na bodové hodnotenie trofejí CIC. Najnižšia variabilita bola zistená v rozpäti parožkov 29,24 %, najvyššia 48,33 % dĺžky pravého kmeňa. Variabilita hmotnosti trofeje resp. objemu parožkov bola 38,63 % resp. 39,02 % (tabuľka 4). Súbor hodnotených trofejí na celoslovenskej výstave v roku 2005 bol vyrovnanejší. Najvyššia hodnota bola zistená pri objeme parožkov 37,27 %, najnižšia pri dĺžke pravého resp. ľavého kmeňa 9,13 resp. 9,37 % (tabuľka 5).

Štatistickým porovnaním vybraných rozmerov trofejí (tabuľka 6), ktoré sa podieľajú na bodovom hodnotení CIC boli zistené

**Tabuľka 4** Základné variačno-štatistiké ukazovatele vybraných znakov CIC hodnotenia srnca lesného v chovateľskej oblasti Tribeč

	$n$	$\bar{x}$ v cm	$\sigma_p$	$X_{\min.}$	$X_{\max.}$
DPK (1)	149	15,28	7,384	0,5	30,00
DLK (2)	149	15,506	7,462	1,0	42,00
PDK (3)	144	15,643	6,916	1,3	26,75
HT (4)	141	251,95	97,330	81,0	470,00
OP (5)	104	72,788	28,400	24,0	160,00
RP (6)	101	10,272	3,003	0,0	16,50

**Table 4** Basic statistical characteristic of CIC evaluation of *Capreolus c. capreolus* from hunting region Tribec  
(1) length of right stem, (2) length of left stem, (3) average length of stems, (4) trophy weight, (5) trophy volume, (6) trophy span

**Tabuľka 5** Základné variačno-štatistiké ukazovatele vybraných znakov CIC hodnotenia srnca lesného na Slovensku

	$n$	$\bar{x}$ v cm	$\sigma_p$	$X_{\min.}$	$X_{\max.}$
DPK (1)	70	24,06	2,20	18,00	29,70
DLK (2)	70	23,86	2,24	18,00	28,90
PDK (3)	70	21,70	2,96	11,63	28,00
HT (4)	70	514,26	48,15	418,00	680,00
OP (5)	70	206,77	77,05	135,00	400,00
RP (6)	70	11,87	2,64	5,50	18,00

**Table 5** Basic statistical characteristic of CIC evaluation of *Capreolus c. capreolus* in the Slovak republic  
(1) length of right stem, (2) length of left stem, (3) average length of stems, (4) trophy weight, (5) trophy volume, (6) trophy span

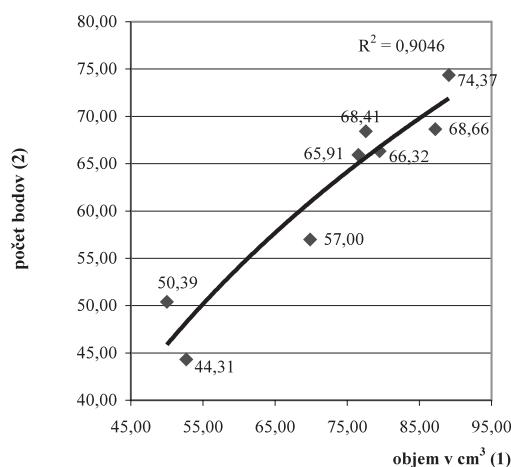
**Tabuľka 6** Testovanie preukaznosti rozdielov vybraných znakov CIC mier srnca lesného v chovateľskej oblasti Tribeč a SR

	Rozdiel (7)	Preukaznosť (8)
RP (6)	-1,596	++
OP (5)	-133,983	++
HT (4)	-262,307	++
PDK (3)	-6,058	++
DLK (2)	-8,355	++
DPK (1)	-8,783	++

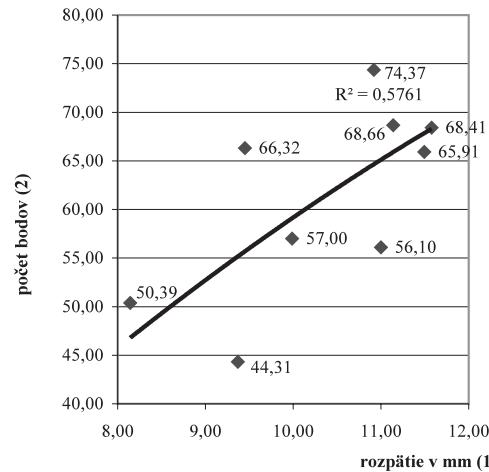
+ P > 0,05; ++ P > 0,001

**Table 6** Results of statistical differences testing of CIC evaluation of *Capreolus c. capreolus* of hunting region Tribec and SR  
(1) length of right stem, (2) length of left stem, (3) average length of stems, (4) trophy weight, (5) trophy volume, (6) trophy span, (7) difference, (8) significance

né vyššie priemerné hodnoty trofejí súboru za Slovensko. Najvýznamnejšie rozdiely boli zistené pri objeme parožkov a hmotnosti trofeje, 133,983 cm<sup>3</sup> resp. 262,307 rozdiely hodnotených rozmerov boli významné ovplyvnené vyšším zastúpením medailových trofejí prezentovaných na celoslovenskej



**Obrázok 5** Bodová hodnota CIC v závislosti od objemu parožkov  
**Figure 5** CIC evaluation dependence on trophy volume  
(1) trophy volume in cm<sup>3</sup>, (2) CIC evaluation points



**Obrázok 6** Bodová hodnota CIC v závislosti od rozpäti parožkov  
**Figure 6** CIC evaluation dependence on trophy span  
(1) trophy span in mm, (2) CIC evaluation points

výstave v roku 2005. Rozdiel v rozpätí parožkov bol 1,596 cm, dĺžka pravého resp. ľavého kmeňa 8,355 cm resp. 8,783 cm. Zistené rozdiely boli vysoko štatisticky preukazné.

Z hľadiska hodnotenia trofejovej kvality sa na výslednom bodovom hodnotení trofejí v chovateľskej oblasti Tribeč podielali objem ( $R^2 = 90,46\%$ ) resp. rozpätie parožkov ( $R^2 = 74,37\%$ ). Rozpätie parožkov je parameter, ktorý je možné zohľadniť pred odstrelom ako selekčné kritérium.

### Korelačná analýza bodového hodnotenia a kraniometrických rozmerov

V štatistickom súbore 153 srncov boli odhadnuté fenotypové korelácie 14 kraniometrických údajov vo vzťahu k bodovému hodnoteniu trofejí CIC. Najvyššiu hodnotu korelácie celkového bodového hodnotenia 0,722 sa odhadli vo vzťahu k maximálnej šírke pravej pučnice (MSPP). Vo vzťahu k celkovej dĺžke lebky (CDL), kondylóbazálnej dĺžky lebky (KBDL) a maximálnej šírky lebky v orbitách (MSLO) sa zistili stredne vysoké korelácie s hodnotami 0,439, 0,433 resp. 0,392. Vo vzťahu k ostatným nameraným údajom sme nezistili signifikantné korelácie. Medzi CDL a dĺžkou kmeňov sa odhadli stredne vysoké korelácie, obdobne ako k hmotnosti trofeje po zrážke a aj bodovému hodnoteniu a objemu trofeje. Taktiež sme zistili stredne vysokú koreláciu k hrotom vetiev. Medzi hmotnosťou trofeje a CDL resp. KBDL sa vypočítali korelácie 0,681 resp. 0,685. Medzi KBDL a dĺžkou kmeňov sa zistili stredne vysoké korelácie. Stredne vysoká korelácia bola zistená aj medzi KBDL a hmotnosťou trofeje po zrážke aj v bodovom hodnotení, objemom parožia, rozpätiom parožia a hrotom vetiev. Medzi bazálnou dĺžkou lebky (BDL), dĺžkou kmeňov a hmotnosťou trofeje sa zistili stredne vysoké korelácie. Stredne vysoké korelácie sa zistili medzi dĺžkou rostra P1 (DRP1), dĺžkou kmeňov, hmotnosťou trofeje. Medzi maximálnou dĺžkou nazálií (MDN), dĺžkou kmeňov a hmotnosťou taktiež existuje stredne vysoká závislosť. Maximálna šírka lebky v orbitách (MSLO) a hmotnosť trofeje sú vysoko korelované  $r_p = 0,667$ . Korelácia medzi MSLO, dĺžkou kmeňov a hmotnosťou trofeje po zrážke bola stredne vysoká. Ako najvýznamnejšie sa javia vzťahy medzi MSPP a dĺžkou kmeňov (0,759 – 0,834), resp. MSPP a hmotnosťou trofeje 0,892. Ostatné hodnoty korelácií neboli signifikantné.

### Záver

Porovnanie trofejovej kvality trofejí srncov poľovnej oblasti Tribeč a trofejí z celoslovenskej výstavy ešte významnejšie poukazuje na rozdiely v trofejovej kvalite a potrebu takého hodnotenia ako podkladu pre skvalitnenie riadenia chovu a plánovania lovov srncov v poľovnej oblasti Tribeč. Zároveň poukazuje na správnosť stanovenia kritérií selektívnych odstrelov srncov na regionálnej úrovni. Cyklické hodnotenie kraniometrických mier a ich vzťahov k veku môže byť využité pri spresnení určenia vekových stupňov diskutabilných trofejí. Vo vzťahu k utváraniu trofejí môže prispieť k zvýšeniu trofejovej kvality úpravou kritérií selektívneho odstrelu v konkrétnych chovateľských oblastiach. Trofejová kvalita je ovplyvnená nielen genofondom, ktorý je dlhodobo na Slovensku na pomerne vysokej úrovni ale aj chovateľským prostredím, ktoré významne ovplyvňuje celkový fenotypový prejav – kvalitu trofejí. Správny manažment z dlhodobého hľadiska môže viesť k zlepšeniu trofejovej kvality srncov nielen v poľovnej oblasti Tribeč. Zhodnotenie utvárania kraniometrických mier poukazuje vo vyššej mieri na vplyvy prostredia, ktoré pôsobia dlhodobo počas ontogenézy a sú založené už počas prenatálneho vývinu. Zhodnotenie trofejovej kvality zas poukazuje na vplyvy prostredia, ktoré sú krátkodobého charakteru a sú výsledkom pôsobenia faktorov počas jedného ročníka resp. se-

zóny. Vzhľadom na to že medzi kraniometrickými mierami a trofejovou kvalitou existujú významné závislosti je potrebné ich zohľadňovať pri starostlivosti o zver.

### Súhrn

Cieľom práce bolo zhodnotenie utvárania kraniologických mier a parožia srnčích trofejí v poľovnej oblasti Tribeč ako predpokladu úspešného manažmentu a selekcie srnčej zveri. Databázu vstupných údajov tvorili údaje o 14 kraniologických mierach srnčích trofejí a ich bodovom hodnotení metodikou podľa CIC. Celkovo bolo do databázy zaradených 153 srnčích trofejí (roky 2003 – 2007) z okresov Nitra, Topoľčany, Partizánske a Zlaté Moravce, na území ktorých sa rozkladá poľovná oblasť Tribeč. Porovnanie bolo vykonané s trofejami prezentovanými na celoslovenskej výstave trofejí v roku 2005. Kraniometrické miery srncov poľovnej oblasti Tribeč nedosahujú priemerné hodnoty mier srncov z celoslovenskej výstavy a zistené rozdiely boli štatisticky vysoko signifikantné. Porovnaním vybraných rozmerov trofejí, ktoré sa podielajú na bodovom hodnotení CIC boli zistené vyššie priemerné hodnoty trofejí v súbore za Slovensko. Z hľadiska hodnotenia trofejovej kvality sa na výslednom bodovom hodnotení trofejí v chovateľskej oblasti Tribeč podielali objem ( $R^2 = 90,46\%$ ) resp. rozpätie parožkov ( $R^2 = 74,37\%$ ). Rozpätie parožkov predstavuje parameter, ktorý je možné zohľadniť pred odstrelom ako selekčné kritérium. Ako najvýznamnejšie sa javia vzťahy medzi minimálnou šírkou pučníc a dĺžkou kmeňov ( $r_{XY} = 0,759 – 0,834$ ), resp. hmotnosťou trofeje (0,892).

**Kľúčové slová:** srnec lesný, kraniometria, trofejová kvalita, selekcia

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## SOIL STRUCTURE OF HAPLIC LUVISOL AS INFLUENCED BY TILLAGE AND THE PLOUGHING OF CROP RESIDUES

### VPLYV OBRÁBANIA PÔDY A ZAPRACOVÁVANIA POZBEROVÝCH ZVÝŠKOV NA PÔDNU ŠTRUKTÚRU HNEDOZEME

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In this field experiment (experimental base of SUA in Nitra) the structural state of Haplic Luvisol and its susceptibility to potential erosion due to the differences in tillage practices and the ploughing of crop residues were evaluated. Two tillage systems (conventional and minimal) and two treatments of fertilization (control and with added crop residues) were appraised. In the study of Haplic Luvisol, the conventional tillage and ploughing of crop residues had a positive effect by increasing the favourable structural macroaggregates, values of structure coefficient and also water-stable macroaggregates. In contrast, in the conventional or minimal tillage study of Haplic Luvisols, it was by about 42% potentially more vulnerable to wind erosion.

**Key words:** water-stable macroaggregates, structural coefficient, Haplic Luvisol, soil tillage, crop residues

The stability of soil structure is one of the most important indicators of soil quality. Soil structure has a direct impact on the complex processes affecting plant growth and the sustainability of production. Plant growth primarily depends on soil structure and the size, distribution and stability of aggregates. The resulting state of the soil structure depends on the impact of different soil properties, farming systems and environmental factors (Six et al., 2000). In addition, the stability of aggregates determines soil resistance to erosion (Barthès and Roose, 2002). Erosion not only has serious effects on crop yields but also negatively affects the soil functions, as it reduces plant rooting depth, removes nutrients and organic matter, reduces infiltration rates and limits soil water available to plants (Pimentel et al., 1995; Lupwayi et al., 2001). In Slovakia, the most important degradation processes include water and wind erosion, which has a direct impact on soil structure. Water erosion presents a potential threat to 46% of agricultural land (1 087 839 hectares) and wind erosion processes potentially threaten 9% of agricultural land which amounts to 202 429 hectares.

The aim of this study was to assess the structural state of Haplic Luvisol and its susceptibility to potential erosion due to the differences in tillage practices and ploughing crop residues.

### Material and methods

In 1999 a field experiment was carried out by the Department of Plant Production (SAU in Nitra) in the locality of Dolná Malanta [lat. 48° 19' 00"; lon. 18° 09' 00"]. The mean temperature of this location is 9.8 °C and average rainfall is 573 mm. Soil, according to FAO classification, is silt loam Haplic Luvisol (WRB, 2006). The soil carbon content was 12.6 g·kg<sup>-1</sup>, while the cation exchange capacity was 154.6 mmol·kg<sup>-1</sup> and the base saturation percentage was 90.3 %. On average, the soil active pH was 6.71. More detailed information about the experimental base of SUA in Nitra (climate, geological, pedological conditions) is published in Tobiašová and Šimanský (2009).

The field experiment included two tillage systems as well as two fertilization treatments.

The variants of tillage were:

- B1 – conventional tillage (medium tilth to a depth 0.22 – 0.25 m),
- B2 – minimal tillage (disking to a depth 0.10 – 0.12 m).

The variants of fertilization were:

- 0 – control (without fertilization),
- CR – crop residues ploughing to soil.

During 2007 – 2010, soil samples were taken from the depths 0 – 0.2 m. These soil samples were dried at laboratory temperature and hand divided by the sieve (dry and wet sieve) to 7 size fractions (Hraško et al., 1962). In fractions of aggregates, the coefficient of structure and content of water-stable macro-aggregates were calculated (Zaujec and Šimanský, 2006). The obtained results were statistically evaluated. Mean values of all variables were compared using an analysis of variance and were separated by the LSD multiple-range test at the 95% confidence level.

### Results and discussion

During the years 2007 – 2010 the climatic conditions had contributed to the major share of the structural changes found in the portion of aggregates within soil tillage systems and the ploughing of crop residues (Fig. 1). Climate is one of the most important factors that influence structural changes through the repeated cycles of drying and wetting or freezing and thawing, which produce the shrinking and swelling that leads to the formation of aggregates (Lal and Shukla, 2004; Šimanský et al., 2006). Tillage and fertilization are very important factors affecting the aggregation processes (Šimanský et al., 2008). A statistical evaluation of the results depending on soil tillage and fertilization is presented in Table 1. Conventional tillage, when compared to the minimal tillage, has a positive effect on the increase of the structural aggregates portion within the

**Table 1** Statistical evaluation of parameters of soil structure stability in Haplic Luvisol (Dolná Malanta) according to LSD multiple-range test

Parameters (1)	Size fractions of aggregates in mm (2)	Tillage system (3)		Fertilization (4)		± Limits (5)	
		B1	B2	0	CR	LSD <sub>0,05</sub>	LSD <sub>0,01</sub>
Content of structural aggregates in % (6)	<0.25	4.56	3.21	4.28	3.49	0.93	1.32
	0.25 – 0.50	4.34	3.04	4.22	3.16	1.35	1.92
	0.50 – 1	13.16	9.04	9.54	12.65	3.63	5.16
	1 – 3	21.85	18.38	18.82	21.42	3.35	4.76
	3 – 5	15.27	16.38	16.26	15.39	1.47	2.10
	5 – 7	13.30	15.77	15.70	13.37	2.05	2.92
	>7	27.53	34.19	33.04	28.67	7.93	11.27
Water-stable macroaggregates (7)		75.66	73.6	70.89	78.37	13.73	19.52
Structure coefficient (8)		2.66	1.98	2.01	2.62	0.82	1.17

B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues

B1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky

**Tabuľka 1**

Štatistické zhodnotenie parametrov stability štruktúry hnedozeme (Dolná Malanta) – LSD testom

(1) parameter, (2) veľkosťné frakcie agregátov, (3) spôsob obrábania, (4) hnojenie, (5) limita, (6) obsah štruktúrnych agregátov, (7) vodooodolné makroagregáty, (8) koeficient štruktúrnosti

**Table 2** Potential amount of soil (Haplic Luvisol in locality Dolná Malanta) vulnerable to wind erosion in t.ha<sup>-1</sup>

Factors (1)	Vulnerable size fractions of structural aggregates (2)		
	<0.25 mm	0.25 – 0.50 mm	Σ
Tillage (3)			
B1	145	138	283
B2	102	97	199
Fertilization (4)			
0	136	134	270
CR	110	101	211

B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues

B1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky

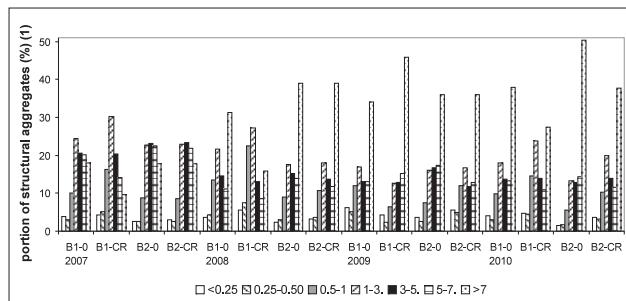
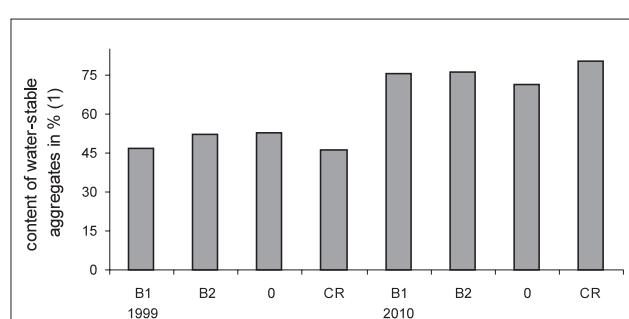
**Tabuľka 2**Potenciálne ohrozené množstvo pôdy veterou eróziou v t.ha<sup>-1</sup> (hnedozem v lokalite Dolná Malanta)

(1) faktory, (2) zraniteľné veľkosťné frakcie štruktúrnych agregátov, (3) obrábanie, (4) hnojenie

0.5 – 1 mm size fraction (46%) and 1 – 3 mm fraction (19%) and also reduces the size fractions of 3 – 5 mm (7%) and 5 – 7 mm

(16%) of the structural aggregates, which confirms the results of Šimanský et al. (2007). The portion of water-stable aggregates as well as the values of the structure coefficient also showed a positive effect of conventionally tilled treatments (Table 1). Under the conventional tillage system, favourable soil aggregation capacity depends on the optimum moisture content during the processing (Šimanský et al., 2007). Crop residues ploughed into the soil had a positive effect on the decrease of microaggregate content and the macroaggregate contents of size fraction 0.25 – 0.5 mm and > 3 mm. On the other hand, it was determined in treatments with added crop residues that the soil had a higher portion of structural aggregates of the size fraction 0.5 – 1 mm (about 33 %) and 1 – 3 mm (about 14%). It was therefore confirmed that the applications of crop residues have a favourable influence on soil aggregation (Lal and Shukla, 2004; Šimanský et al., 2008) (Table 1).

The size and stability of soil aggregates are primary factors that affect the soil susceptibility to wind erosion. Aggregates smaller than 0.84 mm in diameter are considered erodible by wind (Chepil, 1953). Soil samples were taken from the depth 0.2 m and the average bulk density of the investigated Haplic Luvisol (experimental site of SAU in Nitra, Dolná Malanta) is 1.59 t.m<sup>-3</sup> according to published results of Tobiašová and

**Figure 1** Changes in portion of structural aggregates by soil tillage systems and crop residues ploughing during 2007 – 2010  
B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues**Obrázok 1** Zmeny v zastúpení štruktúrnych agregátov v dôsledku obrábania a zaorávania pozberových zvyškov v priebehu rokov 2007 – 2010B1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky  
(1) zastúpenie štruktúrnych agregátov**Figure 2** Water-stable content of macro-aggregates at the beginning (1999) and end of the experiment  
B1 – conventional tillage, B2 – minimal tillage, 0 – control (without fertilization), CR – added crop residues**Obrázok 2** Obsah vodooodolných makroagregátov na začiatku a na konci experimentuB1 – konvenčné obrábanie, B2 – minimalizačné obrábanie, 0 – nehnojená kontrola, CR – zaorané pozberové zvyšky  
(1) obsah vodooodolných makroagregátov