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Grain Yield and Rutin Content of Common and Tartary Buckwheat Varieties Grown in North-Western Hungary

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ABSTRACT

Grain yield and rutin content was assessed in 31 common buckwheat (*Fagopyrum esculentum* Moench) and three tartary buckwheat (*Fagopyrum tataricum* Gaertn.) varieties grown in the summer of 2008 at the Research and Experimental Farm of the Faculty of Agricultural and Food Sciences, University of West Hungary, Mosonmagyaróvár, Hungary. Grain yield of common buckwheat varied from a high of 0.98 t/ha in 'Vlada', 0.94 t/ha in 'Koto' and 0.92 t/ha in 'Anita Belorusskaya' to lows of 0.31 t/ha in 'Arakawa Village', 0.47 t/ha in 'Kora' and 0.48 t/ha in 'Springfield'. Much lower grain yield was observed in the three tartary buckwheat varieties: 0.12 t/ha in 'Ishisoba', 0.37 t/ha in 'Donan' and 0.38 t/ha in 'Golden'. As expected, and unlike grain yield performance, the rutin content observed in *F. tataricum* was as much as two orders of magnitude higher than that of *F. esculentum*, ranging between 974 mg/100 g DW in 'Golden' and 1196 mg/100 g DW in 'Ishisoba'. In common buckwheat, grain rutin content ranged from 8 mg/100 g DW in 'Darja' and 'Kitawasesoba' to 24 mg/100 g DW in 'La Harpe'. The best compromise between grain yield and rutin content in common buckwheat was observed in var. 'Vlada', which had the top yield and ranked third in rutin content. Tartary buckwheat grain was a valuable source of rutin. In general, grain yield and rutin content were largely not correlated, almost as if grain development and rutin accumulation were not competing processes. Rather, rutin accumulation appeared to be the function of a variety's aptitude likely related to origin. European varieties, regardless of their yield potential, expressed quite clearly a somewhat higher rutin content than varieties originating from Pacific areas, namely Japan and Canada.

Keywords: agronomic trials, *Fagopyrum esculentum*, *Fagopyrum tataricum*, flavonoids, HPLC analysis
Abbreviations: DW, dry weight; **HPLC**, high pressure liquid chromatography

INTRODUCTION

Growing concern about the negative health effects of modern diets rich in refined wheat flour, sugar, fat and protein of animal origin (Wadden *et al*. 2002), and recognized as the main causes of obesity, diabetes, cardiovascular disorders and degenerative diseases like cancer, has prompted renewed interest in underutilized minor crops rich in health beneficial bioactive compounds.

In this respect, buckwheat deserves particular attention thanks to the growing evidence of beneficial properties of some grain components on health, including reduced starch digestibility (Skrabanja and Kreft 1998) and consequently low glycaemic indices (Skrabanja *et al*. 2001), anticholesterolemic properties of the protein fraction (Kayashita *et al*. 1995; Kayashita *et al*. 1997; Tomotake *et al*. 2000, 2001) besides the well-balanced amino acid composition (Pomeranz and Robbins 1972), and good source of dietary fiber (Steadman *et al*. 2001a) and minerals (Ikeda *et al*. 1995; Steadman *et al*. 2001b; Ikeda *et al*. 2006). Even more impressive is the wealth of health benefits deployed by the flavonoid rutin (quercetin-3-rutinoside): improved capillary fragility (Griffith *et al*. 1944); retarded development of diabetes (Odetti *et al*. 1990); antilipoperoxidant activities (Negre-Salvayre *et al*. 1991); anticancer activity (Deschner *et al.* 1991); antihyperglycemic effect (Wang *et al*. 1992); protective effects against hemoglobin oxidation (Grinberg *et al*. 1994); a mitigation effect on cardiovascular diseases (He *et al*. 1995); antioxidative property (Oomah and Mazza 1996); antimutagenic activity (Aheme and O'Brien 1999); anti-inflammatory activity (Guardia *et al.* 2001); mitigation of diabetes consequences (Je *et al*. 2002); suppression of protein glycation (Nagasawa *et al*. 2003); antiplatelet formation property (Sheu *et al.* 2004); antiangiogenic effect (Guruvayoorappan and Kuttan 2007); neuroprotective effect (Pu *et al*. 2007).

Knowledge about common buckwheat cultivation in Hungary dates back to the Middle Ages (Sághi 2002). There is evidence that this crop was extensively grown in Southern Transdanubia and Northern Hungary at the turn of the 19th century (Bálint 1998). Thereafter, buckwheat was gradually replaced by the more productive cereal crops (Sághi 2002) and its cultivation is now limited to a few hundred hectares (FAOSTAT 2008).

The possibility of reintroducing buckwheat cultivation in North-Western Hungary implies that satisfactory grain yields of high quality are attainable. However, this condition needs to be proved before proposing the cultivation of buckwheat to farmers. To this end, an agronomic trial was carried out on a group of common buckwheat (*Fagopyrum esculentum* Moench) and a few tartary buckwheat (*Fagopyrum tataricum* Gaertn.) varieties. The latter were included due to the extremely high rutin content of the grain compared to common buckwheat (Kitabayashi *et al*. 1995a; Fabjan *et al*. 2003; Park *et al*. 2004; Brunori and Végvári 2007a; Brunori *et al*. 2008, 2009a, 2010). Because of the relevance of rutin as a health beneficial grain compound, the content of this flavonoid was also assessed.

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Table 1 Buckwheat varieties utilized: Origin and seed source.

Variety	Origin	Source
'Bamby'	Austria	J. Biason, Bolzano, Italy
'Lileja'	unknown	
'La Harpe'	France	Semfor, Casaleone, Verona, Italy
'Darja'*	Bosnia and Herzegovina	Parco Scientifico e Tecnologico del Molise, Campobasso, Italy
'Golden'	Slovenia	
'AC Manisoba', 'Koban', 'Mancan', 'Springfield'	Canada	Kade Research Ltd., Morden, Manitoba, Canada
'Jana', 'Pyra', 'Špačinska'	Czech Republic	University of South Bohemia, Faculty of Agriculture, České Budějovice, Czech Republic
'Kora', 'Luba', 'Panda'	Poland	Stacja Hodowli Róslin Palikije, Wojciechów, Poland
'Koto', 'Manor'	Canada	
'Aelita',	Russia	Department of Gene Bank, Division of Genetics and Plant Breeding,
'Emka', 'Hruszkowska'	Poland	Research Institute of Crop Production, Prague-Ruzyne, Czech Republic
'Prego'	Germany	
'Aleksandrina', 'Anita Belorusskaya', 'Iliya', 'Karmen', 'Lena', 'Vlada', 'Zhnayarka'	Belarus	RUP 'The Institute of Arable Farming and Plant Breeding of the National Academy of Sciences of Belarus', Zhodino, Minsk District, Belarus
'Arakawa Village', 'Botan'	Japan	Plant Germ-Plasm Institute, Graduate School of Agriculture, Kyoto University, Japan
'Donan'*, 'Ishisoba'*, 'Kitawasesoba', 'Kitayuki'	Japan	Plant Genetic Resources Laboratory, Dept. of Upland Agriculture, National Agricultural Research Center for Hokkaido Region, Shinsei, Memuro-cho, Kasai-gun, Hokkaido, Japan

* *F. tataricum* varieties

MATERIALS AND METHODS

In the present investigation 31 common buckwheat and three tartary buckwheat varieties, either purchased or kindly provided as shown in **Table 1**, were compared. Locally developed, Hungarian-bred common buckwheat cultivars (e.g., 'Hajnalka', 'Oberon') were not included in the study.

Three replicated plots of 7.2 m^2 each were cultivated in the summer of 2008 at the Research and Experimental Farm of the Faculty of Agricultural and Food Sciences, University of West Hungary in Mosonmagyaróvár. In the rotation, the cultivation of buckwheat followed winter barley which, at the time of seedbed preparation, had received 400 kg/ha of a Genezis NPK (15:15:15) fertilizer.

Barley was harvested on the 2nd of July. Buckwheat was sown on the 18th of July after 10 l/ha AZOTER® soil bacterium fertilizer mixture had been distributed and immediately ploughed under.

Approaching seed ripening, severe and sudden bird damage occurred randomly in dispersed spots, impairing any sound evaluation of grain yield. However, an estimate of grain yield potential was tentatively inferred by considering the best yield expressed by individual varieties within the three replicated plots.

For rutin (quercetin-3-rutinoside) [CAS Registry Number: 153-18-4] analysis the grain harvest of the three replicated plots was pooled. Wholemeal was obtained from clean grains by the use of a FOSS TECATOR CYCLOTEC 1093 sample mill. Three replicated samples of 200 mg wholemeal were extracted with either 2 ml (*F. esculentum*) or 4 ml (*F. tataricum*) of methanol (HPLC grade). Extraction was performed in the dark, for 24 h, at room temperature.

Rutin content was determined with HPLC (Waters Co. Milford, MA, USA) according to a procedure described previously (Brunori and Végvári 2007b) at 350 nm. The standard was purchased from Sigma-Aldrich Co., St. Louis, MO, USA.

Statistical differences in mean rutin content of the grain were analysed by the *t*-test ($P = 0.05$).

The relationship between grain yield and grain rutin content was established by linear regression analysis.

RESULTS

Grain yield

The grain yield of common and tartary buckwheat varieties used in this study is shown in **Table 2**.

Average grain yield of common buckwheat varied from a high of 0.98 t/ha in 'Vlada', 0.94 t/ha in 'Koto' and 0.92 t/ha in 'Anita Belorusskaya' to lows of 0.31 t/ha in 'Arakawa Village', 0.47 t/ha in 'Kora' and 0.48 t/ha in 'Springfield'. Because some plots were severely damaged by local fauna, the best yield performance among the three replicates, highlighted as bold figures in **Table 2**, was also taken into account and tentatively assumed as a measure of the actual yield potential of individual varieties. In this case, much higher grain yields can be envisaged in that some varieties, like 'Anita Belorusskaya', 'Koto', 'La Harpe', 'Prego', 'Vlada' and 'Zhnayarka', showed values well above 1 t/ha.

A rather low average grain yield was observed in the three tartary buckwheat varieties: 'Donan' (0.37 t/ha), 'Golden' (0.38 t/ha) and 'Ishisoba' (0.12 t/ha). However, these varieties suffered heavy bird damage.

Grain rutin content

The rutin content of common buckwheat grain varied from lows of 8 mg/100 g DW of 'Darja' and 'Kitawasesoba' and 9 mg/100 g DW of 'Koban' to 24 mg/100 g DW of 'La Harpe', 22 mg/100 g DW of 'Kora' and 21 mg/100 g DW of 'Vlada' (**Table 3**).

Compared to common buckwheat, tartary buckwheat expressed a much higher rutin content of the grain: 1196 mg/100 g DW ('Ishisoba'), 1085 mg/100 g DW ('Donan') and 974 mg/100 g DW ('Golden') (**Table 3**).

Relationship between grain yield potential and rutin content of the grain

The relationship between grain yield potential inferred from the best yielding plot (bold figures in **Table 2**) and the rutin content of the grain are presented in **Fig. 1**.

Evidence of any clear correlation between grain yield potential and grain rutin content was not apparent, judging from the very low R^2 values regardless of each variety's origin, i.e., either from Pacific area or Europe. In general, varieties originating from the Pacific area presented a somewhat lower rutin content of the grain.

DISCUSSION

In spite of the often severe bird grain predation, the present results would indicate that several of the 31 common buckwheat varieties were able to express grain yields around 1 t/ha, in line with the average commercial grain yield for Hungary (960 kg/ha) and for the World (913 kg/ha) (FAOSTAT 2008). However, if the best yielding replication of each variety is taken as an indication of the actual yield potential, the picture becomes much more favourable and yield levels well above 1 t/ha can confidently be envisaged in the environment of North-West Hungary. Particularly meaningful is the high number of common buckwheat vari-

Table 2 Grain yield of common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*Fagopyrum tataricum* Gaertn.) varieties.

Variety	Grain yield (g/plot)				Average yield (kg/ha)	Best plot yield (kg/ha)
	Rep 1	Rep 2	Rep 3	Mean		
Fagopyrum esculentum						
'AC Manisoba'	332	**644***	398	458	637	896
'Aelita'	300	**658**	352	437	608	915
'Aleksandrina'	400	**468**	328	399	555	651
'Anita Belorusskaya'	584	542	**854**	660	918	1188
'Arakawa Village'	**276**	182	214	224	312	384
'Bamby'	**486**	476	156	373	518	676
'Botan'	**532**	338	190	353	492	740
'Darja'	448	**558**	408	471	656	776
'Emka'	**574**	292	486	451	627	799
'Hruszkowska'	**600**	364	268	411	571	835
'Iliya'	**586**	578	390	518	721	815
'Jana'	534	**708**	376	539	750	985
'Karmen'	**680**	558	468	569	791	946
'Kitawasesoba'	452	322	**546**	440	612	760
'Kitayuki'	410	330	362	367	511	570
'Koban'	**636**	334	580	517	719	885
'Kora'	348	**486**	172	335	467	676
'Koto'	**840**	658	528	675	940	1169
'La Harpe'	**836**	572	412	607	844	1163
'Lena'	**654**	454	456	521	725	910
'Lileja'	674	**694**	330	566	787	966
'Luba'	524	**694**	286	501	698	966
'Mancan'	290	**516**	394	400	557	718
'Manor'	456	354	**602**	471	655	838
'Panda'	**656**	420	358	478	665	913
'Prego'	**792**	206	110	369	514	1102
'Pyra'	**586**	250	368	401	558	815
'Špacinska'	**662**	372	352	462	643	921
'Springfield'	**420**	368	237	342	475	584
'Vlada'	**794**	768	550	704	979	1105
'Zhnayarka'	362	**870**	208	480	668	1210
Fagopyrum tataricum						
'Donan'	198	266	**344**	269	375	479
'Golden'	**338**	214	276	276	384	470
'Ishisoba'	86	**92**	74	84	117	128

* The best yield observed among the three replicated plots of each variety is highlighted in bold.
Note: Presenting the yield of the three replicates is meant to highlight the heaviness of bird predation on certain plots. In this situation, to calculate the standard deviation would appear meaningless due to the enormous differences between replicates. Under the present circumstance, the only possibility to hint at the yield potential of buckwheat in North-West Hungary remains to point to the best yield observed.

Table 3 Grain rutin content of common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*Fagopyrum tataricum* Gaertn.) varieties.

Variety	Rutin (mg/100 g DW)	SD
Fagopyrum esculentum		
'AC Manisoba'	10 fg	0.40
'Aelita'	17 bcde	1.59
'Aleksandrina'	17 bcd	0.79
'Anita Belorusskaya'	17 bcde	0.96
'Arakawa Village'	12 f	0.74
'Bamby'	14 def	0.50
'Botan'	14 cdef	1.39
'Darja'	8 g	0.27
'Emka'	19 abc	1.20
'Hruszkowska'	19 bc	0.68
'Iliya'	17 c	0.15
'Jana'	14 e	0.07
'Karmen'	19 abc	1.32
'Kitawasesoba'	8 g	0.79
'Kitayuki'	14 def	0.98
'Koban'	9 fg	0.48
'Kora'	22 ab	0.89
'Koto'	14 def	0.60
'La Harpe'	24 a	0.96
'Lena'	17 c	0.43
'Lileja'	12 ef	0.74
'Luba'	16 cd	0.60
'Mancan'	11 fg	0.62
'Manor'	10 fg	0.57
'Panda'	18 bc	0.75
'Prego'	14 cdef	2.12
'Pyra'	15 d	0.14
'Špacinska'	19 bc	0.83
'Springfield'	13 def	0.91
'Vlada'	21 ab	0.67
'Zhnayarka'	19 b	0.38
Fagopyrum tataricum		
'Donan'	1085 b	12.45
'Golden'	974 c	31.88
'Ishisoba'	1196 a	22.11

Values with the same letter are not statistically different according to the *t*-test at $P = 0.05$.

eties that, according to the best plot yield as stated above, would appear well adapted to this specific environment (viz. 'Anita Belorusskaya', 'Koto', 'La Harpe', 'Prego', 'Vlada' and 'Zhnayarka') (**Table 2**). It may be of interest to note that all of these, with the exception of 'Koto', are of European origin, in a way demonstrating the success of breeding efforts on this continent and, more in general, that selection in a specific environment for traits like yield is an activity worth pursuing.

Since there is a relatively high number of established buckwheat varieties available for production, it appears safe to regard agronomic trials as an effective way to identify the best adapted genetic material to any given environment whose climatic conditions are susceptible to host the cultivation of this crop as confirmed by recent results obtained in Central and Southern Italy where buckwheat cultivation had never been attempted before (Brunori *et al*. 2010).

As for tartary buckwheat, grain spoilage due to bird predation was too severe to allow any assessment of the yield potential of the crop which, because of the great interest related to the high rutin content, deserves further exploratory efforts.

The grain rutin content of common buckwheat ranged from less than 10 mg 100/g DW to 24 mg/100 g DW, with most of the varieties around 15 mg/100 g DW, in line with values previously reported varying between 13 and 36 mg/100 g DW (Kitabayashi *et al*. 1995b) and between 5 and 58 mg/100 g DW (Brunori *et al*. 2010). However, as clearly shown in **Fig. 1**, it would appear that those varieties originating in Europe tended to accumulate more rutin in the grain than those from the Pacific area.

Tartary buckwheat is able to form a much higher rutin content of the grain – 1110-1950 mg/100 g DW (Kitabayashi *et al*. 1995a); 941-1694 mg/100 g DW (Brunori *et al*. 2009b) – than common buckwheat, a fact that was confirmed in the North-Western Hungarian environment in this study.

In line with previous, though preliminary, data (Brunori and Végvári 2007b) and regardless of the origin of the variety, the rutin content of the grain would appear in no way related to grain yield potential as the data presented in **Fig. 1** would suggest.

Thanks to the grain yield comparable to world average (FAOSTAT 2008) it seems safe to conclude that several common buckwheat varieties among the 31 genotypes assessed can be considered to be adapted to North-West Hungary, some of which express appreciable rutin content of the grain. However, in view of the many beneficial health properties attributed to this flavonoid (Christa and Soral-Śmietana 2008), varieties like 'Vlada', expressing good yield and characterised by relatively high rutin content of the grain, deserve particular attention if high yield and high quality are to be pursued.

On the other hand, despite the initial good vegetative growth and seed setting, due to the heavy bird predation, it

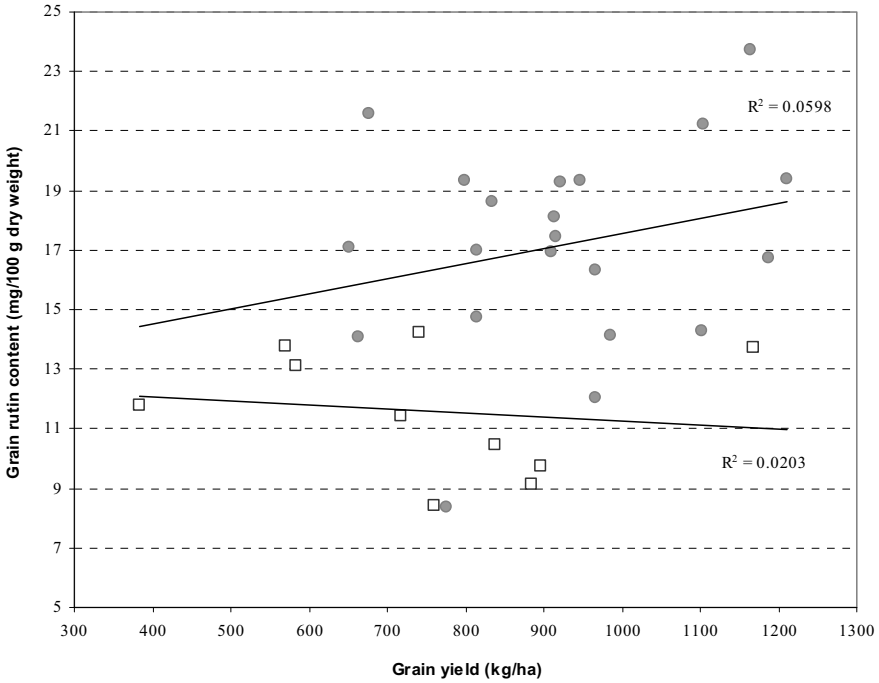

Fig. 1 Correlation between grain yield potential and grain rutin content of the common buckwheat varieties studied. Symbols: □ Varieties originating from the Pacific area; ● Varieties originating from Europe.

was not possible to evaluate the yield potential of tartary buckwheat. Nevertheless, this crop is worth further investigation for it may represent a rich source of rutin within the rationale of preventive nutrition.

Tartary buckwheat is a commodity not available on the international market, hence it needs to be locally supplied. Therefore, it is important to keep pursuing the identification of well adapted varieties and the most suited agronomic practices. Thus, along with common buckwheat varieties it seems advisable to also consider tartary buckwheat when aiming to promote the cultivation of *Fagopyrum* towards the development of more efficient buckwheat-based foods with regard to its attainable health benefits.

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