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Assessment of genetic diversity of selected tartary and common buckwheat accessions

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Abstract

Genetic diversity of plant genetic resources for food and agriculture is a unique and irreplaceable source for further crop genetic improvement. The aim of this paper was the field evaluation of buckwheat genetic resources in the Czech Republic. In the case of the 77 common buckwheat (*Fagopyrum esculentum* Moench.) genotypes, most had reddish-green stems (80%), cordate leaves (82%), white flowers (87%), and grey ovate achenes (44% and 57%, respectively). Vegetative growth duration ranged from 104 to 131 days. The 1000 seed weight (TSW) varied from 18.6 to 33.2 g. In the 15 tartary buckwheat (*Fagopyrum tataricum* Gaertn.) genotypes, there were no remarkable differences in morphological traits. Vegetative growth duration was 101 to 148 days, and the TSW varied from 8.10 to 20.0 g. Similarity/dissimilarity dendograms were calculated using the results of the field evaluation. Principal component analysis was also performed. The dendrograms showed high diversity in the morphological and phenological characteristics evaluated. Performance of the buckwheat varieties, particularly, their developmental stages, depended highly on the weather conditions of the year. Only days to flowering seemed to be affected by variety. Because the evaluation was made according to the IPGRI buckwheat descriptors the characteristics are compatible with data from other gene banks.

Additional key words: cluster analysis, dendrogram, descriptor, *Fagopyrum* sp. collection, genetic resources, principal component analysis, pseudocereals.

Resumen

Evaluación de la diversidad génetica en alforfón de Tartaria y trigo sarraceno

Para la mejora vegetal es imprescindible disponer de diversidad genética en los recursos fitogenéticos para la alimentación y la agricultura. El objetivo de este estudio fue la evaluación en campo de la morfología y fenología de 77 accesiones de alforfón de Tartaria (*Fagopyrum tataricum* Gaertn.) y 15 de trigo sarraceno (*Fagopyrum esculentum* Moench.) en las condiciones de Europa Central, en la República Checa. La mayoría de los genotipos del trigo sarraceno poseen pedúnculos de color rojo-verde (80%), hojas acorazonadas (82%), flores blancas (87%) y semillas de color gris y oblongas (44% y 57%, respectivamente); el ciclo vegetativo oscila entre 104 y 131 días y el peso de mil semillas (TSW) entre 18,6 y 33,2 g. En el caso del alforfón de Tartaria no se detectaron diferencias significativas en los caracteres morfológicos; el ciclo vegetativo oscila entre 101 y 148 días; y el TSW entre 8,10 y 20,0 g. En base a estos resultados se creó un dendrograma de similitud y disimilitud generado por un análisis de componentes principales. El dendrograma indica una gran diversidad en las características morfológicas y fenológicas. Las fases de desarrollo dependieron principalmente de las condiciones climáticas del año en variedades de trigo sarraceno. Solo el carácter «días hasta floración» parece afectado por la variedad. Debido a que la evaluación se hizo de acuerdo con los descriptores para trigo sarraceno del IPGRI, los resultados son compatibles con los datos de otros bancos de germoplasma.

Palabras clave adicionales: análisis de componentes principales, análisis cluster, colección de genotipos de *Fagopyrum* sp., dendrograma, descriptores, pseudocereales, recursos genéticos.

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Abbreviations used: CRI (Crop Research Institute), HSD (Tukey's honestly significant differences), IPGRI (International Plant Genetic Resources Institute), PGR (plant genetic resources), UPGMA (unweighted pair group method with arithmetic mean), TSW (thousand seed weight).

Introduction

Genetic diversity of plant genetic resources (PGR) for food and agriculture is a unique and irreplaceable resource for further crop genetic improvement and for increasing crop diversity and cultivars in agriculture (Dotlačil *et al*., 2003). They are a reservoir of genetic adaptability, which act as a buffer against potentially harmful environmental and economic changes. Erosion of these resources poses a severe threat to world food security in the long term. Although often undervalued, there is an urgent need to conserve and utilize PGR as a safeguard against an unpredictable future (FAO, 1993). Gene banks have to define more clearly, what their role will be in a concerted action to reduce genetic erosion (Hammer *et al*., 2003). Seed storage in gene banks is the predominant form of PGR conservation, representing about 90% of total accessions held *ex situ*. Some countries are now consolidating national collections that represent available indigenous diversity and include other diversity of potential importance to the country (FAO, 1997). Characterization of PGR accessions which provides information on morphological and agronomic aspects of the material is essential for gene bank management. Most gene banks are characterizing their collections according to international descriptors, such as those published by the IPGRI (Perry and Ayad, 1995).

Common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*Fagopyrum tataricum* Gaertn.) belong to the *Polygonaceae* and are two cultivated pseudocereal species used for human consumption (Ikeda, 2002; Bavec and Bavec, 2006). Although originally from China, at present buckwheat is widely cultivated as a minor crop in many countries around the world. Common buckwheat grain has attracted increased attention because of its protein content and high nutritional value, which is the results of a favourable amino acid composition as well as starch with special properties that differ from other cereals (Tomotake *et al*., 2000). In addition, the seed also contains high levels of vitamins, fibre, minerals, and flavonoids, which have positive effects on some chronic diseases, such as diabetes, hypertension, hypercholesterolemia, and cardiovascular disorders (Kayashita *et al*., 1995; Tomotake *et al*., 2000; Ikeda, 2002; Bonafaccia *et al*., 2003; Hinneburg and Neubert, 2005). In the present Czech Republic, the oldest records of common buckwheat date back to the 12th century. It was a common food in the 16th and 17th century. Afterwards cultivation decreased due to expansion of wheat bakery products and the popularity of the potato (Dotlačil *et al*., 2003). Tartary buckwheat is an important crop in high mountain areas of southern China and in the Himalayas due to its cold resistance and high yielding ability under poor soil conditions (Tsuji and Ohnishi, 2001). Recently, there has been demand for tartary buckwheat, as a medicinal plant, because of its high rutin content and other polyphenols and its suitability for production of nutraceutical and functional foods (Michalová, 2000; Fabjan *et al*., 2003). Both species belong to a group of crops with relatively low demands for fertilizers and pesticides. They can be grown successfully in low-input systems and less favourable areas. These important characteristics, emphasized by their specific nutritional value, designate them as crops convenient for organic agriculture and as a base for bio-food production (Dotlačil *et al*., 2003).

The Czech buckwheat collection was established in 1993 (Michalová, 2000) in the Gene Bank of the Crop Research Institute (CRI) in Prague Ruzyne. At present, common and tartary buckwheat, collections include 170 accessions; most of which were obtained from foreign gene banks. Some of them have been selected for more detailed study. Material from the Czech Republic is a small part of the collection. Studies of large buckwheat collections can offer general information on the variability range of the characteristics evaluated and can be a useful tool for plant breeders and end-users.

The main aim of this work was to compare tartary and common buckwheat genotypes cultivated under Czech conditions using international buckwheat descriptors of IPGRI (1994). Field data was collected for three years and was used to create similarity/dissimilarity dendrograms using Euclidean distance to generate a UPGMA dendrogram showing the relatedness among common and tartary buckwheat accessions.

Material and methods

All the samples of common and tartary buckwheat genotypes were from the buckwheat collection of the Czech Gene Bank at the CRI. The passport data on the origins of the samples are shown in Table 1. A set of 77 common buckwheat and 15 tartary buckwheat genotypes were sown during 2004-2006 in the experimental fields of the CRI. Seed was hand sown, at the beginning of May, in double-row 1.5 m long with 0.25 m between the rows. There were 50 seeds per one row. Ten reference plants were selected for evaluation. The following traits were recorded according to IPGRI

Table 1. List of common and tartary buckwheat accessions used for evaluations

No.	ECN[a]	Name of variety	Origin
Common buckwheat (*Fagopyrum esculentum*)			
1	01Z5000002	Astoriya	Former USSR
2	01Z5000004	Chishiminskaya	Former USSR
3	01Z5000005	Kalininskaya	Former USSR
4	01Z5000006	Krasnostreletskaya	Former USSR
5	01Z5000007	Lada	Former USSR
6	01Z5000008	Maiskaya	Former USSR
7	01Z5000009	Prikamskaya	Former USSR
8	01Z5000010	Sibiryachka	Former USSR
9	01Z5000011	Skorospelaya 81	Former USSR
10	01Z5000012	Shatilovskaya 5	Former USSR
11	01Z5000013	Alaya 846	Ukraine
12	01Z5000014	Viktoriya Podolskaya	Former USSR
13	01Z5000015	Vita Galeya	Former USSR
14	01Z5000016	Local	Russia
15	01Z5000017	Monori	Unknown
16	01Z5000018	Lehnicka krajova	Slovakia
17	01Z5000020	Orbita	Ukraine
18	01Z5000021	Slavyachka	Ukraine
19	01Z5000022	Unnamed	Unknown
20	01Z5000023	Unnamed	Unknown
21	01Z5000024	Unnamed	Unknown
22	01Z5000029	Unnamed	Bhutan
23	01Z5000030	Unnamed	Bhutan
24	01Z5000036	Unnamed	Bhutan
25	01Z5000037	Unnamed	Bhutan
26	01Z5000038	Unnamed	Bhutan
27	01Z5000039	Unnamed	Bhutan
28	01Z5000040	Unnamed	Bhutan
29	01Z5000041	Unnamed	Bhutan
30	01Z5000042	Unnamed	Bhutan
31	01Z5000043	Unnamed	Zimbabwe
32	01Z5000045	Unnamed	Zimbabwe
33	01Z5000046	Iwate Zairai (MIDOU)	Japan
34	01Z5000047	Tokushima Zairai	Japan
35	01Z5000048	Takizawa Zairai	Japan
36	01Z5000051	Botansoba	Japan
37	01Z5000052	Hara Zairai	Japan
38	01Z5000055	Arihira Zairai	Japan
39	01Z5000058	Ballada	Former USSR
40	01Z5000060	Sumcanka	Former USSR
41	01Z5000062	Bolshevik 4	Former USSR
42	01Z5000063	Pyra	Czech Republic
43	01Z5000067	Chernigovskaya 17	Ukraine
44	01Z5000069	Vychodoslovenska krajova	Slovakia
45	01Z5000070	Špačínská 1	Slovakia
46	01Z5000071	Dozhdik	Belarus
47	01Z5000072	Sudtirol Nr. 3	Unknown
48	01Z5000074	Unnamed	Unknown
49	01Z5000084	Anita Beloruskaya	Belarus
50	01Z5000092	Kasanskaya	Former USSR
51	01Z5000093	Jezyk	Unknown
52	01Z5000094	Yubileina	Unknown
53	01Z5000095	Kora	Unknown

Table 1 (cont.). List of common and tartary buckwheat accessions used for evaluations

No.	ECN[a]	Name of variety	Origin
54	01Z5000100	Green corolla 2	Unknown
55	01Z5000103	Unnamed	Former USSR
56	01Z5000105	Komsta	Former USSR
57	01Z5000112	Gema	Poland
58	01Z5000113	Lopfe	Unknown
59	01Z5000115	Kasanskaya	Former USSR
60	01Z5000116	Troika	Former USSR
61	01Z5000117	Demetra	Former USSR
62	01Z5000118	Podolyanka	Former USSR
63	01Z5000119	Siva	Slovenia
64	01Z5000120	Darja	Slovenia
65	01Z5000121	Rana 60	Slovenia
66	01Z5000122	Darina	Slovenia
67	01Z5000123	Kara-Dag	Ukraine
68	01Z5000124	Bong Pyung	Korea
69	01Z5000127	Jana	Ukraine
70	01Z5000128	Panda	Russia
71	01Z5000129	Luba	Russia
72	01Z5000133	Roksolana	Russia
73	01Z5000134	Rubra	Russia
74	01Z5000135	Bamby	Austria
75	01Z5000142	Mesteaja Olginskaja	Former USSR
76	01Z5000161	Dolenjska siva	Slovenia
77	01Z5000162	Radouljica	Slovenia
Tartary buckwheat (*Fagopyrum tataricum*)			
1	01Z5100001	Unnamed	Bhutan
2	01Z5100002	Unnamed	Bhutan
3	01Z5100003	Unnamed	Bhutan
4	01Z5100004	Unnamed	Bhutan
5	01Z5100005	Unnamed	Bhutan
6	01Z5100007	Unnamed	Bhutan
7	01Z5100008	Unnamed	Bhutan
8	01Z5100009	Unnamed	Bhutan
9	01Z5100010	Lifago	Germany
10	01Z5100011	Unnamed	Pakistan
11	01Z5100012	Unnamed	Czech Republic
12	01Z5100013	Unnamed	Mexico
13	01Z5100014	Unnamed	USA
14	01Z5100017	Unnamed	Unknown
15	01Z5100019	Unnamed	unknown

[a] Gene Bank identification number (national accession number).

(1994) buckwheat descriptors: stem colour, leaf blade colour, leaf taste, leaf blade shape, compactness of inflorescence, flower colour, number of inflorescences, number of days from sowing to emergence, number of days from emergence to flowering, number of days from emergence to maturity, plant height, seed colour, seed shape, and 1,000-seed weight (TSW).

Analysis of variance (ANOVA) and the Tukey HSD test were used for statistical evaluation. The dendrogram of distance among tested genotypes was calculated using average values using cluster analysis (software-Statistica 7.0 CZ).

Results

Figure 1 shows the temperatures and rainfall during vegetative growth in 2004-2006. Table 2 shows the

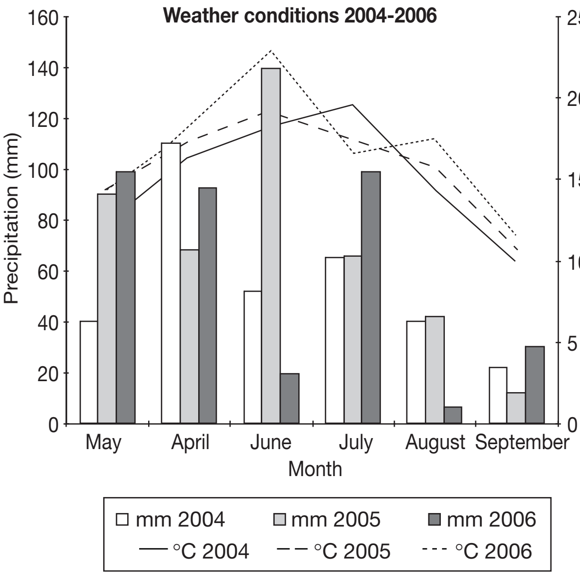

Figure 1. Weather conditions during the field experiment from 2004 until 2006.

phenological evaluation of the common and tartary buckwheat collection according to IPGRI (1994) descriptors. The period from sowing to emergence ranged from 8 to 35 d in common buckwheat and in tartary buckwheat the interval was similar (9-25 d). The mean value of this character was 2 d shorter in tartary buckwheat. Common buckwheat began to flower on average within 30 d compared with tartary buckwheat, which started to flower much later with a mean value of 46 d (mean value) under the conditions in Prague. Despite the later flowering of tartary buckwheat accessions, maturity was almost equal in both species. In tartary buckwheat, three accessions 01Z5100014, 01Z5100017 and 01Z5100019 gave the earliest harvest at 101 d in 2005. Accession 01Z5100001 had the longest vegetative period at 148 d. In common buckwheat varieties with the minimum vegetative period ranged from 91 in common buckwheat varieties 01Z5000045, Kara-Dag and Siva in 2005 to 148 d reached by the variety Radouljica in 2006. In both common and tartary buckwheat, there were confirmed statistical significant differences in duration of vegetative period among evaluated years. Generally, the longest mean vegetative period was observed in the year 2006 in both species. The mean TSW of common buckwheat was nearly double (25.8 g) that of tartary buckwheat (14.1 g). The TSW of tartary buckwheat was a stable characteristic throughout the years evaluated. The maximum TSW was in a Japanese variety Arihira Zairai (37.2 g). ANOVA and Tukey's tests showed that the TSW was significantly influenced by variety and year in common buckwheat. In tartary buckwheat, there were no significant statistical differences among varieties or years.

Tartary buckwheat varieties reached a greater plant height (97.8 cm) than common buckwheat (90.8 cm) despite the same duration of vegetative growth. Common buckwheat accession 01Z5000043, from Zimbabwe, was the shortest (52 cm) in 2006. There were no statistical significant differences among varieties, only among years in plant height.

A higher number of inflorescences were noted on common buckwheat (29) with a range from 5 to 81 inflorescences. The highest number of inflorescences on tartary buckwheat was 33. The number of inflorescences varied from among years.

Morphological features of common buckwheat (percentages) are shown in Table 3. Most genotypes had reddish-green stems (80%), cordate leaves (82%), white flowers (87%), and grey and ovate achenes (44% and 57% respectively).

Based on the results of the field evaluation, similarity/dissimilarity dendrograms were created using Euclidean

Table 2. Means, standard deviations and range of value of phonological traits used for common and tartary buckwheat accessions

	Common buckwheat			Tartary buckwheat		
	Mean ± SE	**Range**	**CV**	**Mean ± SE**	**Range**	**CV**
Days from sowing to emergence	16.16 ± 0.49	8.00 - 35.00	46	14.64 ± 0.73	9.00 - 25.00	34
Days from emergence to flowering	29.58 ± 5.01	9.00 - 51.00	16	45.62 ± 0.55	40.00 - 53.00	8
Days from emergence to ripeness	123.54 ± 12.93	91.00 - 148.00	10	121.60 ± 2.31	101.00 - 148.00	13
1000-seed weight (g)	25.78 ± 4.61	13.85 - 37.19	17	14.07 ± 0.34	8.10 - 20.01	17
Plant height (cm)	90.78 ± 14.56	52.00 - 123.00	16	97.76 ± 2.31	63.00 - 128.00	16
Number of inflorescences	29.06 ± 13.45	5.00 - 81.00	46	15.58 ± 0.94	6.00 - 33.00	40

SE: standar error. CV: coefficient of variance.

Table 3. Frequency of morphological features according to IPGRI (1994) buckwheat descriptors for 77 common buckwheat genotypes

Descriptors	Features	Common buckwheat
Stem colour	1-green-red, 3-green, 5-pink, 7-red	80:15:1:4
Leaf colour	1-pale green, 3-green, 5-pink, 7-red	0:99:0:1
Leaf taste	3-bitter, 5-sour, 7-sweet	0:10:39:51
Leaf blade shape	1-ovate, 2 - hastate, 3-sagittate, 4-cordate, 5-other	0:4:14:82:0
Compactness of inflorescence	3-cyme loose, 5-cyme semi-compact, 7-cyme compact	31:68:1
Flower colour	1-white, 3-greenish yellow, 7-pink, 9-red	87:1:11:1
Seed colour	3-grey, 5-brown, 7-black, 9-mottled	39:44:13:4
Seed shape	1-triangular, 2-ovate, 3-conodial, 4-other	29:57:14:0

distance to generate a UPGMA dendrogram showing relatedness among common buckwheat and tartary buckwheat accessions. In common buckwheat, five major clusters were found (Fig. 2). The broadest cluster (Cluster A) was mainly represented by accessions with the following origins –10 from the former Soviet Union, 6 of unknown origin, 3 from Ukraine and Russia, 1 each Slovakia and Poland. The relationship within these accessions was high (on the level 50-82%) and their places of origin were very close geographically. Cluster B was represented by individual accessions of common buckwheat with high-observed diversity in morphological characteristics and had very low similarity level. The following two clusters, clusters C and D,

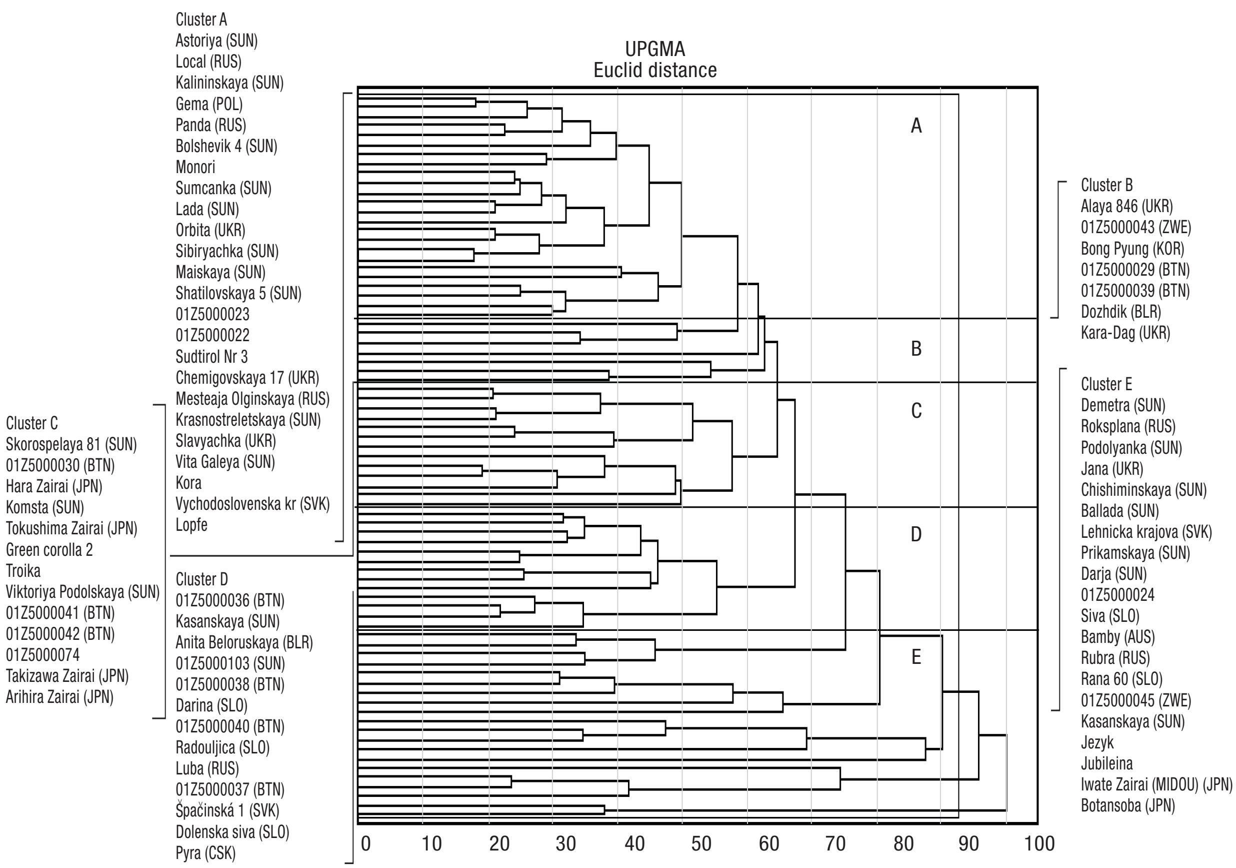

Figure 2. Dendrogram for 77 common buckwheat varieties produced by cluster analysis based on morphological and phenological traits.

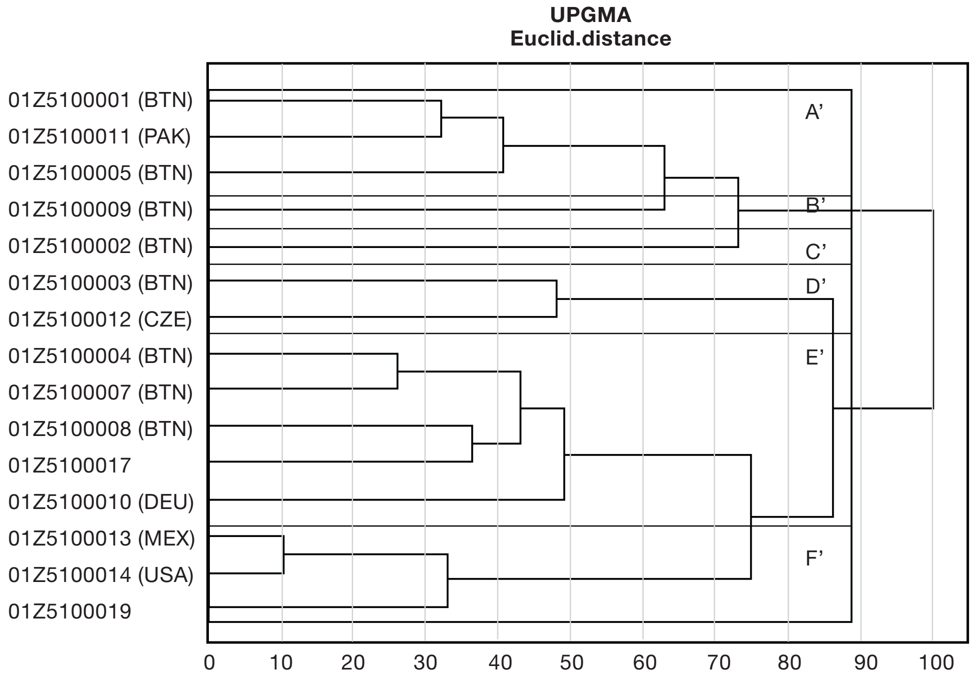

Figure 3. Dendrogram for 15 tartary buckwheat varieties produced by cluster analysis based on morphological and phenological traits.

included 13 accessions with very similar levels of diversity. There were 4 Japanese accessions, 3 accessions from Bhutan, 3 from the former Soviet Union and 3 of unknown origin in cluster C. All these accessions had an identical seed shape and a mean growth period of 126-131 d, as well as the number of days from sowing to emergence. Finally, Cluster D was represented by accessions with different geographical origins; but they had the most stable TSW (20-25 g) among the accessions in the locality of Prague. The second broadest cluster of the dendrogram, E, included 20 accessions. The dendrogram showed high diversity in the morphological and phenological characteristics evaluated. Cluster E mainly generated individual accessions.

The tartary buckwheat dendrogram, based on mean values, clustered the accessions into six clusters. Among the accessions there was no 100% identity observed in morphological and phenological characteristics. A Mexican (01Z5100013) and American (01Z5100014) accession showed the closest similarity (Fig. 3). These two accessions with 01Z5100019, of unknown origin, were cluster F. Accessions in this cluster were characterized by early maturing cultivars (112-113 d) with black, oval shaped achenes. Two accessions from Bhutan (01Z5100001and 01Z5100005) and one from Pakistan (01Z5100011) were cluster A'. They had the following uniform features: growth duration (127 d) and brown, cone-shaped seed. Cluster B and cluster C were represented by single accessions 01Z5100009 and 01Z5100002 respectively, from Bhutan. Accession 01Z5100009 had the shortest period from sowing to emergence and plants were short. On the other hand, 01Z5100002 had one of the longest periods from sowing to emergence and from emergence to flowering. Cluster D consisted of two accessions with very different origins 01Z5100012 and 01Z5100003. They had a similar mean TSW (13.6 g and 13.9 g) and emerged at an identical time (15 d). They were uniform in seed colour and shape. Three Bhutanese accessions, one of unknown origin (01Z5100017) and one from Germany (01Z51000013) gave the broadest cluster E. There were characterised by a range in plant height (103.7 to 107.0 cm), a similar TSW and identical seed shape. The highest mean plant height (116.3 cm) was in 01Z5100010, from Germany.

Figure 4 shows the common and tartary buckwheat accessions grouped according to important traits for plant breeders such as days from sowing to emergence, days from emergence to flowering, days from emergence to maturity, TSW, plant height and inflorescences per plant. The buckwheat collection assessed has important characteristics with regard to the extent of the growth period and provide a good source of genotypes for breeding. The identification of a principal

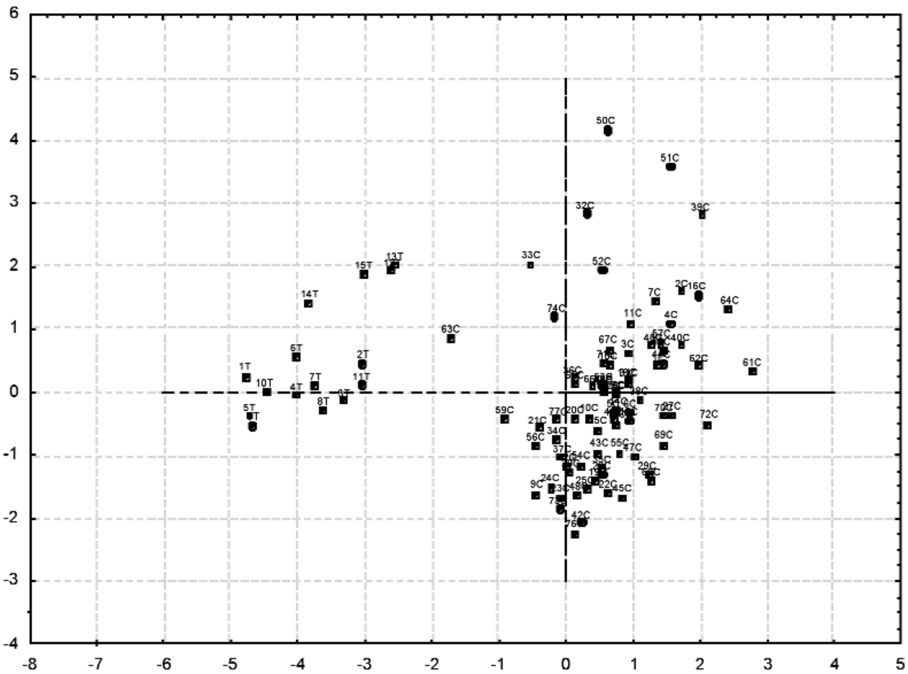

Figure 4. Relationship among tartary (T) and common (C) buckwheat accessions (for legend see Table 1) shown by PCA based on selected traits (stem colour, leaf blade colour, leaf taste, leaf blade shape, compactness of inflorescence, flower colour, number of inflorescences, days from sowing to emergence, days from emergence to flowering, days from emergence to maturity, plant height, seed colour, seed shape, and 1,000-seed weight).

component was based on correlations among different characters. From the correlation matrix, some characters showed important correlations *e.g.* days from sowing to emergence was moderately, positively, correlated (r = 0.35) with the number of inflorescences, days from emergence to maturity was also moderately positively correlated (r = 0.34) with the number of inflorescences. There was a positive correlation between TSW and days from sowing to emergence (r = 0.21). However, days from sowing to emergence was negatively correlated with days from emergence to flowering (r = –0.49).

Discussion

The time from emergence to flowering of the buckwheat accessions tested (means 2004-2006) was generally shorter than values for 1995-1997 when 20 varieties were assessed by Michalová e*t al*. (1998). For instance, days to flowering of Pyra with a mean value in 2004-2006 of 29 d in 1995-1997 took 41 d. Flowering starts earlier at higher temperatures (Michiyama *et al*., 2001). Michalová (1998) identified the optimal temperature for flowering in the Czech Republic as 18°C. In the locality of Prague, in 2004-2006, it was often at the optimal temperature or higher, apart from August 2006. This may explain the earlier flowering of accessions in our experiment. On the other hand, the tartary buckwheat genotypes responded to the Czech conditions late flowering (44.1-46.9 d). Halbrecq *et al*. (2005) reported that flowering started sooner in earlier sown plants than in later sown ones. Early sowing thus resulted in better crop performance, earlier maturity, a higher number of brown seeds but relatively high seed abortion. This, however, only applied when plants were sown from the end of May and later.

There was no significant correlation between varieties and the number of inflorescences. There is a high influence of the year characteristics, especially the weather (Kalinová, 2002). The best plant performance was in 2006. In that year, there was a relatively warm rainy June, which presumably had a positive effect on inflorescence production (Michalová, 1998). The number of inflorescences was therefore affected by the weather during vegetative growth. Adhikari (1997) noted a high positive correlation between the number of branches and the number of inflorescences per plant.

However, contrary to his conclusion, branching in 2006 was less than in the previous years.

Michiyama *et al.* (2001) observed that flowering was prolonged at higher temperatures enabling the development of more flower clusters. Campbell (1997) reported that buckwheat wilts badly and grows very slowly when affected by low soil moisture. If moisture is received, plants will often start to regrow but their maturity is delayed.

Buckwheat ripening was closely associated with flowering habit; the speed of seed ripening. The time of initiation of seed shattering appear to be independent and varied among years (Funatsuki *et al.*, 2000; Michiyama *et al.*, 2001).

Michalová (1998) stated that interpretation of the influence of agrometeorological factors on buckwheat yield is complicated due to its low tolerance to temperature limits, its sensitivity to drought and excess rainfall, autoincompatibility and dependence on pollinators. This may explain why the latest ripening was in 2006. The crop was harvested at the beginning of October, 135 d after emergence in the case of common buckwheat and 138 d in tartary buckwheat due to low temperatures and excess rain in August. However, Michalová (1998), and Komenda Ronka *et al*. (1991), identified Japanese common buckwheat varieties as a group with long growth period requiring 135-145 d to maturity. In 2004-2006, the Japanese varieties matured earlier (114-127 d), like former Soviet varieties (Komenda Ronka *et al*., 1991). The Bhutanese varieties formed a late maturing group (127-129 d), though they were not a distinct group from other varieties. Fluctuation in the time to maturity at the CRI in 2004-2006 was not as dramatic (104-131 d) as in other location, for instance in India, the range was 67-161 d (Rana, 2004) and in Poland 90-150 d (Komenda Ronka *et al*., 1991).

The TSW is affected by variety and is higher in tetraploid varieties (Michalová, 1998; Kalinová, 2002; Moudrý *et al*., 2005). Komenda Ronka *et al*. (1991) identified the range of TSW for diploid varieties as 15.1-25.2 g. It was 28.1-33.5 g in tetraploids. Varietal performance may be affected by year and location, as Michalová (1998) recorded several diploid varieties exceeded 30 g. For instance, Sumcanka had a TSW 32.5 g in 1995-1997 (Michalová, 1998) whilst it was only 25.4 g in our experiment in 2004-2006.

The height of buckwheat varieties is unpredictable, and presumably depends on environmental conditions rather than variety. Hagiwara *et al*. (2002) assessed the effect of water stress on main stem length and found a correlation. The stem was shortest when buckwheat was treated with water every other day suggesting water stress has a negative effect plant height. However, the stem was always longest under natural conditions compared to irrigation. Joshi (1999) suggested a correlation between plant height and leaf width. Honda *et al*. (2003) observed that plant height was mostly affected by upper node elongation and distinguished plant size according to place of origin. For instance, Japanese and Nepali varieties were classified as large, whilst Chinese, Polish and Slovenian varieties were classified as small. The experiment at CRI in 2004-2006 indicated that Japanese varieties were characterised by a steady mean performance (about 90 cm) while Slovenian varieties are very variable: on average Dolenjska Siva was the tallest variety of all the assessed ones (108 cm) but Darja was the shortest (69.3 cm).

Flower colour is usually white in European, North American and Japanese buckwheat genotypes but is usually pink in South East Asian and southern Chinese varieties (Campbell, 1997); this fact was not confirmed in this common buckwheat collection. Only some accessions from Bhutan had pink flowers. Rout and Chrungoo (2007) reported the existence of pink flowers in some *F. esculentum* accessions. As described by Ohnishi (1990), the mostly commonly occurring stem colours were yellow, green to pink red and brown. The green leaves are generally described as triangular to ovate triangular at the base cordate or hastate.

In this study, principal components analysis (PCA) was used to identify patterns in the data set. This type of analysis essentially restructures data sets containing many correlated variables into smaller sets of components of the original variables (Iezzoni and Pritts, 1991). The PC analysis gave a classification of buckwheat accessions applicable for breeding. The dendrogram and PCA graph confirmed the high variability in a common buckwheat population based on morphological and phenological data. Some studies based on DNA fingerprinting (Rout and Chrungoo, 2007) and variability of protein subunits (Li *et al*., 2008) demonstrated very similar results in the case of common buckwheat. On the other hand, in this study there were no identical accessions of common buckwheat detected contrary to those, described by Rout and Chrungoo (2007). The variability of the tartary buckwheat accessions shown in the dendrogram is lower than in common buckwheat. This is supported by some studies based on using molecular markers (Tsuji and Ohnishi, 2001) who concluded that genetic variability among landraces and cultivated tartary buckwheat was low which may suggest that cultivated tartary buckwheat has developed recently over a short period.

In conclusion the performance of buckwheat varieties, particularly, their developmental stages depended highly on the annual weather conditions. Only days to flowering seemed to be affected by variety. The results confirm that several genotypes, domesticated under similar conditions, showed a narrow range of values for the traits investigated. Because this evaluation was made according to IPGRI buckwheat descriptors, the characteristics are compatible with data in other gene banks. Detailed nutritional analyses of (*e.g.* starch, lipid, proteins etc.) of common buckwheat are being conducted to gain better knowledge of the potential use of this collection.

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