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Front page photo: Buckwheat variety Bashkirskaya Krasnostebelna (See paper of Chuiko et al., page 44).

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Research paper

Differentiation of buckwheat cultivars (*Fagopyrum esculentum* Moench) by yield structure elements and productivity under the conditions of the Forest-Steppe of Ukraine

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ABSTRACT

The results of a three-year research (2023–2025) of 31 common buckwheat varieties (*Fagopyrum esculentum* Moench) of different ecological and geographical origins under the conditions of the Eastern Forest-Steppe of Ukraine are presented. The peculiarities of the formation of plant height, number of leaves and inflorescences, plant productivity, thousand-kernel weight, number of kernels per plant, and kernel set were investigated. The determining role of growth type in shaping plant architecture and productivity was established.

It was found that productivity is formed mainly due to the number of kernels per plant and kernel set ($r = 0.95$), whereas thousand-kernel weight is a relatively stable trait ($V = 7.5\%$). According to the results of k-means clustering, a group of intensive-type varieties was identified, characterized by the highest average values within the cluster for plant productivity (2.4 g), number of kernels (85.7 pcs.), thousand-kernel weight (27.9 g), and kernel set (3.8).

The varieties 'Pidmoskovna T', 'M NF-84B', 'Mariia', 'Sumchanka', 'Roksolana', 'Krupynka', 'Selianochka', and 'Simka' were identified as promising sources of valuable traits for further breeding aimed at improving productivity and thousand-kernel weight.

INTRODUCTION

Effective common buckwheat (*Fagopyrum esculentum* Moench) breeding requires the availability of broad genetic diversity preserved in buckwheat germplasm collections worldwide. Global buckwheat germplasm has demonstrated considerable variation in morphological and agronomic traits (Janovská et al., 2021; Rauf et al., 2020; Ghiselli et al., 2016). This diversity represents a fundamental resource for breeding programs, as genetic variability is the primary driver of selection and evolution and serves as the genetic basis for breeders (Dutta et al., 2025; Bhandari et al., 2017).

A detailed study of the morphological and genetic diversity of germplasm is indispensable for identifying genomic regions controlling important agronomic traits and for detecting valuable genetic accessions carrying favorable alleles that can be used in marker-assisted breeding programs (Pipan et al., 2023). Buckwheat varieties that have undergone production testing and have been cultivated in different countries are of particular value as breeding material, since their performance can serve as a reliable basis for comparative evaluation.

Significant progress in global buckwheat breeding practice has been achieved in addressing key agronomic problems through conventional breeding methods. Improvement of individual traits occurs gradually, and in Japan, varieties resistant to lodging such as 'Tachiakane' and 'Nijiyutaka', as well as a variety resistant to pre-harvest sprouting, 'Harunoyuki', have been developed (Ohsawa, 2020). Modern breeding efforts have also demonstrated success in developing regionally adapted, high-yielding varieties for Ukraine's conditions, including 'Oranta', 'Ruslan', and 'Volia' (Shakalii et al., 2023). These achievements of classical breeding illustrate effective solutions to fundamental production constraints that previously limited buckwheat acreage and yield.

Despite achievements in buckwheat breeding, several significant challenges remain in developing modern varieties. The main issues include insufficient understanding of the inheritance patterns of most economically valuable traits related to yield and the synthesis of biologically active compounds, low seed productivity, seed shattering, uneven flowering, and limited knowledge of gene functioning. Prospects for further breeding include reducing polyphenol content through selection and developing varieties with improved processing and storage characteristics. In general, breeding efforts aim to improve buckwheat's agronomic traits through conventional breeding combined with biotechnological methods (Luthar et al., 2021; Chuiko & Tryhub, 2025; Suzuki et al., 2020).

Thus, the main objective of our study was to evaluate a collection of diploid common buckwheat varieties (*F. esculentum* Moench) of different ecological and geographical origins obtained from the Plant Genetic Resources Bank of Ukraine for the expression of key agronomically valuable traits under the conditions of the Eastern Forest-Steppe of Ukraine.

MATERIAL AND METHODS

Field and laboratory studies of a collection of diploid common buckwheat varieties (*F. esculentum* Moench) were conducted during 2023–2025 at the experimental field of the Department of Genetics, Breeding and Seed Production of the State Biotechnological University. The experimental fields are located in the central part of Kharkiv region (Dokuchaievske settlement, Ukraine) at the boundary of the Forest-Steppe and Steppe natural-climatic zones (geographical coordinates: 49.902144, 36.446238).

The experimental plots were established according to standard breeding methodologies within a breeding crop rotation. The predecessor was bare fallow. Sowing was

Figure 1. *Buckwheat variety Bashkirskaya Krasnostebelny (UC0102179).*

Table 1. *Characteristics of the studied common buckwheat varieties (F. esculentum Moench.).*

№	National Catalogue ID	Region and country of origin	Variety name	Growth type*
1	UC0100246	Primorsky Kray (RU)	Prymorska 5	Indet.
2	UC0100261	Primorsky Kray (RU)	Mariia	Indet.
3	UC0100989	Minsk Region (BY)	Biloruska Skorostyhla	Indet.
4	UC0101130	Oryol Oblast (RU)	Kozachka	Indet.
5	UC0100991	Minsk Region (BY)	Biloruska Odnostebelna	Indet.
6	UC0101006	Oryol Oblast (RU)	Krupynka	Det.
7	UC0101083	Poltavska Oblast (UA)	Pidmoskovna T	Indet.
8	UC0100352	Khmelnytskyi Oblast (UA)	M NF-84B	Indet.
9	UC0100362	Minsk Region (BY)	Biloruska Homostylna	Indet.
10	UC0100365	Minsk Region (BY)	Chornohlazka	Indet.
11	UC0100367	Minsk Region (BY)	Zhniarka	Indet.
12	UC0100501	Sumska Oblast (UA)	Yampolska Mistseva	Indet.
13	UC0101981	Sumska Oblast (UA)	Yuvileina 100	Det.
14	UC0101987	Minsk Region (BY)	Karmen	Det.
15	UC0100942	Khmelnytskyi Oblast (UA)	Exida	Indet.
16	UC0101189	Minsk Region (BY)	Anita Biloruska	Indet.
17	UC0101200	Khmelnytskyi Oblast (UA)	Viktoriia Podilska	Indet.
18	UC0101198	Khmelnytskyi Oblast (UA)	Roksolana	Indet.
19	UC0101190	Minsk Region (BY)	Zhaleika	Indet.
20	UC0101197	Minsk Region (BY)	Smuhlianka	Det.
21	UC0101977	Japan (JP)	Ketavase	Indet.
22	UC0102165	Minsk Region (BY)	Kvietka Determinantna	Det.
23	UC0102166	Minsk Region (BY)	Charovnitsa	Indet.
24	UC0102186	Sumska Oblast (UA)	Sumchanka	Det.
25	UC0102179	Republic of Bashkortostan (RU)	Bashkyrska Krasnostebelna	Indet.
26	UC0102193	Minsk Region (BY)	Vlada	Det.
27	UC0102203	Minsk Region (BY)	Amethyst	Indet.
28	UC0102204	Minsk Region (BY)	Lakneia	Det.
29	UC0100206	Sumska Oblast (UA)	Selianochka	Indet.
30	UKR008:01705	Sumska Oblast (UA)	Simka	Indet.
31	UC0102228	Sumska Oblast (UA)	Oksana	Indet.

– Growth type:* ***Indeterminate type* *– Indet.;* ***Determinate type*** *– Det.*

carried out in the second decade of May. Each variety was grown in four replications. The seeding rate was 80 viable seeds per linear meter with row spacing of 45 cm. The arrangement of replications was systematic (Ermantraut et al., 2014). No additional fertilization or herbicide application was performed. According to the FAO soil classification, the soil of the experimental field is defined as Calcic Voronic Chernozem CL UE1 (Jahn et al., 2006).

The research material consisted of 31 varieties obtained from the Ustymivka Experimental Station of Plant Production of the V.Ya. Yuryev Institute of Plant Production of NAAS of Ukraine. The collection includes buckwheat varieties of different ecological and geographical origins. A detailed description of the studied common buckwheat accessions is presented in Table 1 (Fig. 1).

Observations and measurements in the experimental plots were carried out in accordance with the "Methodological guidelines for studying collection accessions of maize, sorghum, and cereal crops (millet, buckwheat, rice)" (Shmaryayev et al., 1968) and the "Methodology of state variety testing of agricultural crops (cereals, pseudocereals, and legumes)" (Volkodav, 2001).

Morphological and productivity traits were evaluated on 20 representative plants in each replication. Plant height was measured from the soil surface to the plant apex. The number of leaves and inflorescences per plant was determined by direct counting. Plant productivity was assessed through manual threshing followed by weighing, and the mean value was calculated for each replication. The seed set index was determined as the ratio of the average number of seeds per plant to the average number of inflorescences per plant within a replication.

In 2023, temperature conditions during the buckwheat growing season were close to the long-term average. In May and June, a slight decrease in temperature was observed (–0.2 and –0.4 °C, respectively), whereas in July, August, and September, temperatures exceeded the norm by 0.8, 2.7, and 2.3 °C, respectively.

In 2024, warmer conditions prevailed throughout the growing season. May was slightly cooler (–0.8 °C), but from June to September, a significant excess over the long-term averages was recorded: +2.6 °C in June, +4.5 °C in July, +2.9 °C in August, and +5.3 °C in September.

The temperature regime in 2025 was moderate, close to the long-term average. In May and June, temperatures were below the norm by 0.9 and 0.6 °C, in July they exceeded it by 3.0 °C, in August they were close to the norm (–0.3 °C), and in September they were higher by 1.3 °C.

In 2023, the distribution of precipitation during the buckwheat growing season was contrasting: moisture deficit in May and June (–13.0 and –17.3 mm from the norm) was followed by excessive rainfall in July, when 153.8 mm of precipitation fell, which was 2.5 times higher than the long-term average. In August and September, a precipitation deficit was again observed (–13.2 and –18.5 mm).

In 2024, a pronounced drought occurred: only 92.1 mm of precipitation fell during the growing season, which is about one-third of the norm. All months were characterized by a significant moisture deficit, with July being the most critical (–47.0 mm), and no precipitation was recorded in September.

In 2025, moisture conditions were better than in 2024 and generally close to the norm. In May, July, and August, precipitation exceeded the long-term averages by 21.8, 12.8, and 9.9 mm, respectively, while in June and September a deficit was observed (–29.4 and –21.8 mm). Overall, during the growing season, total precipitation was 6.7 mm below the long-term average.

Statistical data processing was performed using PAST 5.3 software (Hammer & Harper, 2001). To characterize the studied varieties, cluster analysis with Euclidean distances (k-means clustering) was applied. The relationships between traits were evaluated using Pearson's linear correlation.

To normalize the values for cluster analysis, the Z-score standardization method (standardization by mean and standard deviation) was applied according to the formula (Cheadle et al., 2003):

$$z = \frac{x - \mu}{\sigma}$$

where:

z — standardized (normalized) value;

x — original value;

μ — arithmetic mean of the trait;

σ — standard deviation of the trait.

RESULTS AND DISCUSSION

Plant height is an important technological and breeding trait in buckwheat. This trait can vary considerably across plant genotypes. The main factors influencing plant height are growth type (determinate or indeterminate) and the length of the growing period, which may be associated with the genotype's ecological and geographical origin.

According to our field studies conducted in 2023–2025, growth type (determinate or indeterminate) was the primary factor determining plant height in the studied buckwheat varieties. The greatest plant height was observed in indeterminate varieties such as 'Ketavase' – 114.3 ± 14.0 cm, 'M NF-84B' – 104.9 ± 11.1 cm, 'Mariia' – 102.6 ± 18.2 cm, 'Viktoriia Podilska' – 102.1 ± 8.7 cm, and 'Roksolana' – 102.1 ± 2.2 cm.

Conversely, the lowest plant height over the years of study was recorded in determinate varieties, for example 'Vlada' – 74.7 ± 3.8 cm, 'Lakneia' – 78.7 ± 9.6 cm, and 'Krupynka' – 83.3 ± 13.4 cm (Figure 2). Similar patterns in plant height distribution have been reported by other authors under different climatic conditions (Amelin et al., 2020; Kharchenko & Tryhub, 2018; Kasajima et al., 2016).

Buckwheat productivity is influenced by numerous interrelated plant characteristics that affect both photosynthetic capacity and seed yield. The leaf system serves as the main photosynthetic apparatus, converting solar energy into resources that support growth and seed for-

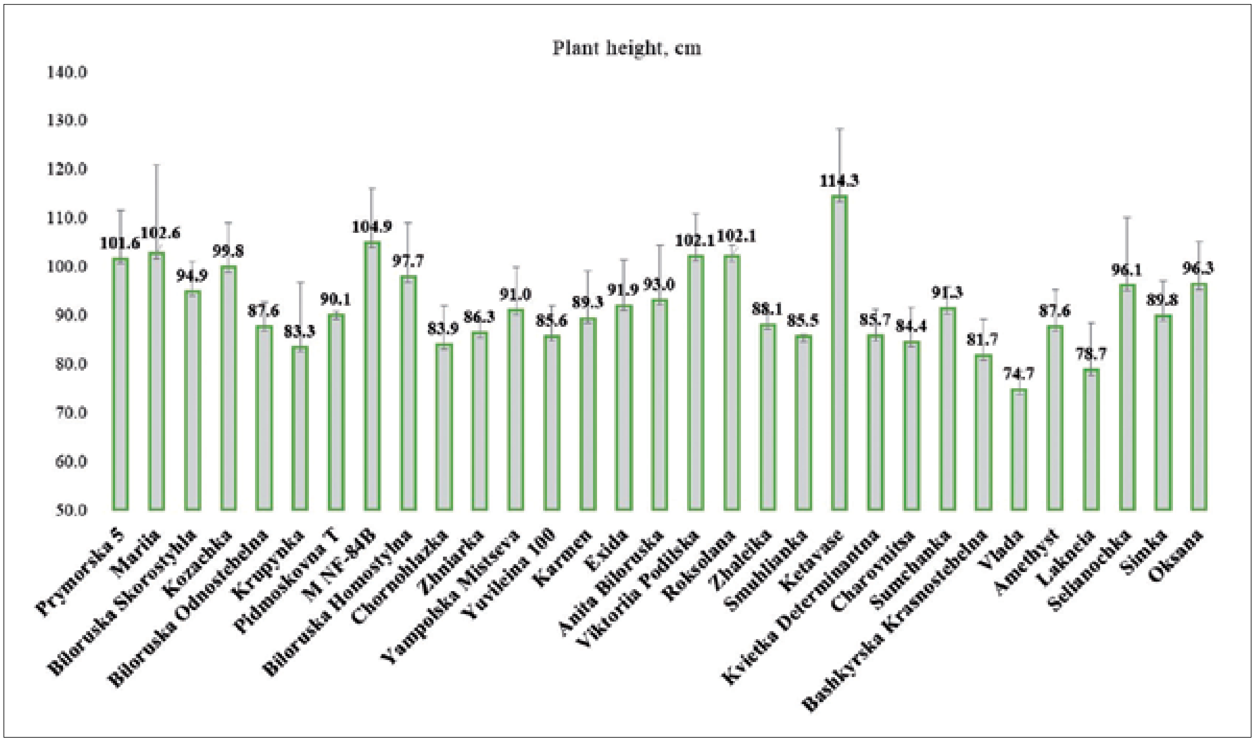

Figure 2. *Formation of height traits in buckwheat varieties, average for the years of study.*

mation. Buckwheat exhibits an indeterminate growth pattern, continuously forming both leaves and flowers during most of the growing season, which makes the balance between vegetative and reproductive structures particularly important for optimizing overall plant productivity. In general, the ratio of the number of leaves to the number of inflorescences in buckwheat (*F. esculentum* Moench) is approximately 1:1 (Alekseyeva et al., 2004). The main problem is the insufficient supply of photosynthetic surface to support a large number of inflorescences, which leads to excessive abortion of seed ovaries at early stages of development.

According to our results, the number of leaves and the number of inflorescences per plant varied considerably depending on the year of cultivation. The highest average values over the years were observed in the varieties 'Prymorska 5', 'Mariia', 'Biloruska Skorostyhla', 'Kozachka', and 'Biloruska Homostylna', ranging from 41.1 to 48.5 leaves and from 30.1 to 35.9 inflorescences per plant, respectively.

At the same time, low-growing varieties such as 'Bashkyrska Krasnostebelna', 'Vlada', 'Amethyst', 'Lakneia', and 'Selianochka' proved to be the most efficient in terms of plant architecture and leaf support of inflorescences, with average values of 24.8–31.2 leaves and 14.6–20.6 inflorescences per plant, respectively. Thus, these varieties exhibited the highest leaf-to-inflorescence ratio, ranging from 1.5 to 1.7 leaves per inflorescence. In other studies, a reduction in the number of inflorescences combined with an increase in leaf number has been shown to enhance plant productivity and overall buckwheat yield (Hornyák et al., 2020). In the other studied varieties, the leaf supply per inflorescence ranged from 1.2 to 1.5 (Fig. 3).

The generalized results of the field experiments indicate substantial genotypic variability among the studied buckwheat cultivars. The mean productivity per plant was 1.7 g, ranging from 1.1 to 3.2 g; thousand-kernel weight averaged 27.0 g (23.1–31.5 g); the number of kernels per plant was 63.5 (43.4–112.7); and the seed set index was 3.0 (1.4–4.7). The coefficient of variation was highest for productivity per plant (26.2%), number of kernels per plant (24.1%), and seed set index (27.1%), indicating a high sensitivity of these traits to genotype and growing conditions, whereas thousand-kernel weight was relatively stable (V = 7.5%).

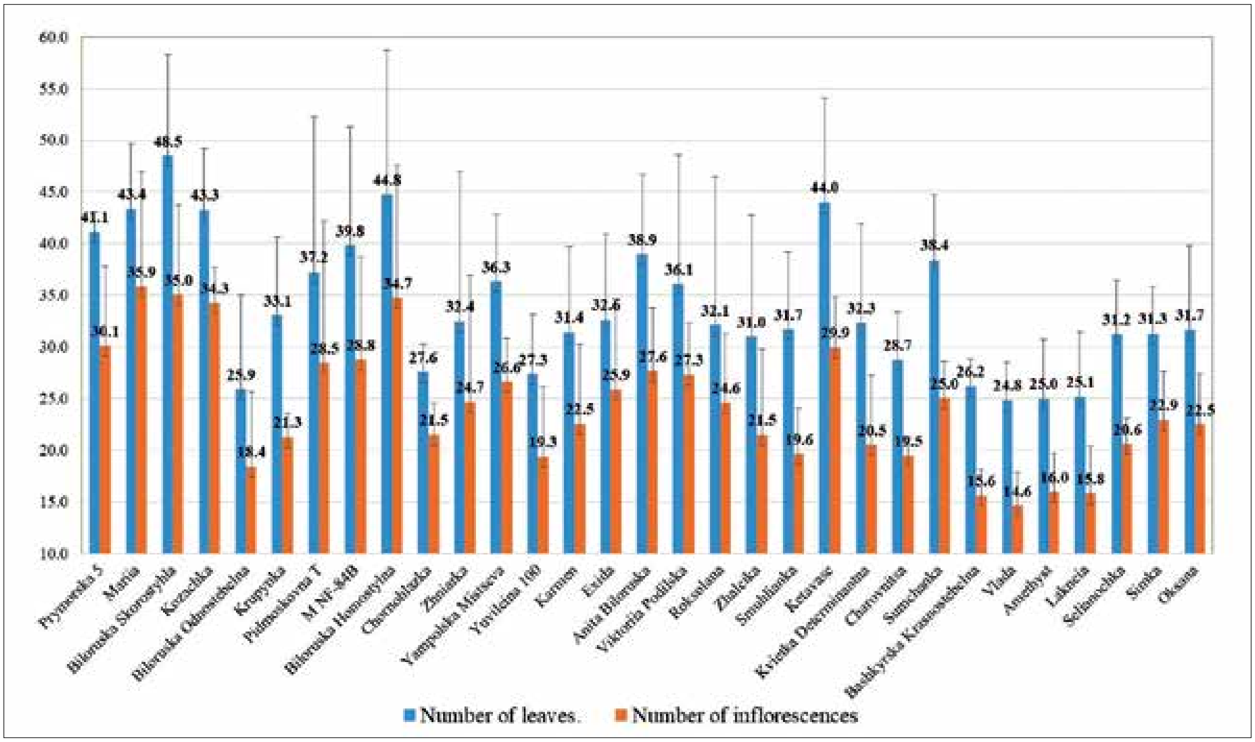

Figure 3. *Characteristics of leaf and inflorescence formation in buckwheat varieties, multi-year average.*

The highest productivity per plant was recorded for the cultivar 'Pidmoskovna T' (3.2 ± 1.9 g), which was accompanied by the maximum number of kernels per plant (112.7 ± 56.2) and the highest seed set index (4.7 ± 2.1). High values of productivity and kernel number were also observed in the cultivars 'M NF-84B' (2.6 ± 0.6 g; 82.7 ± 12.3 kernels), 'Mariia' (2.3 ± 0.7 g; 80.5 ± 21.4 kernels), and 'Sumchanka' (2.3 ± 1.1 g; 83.2 ± 39.7 kernels). These cultivars combine increased seed productivity with a relatively large number of formed kernels, indicating efficient realization of the generative potential of the plants.

Cultivars with the lowest productivity per plant — 'Exida' (1.1 ± 0.4 g), 'Ketavase' (1.2 ± 0.4 g), 'Biloruska Skorostyhla' (1.3 ± 0.3 g), and 'Biloruska Odnostebelna' (1.3 ± 0.5 g) — were also characterized by a comparatively lower number of kernels per plant (43.4–49.4), demonstrating a direct dependence of productivity on the quantitative parameters of generative organs and a very strong correlation between productivity per plant and kernel number (r = 0.95).

Thousand-kernel weight varied within a relatively narrow range; however, cultivars with larger kernels were clearly distinguished, including 'M NF-84B' (31.5 ± 2.5 g), 'Roksolana' (30.7 ± 1.8 g), 'Krupynka' and 'Selianochka' (29.6 g each), 'Simka' (29.3 ± 1.1 g), and 'Kozachka' (29.0 ± 2.8 g). In contrast, the lowest thousand-kernel weight was observed in 'Exida' (23.1 ± 0.5 g), 'Yampolska Mistseva' (24.2 ± 0.9 g), 'Bashkyrska Krasnostebelna', and 'Charovnitsa' (24.5 ± 1.0 g), which may limit their value for groat production but does not necessarily reduce overall productivity.

The seed set index, which reflects the ratio between the number of kernels and inflorescences, showed pronounced differentiation among the cultivars. The highest values were recorded for 'Pidmoskovna T' (4.7 ± 2.1), 'Vlada' (4.6 ± 2.1), 'Zhniarka' (4.1 ± 1.7), 'Lakneia' (3.9 ± 1.7), 'Bashkyrska Krasnostebelna' (3.9 ± 1.7), and 'Smuhlianka' (3.6 ± 1.4). This indicates a more efficient realization of fertilization potential and a lower level of ovary abortion. In contrast, the lowest seed set indices were observed in 'Biloruska Skorostyhla' (1.4 ± 0.3), 'Ketavase' (1.5 ± 0.6), and 'Kozachka' (1.5 ± 0.7), suggesting less efficient seed formation under a comparable number of inflorescences per plant.

Overall, the analysis of yield structure demonstrates that high productivity in buckwheat is primarily determined by an increase in the number of kernels per plant and a high level of seed set, whereas thousand-kernel weight plays a stabilizing but secondary role. The identified cultivars 'Pidmoskovna T', 'M NF-84B', 'Mariia', and 'Sumchanka' represent valuable sources of seed productivity traits, while 'M NF-84B', 'Roksolana', 'Krupynka', and 'Simka' are important sources of large seed size for further buckwheat breeding programs (Table 2).

Table 2. *Characteristics of buckwheat varieties by yield component traits, multi-year average.*

Cultivar	Productivity per plant, g., ±SD*	Thousand-kernel weight, g., ±SD	Number of kernels per plant, pcs., ± SD	Number of kernels per inflorescence, ± SD
Prymorska 5	1.7 ±0.4	26.7 ±2.8	63.5 ±14.0	2.1 ±0.1
Mariia	2.3 ±0.7	28.7 ±0.8	80.5 ±21.4	2.6 ±1.3
Biloruska Skorostyhla	1.3 ±0.3	27.2 ±2.3	46.8 ±7.1	1.4 ±0.3
Kozachka	1.4 ±0.7	29.0 ±2.8	47.3 ±17.8	1.5 ±0.7
Biloruska Odnostebelna	1.3 ±0.5	26.5 ±1.3	49.4 ±17.7	3.0 ±1.2
Krupynka	1.8 ±0.7	29.6 ±3.6	60.9 ±19.2	3.0 ±1.3
Pidmoskovna T	3.2 ±1.9	27.5 ±2.6	112.7 ±56.2	4.7 ±2.1
M NF-84B	2.6 ±0.6	31.5 ±2.5	82.7 ±12.3	3.2 ±0.8
Biloruska Homostylna	2.2 ±0.3	24.9 ±1.7	86.5 ±6.9	2.9 ±1.1
Chornohlazka	2.0 ±0.3	25.6 ±0.6	77.0 ±10.2	3.6 ±0.3
Zhniarka	2.1 ±0.4	25.7 ±0.6	80.2 ±14.4	4.1 ±1.7
Yampolska Mistseva	1.7 ±0.4	24.2 ±0.9	72.8 ±20.8	2.9 ±1.1
Yuvileina 100	1.5 ±0.3	27.4 ±2.1	54.1 ±8.4	3.2 ±1.2
Karmen	1.6 ±0.3	26.8 ±3.1	58.6 ±7.0	3.0 ±1.1
Exida	1.1 ±0.4	23.1 ±0.5	47.8 ±19.0	2.3 ±1.4
Anita Biloruska	1.8 ±0.4	25.5 ±1.5	69.2 ±14.4	2.5 ±0.2
Viktoriia Podilska	1.5 ±0.7	24.7 ±1.4	61.3 ±24.8	2.3 ±0.8
Roksolana	1.4 ±0.3	30.7 ±1.8	46.2 ±12.7	2.2 ±1.0
Zhaleika	1.3 ±0.2	24.9 ±0.8	50.5 ±7.9	2.7 ±1.2
Smuhlianka	1.7 ±0.5	26.7 ±1.1	64.9 ±13.8	3.6 ±1.4
Ketavase	1.2 ±0.4	26.8 ±2.2	43.4 ±9.7	1.5 ±0.6
Kvietka Determinantna	1.4 ±0.2	28.3 ±1.0	49.8 ±6.7	2.8 ±1.0
Charovnitsa	1.5 ±0.7	24.5 ±1.8	60.3 ±29.8	3.2 ±1.7
Sumchanka	2.3 ±1.1	27.0 ±0.7	83.2 ±39.7	3.4 ±1.6
Bashkyrska Krasnostebelna	1.4 ±0.5	24.5 ±1.0	57.7 ±18.9	3.9 ±1.7
Vlada	1.8 ±0.8	27.7 ±2.2	61.0 ±25.1	4.6 ±2.1
Amethyst	1.4 ±0.6	28.1 ±1.7	52.0 ±22.1	3.7 ±1.8
Lakneia	1.5 ±0.5	28.1 ±1.9	54.0 ±14.0	3.9 ±1.7
Selianochka	1.9 ±0.9	29.6 ±1.9	65.7 ±32.4	3.4 ±2.0
Simka	2.0 ±0.6	29.3 ±1.1	66.7 ±19.2	3.2 ±1.5
Oksana	1.6 ±0.8	25.8 ±2.4	62.1 ±29.8	3.2 ±1.9
Min	**1.1**	**23.1**	**43.4**	**1.4**
Max	**3.2**	**31.5**	**112.7**	**4.7**
Mean	**1.7**	**27.0**	**63.5**	**3.0**
Std. error	**0.1**	**0.4**	**2.8**	**0.1**
Stand. dev	**0.5**	**2.0**	**15.3**	**0.8**
Coeff. var	**26.2**	**7.5**	**24.1**	**27.1**
Variance	**0.2**	**4.1**	**234.6**	**0.7**

**±SD – Standard Deviation*

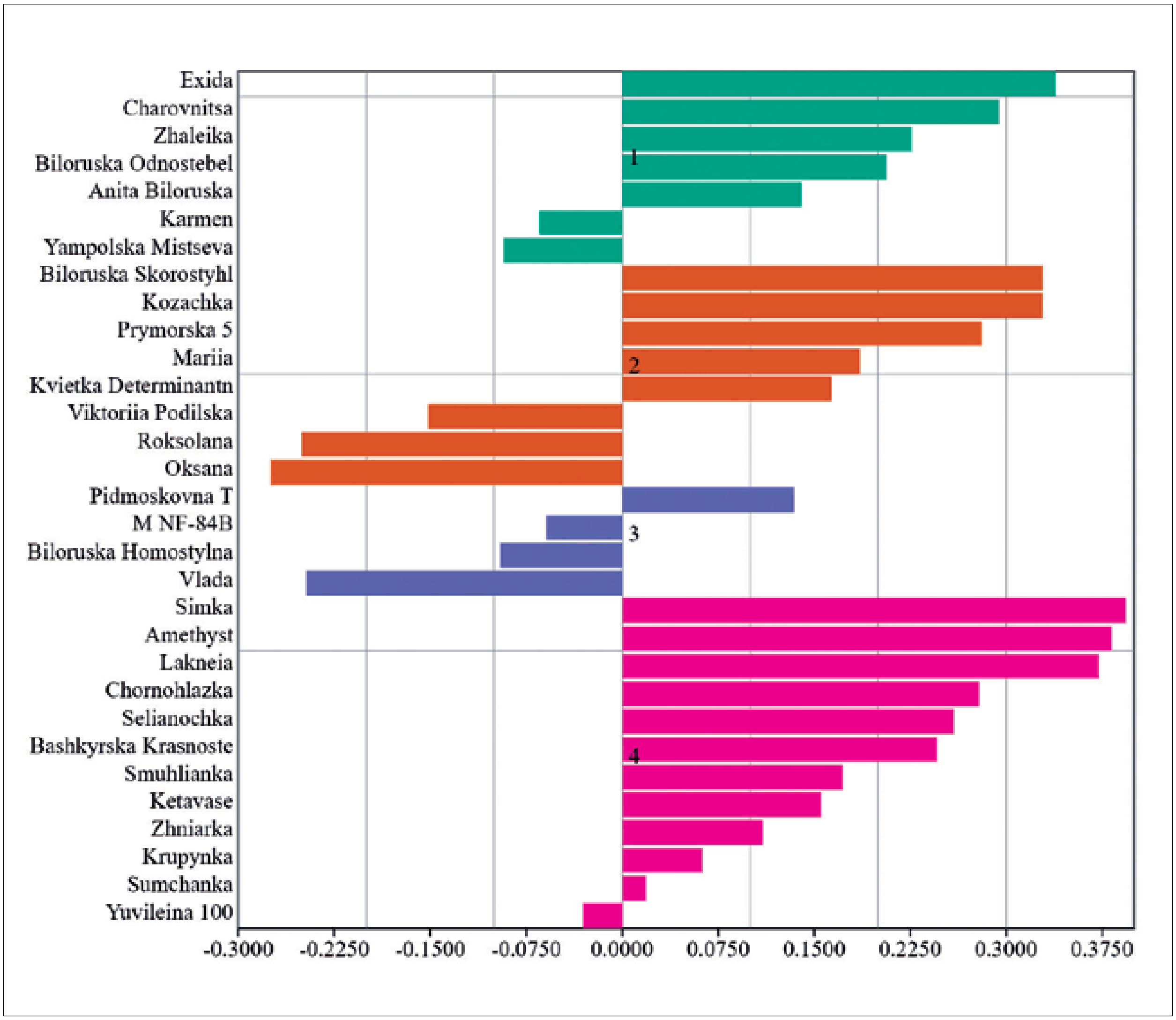

Figure 4. *Dendrogram of cluster analysis (k-means clustering).*

According to the obtained results, most of the studied buckwheat cultivars exhibit a high potential for productivity realization under the conditions of the Eastern Forest-Steppe of Ukraine, which is consistent with reports by other authors obtained in different climatic environments (Bisht et al., 2018; Kabanets et al., 2018; Amelin et al., 2020).

Clustering of the buckwheat cultivars was performed using the k-means method according to Ward's algorithm with Euclidean distance. Prior to the analysis, all traits were standardized using the z-score method. With the predefined number of clusters (k = 4), the following clustering structure was identified.

Cluster 1 includes buckwheat cultivars with intermediate morphological and productivity traits. Plants in cluster 1 are characterized by medium plant height (91.2 cm), a moderate number of leaves (31.5 per plant), and inflorescences (22.9 per plant). Productivity per plant is the lowest among all groups (1.4 g), and thousand-kernel weight is also minimal (25.9 g). The number of kernels per plant and the seed set index are at intermediate levels. This cluster represents cultivars with a baseline level of agronomically valuable traits.

Cluster 2 includes cultivars exhibiting the shortest plant height (89.4 cm) and the lowest number of inflorescences (21.6 per plant). Despite these characteristics,

Table 3. *Mean values of traits by cluster.*

Cluster	Plant height, cm.	Number of leaves, pcs.	Number of inflorescences, pcs.	Productivity per plant, g	Thousand-kernel weight, g	Number of kernels per plant, pcs.	Number of kernels per inflorescence
Cluster 1	91.2	31.5	22.9	1.4	25.9	53.9	2.7
Cluster 2	89.4	31.5	21.6	1.7	27.0	63.6	3.3
Cluster 3	91.9	36.7	26.6	2.4	27.9	85.7	3.8
Cluster 4	97.8	40.8	30.5	1.6	27.4	58.2	2.1

productivity per plant is slightly higher than in Cluster 1 (1.7 g per plant), while the seed set index (3.3) and the number of kernels per plant (63.6) substantially exceed those of the first cluster. This may indicate a compact plant habit with relatively efficient yield formation.

Cluster 3 is the most valuable in terms of the analyzed traits. Cultivars in this group are characterized by the highest productivity per plant (2.4 g), the greatest number of kernels per plant (85.7), the highest thousand-kernel weight (27.9 g), and the best seed set index (3.8). At the same time, plant height and the number of vegetative organs remain at intermediate levels. This cluster represents an intensive type of cultivars and is the most promising for breeding purposes.

Cluster 4 includes cultivars with the most pronounced vegetative development. Plants in this cluster are tall (97.8 cm) and have the maximum number of leaves (40.8 per plant) and inflorescences (30.5 per plant). However, strong vegetative growth does not correlate with high productivity per plant (1.6 g), which remains low, while the seed set index (2.1) is the lowest among the identified clusters (Fig. 4, Table 3) (Bisht et al., 2018; Ghiselli et al., 2016).

CONCLUSION

As a result of studying the buckwheat cultivar collection, significant genotypic variability was observed for a complex of morphological and agronomically valuable traits under conditions in the Eastern Forest-Steppe of Ukraine. This confirms the expediency of using collection material of diverse ecological and geographical origins in breeding programs.

It was demonstrated that the formation of high buckwheat productivity is primarily determined by the number of kernels per plant and the level of seed set, both of which show a very strong positive correlation with productivity (r = 0.95). Thousand-kernel weight is characterized by relative stability (V = 7.5%) and plays a stabilizing, rather than a determining, role in yield structure.

It was established that cultivars with a moderate number of inflorescences and better leaf surface supply per inflorescence (1.5–1.7 leaves per inflorescence) ensure more efficient realization of the generative potential of plants compared with tall forms exhibiting excessive vegetative development.

Based on the results of cluster analysis, a group of cultivars was identified that is characterized by maximum productivity per plant (2.4 g), the highest number of kernels per plant (85.7), high thousand-kernel weight (27.9 g), and a high seed set index (3.8). These cultivars are the most promising for breeding use. According to the study results, valuable sources of breeding traits include the cultivars ‘Pidmoskovna T’, ‘M NF-84B’, ‘Mariia’, ‘Sumchanka’, ‘Roksolana’, ‘Krupynka’, ‘Selianochka’, and ‘Simka’.

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IZVLEČEK

Diferenciacija sort ajde (*Fagopyrum esculentum* Moench) glede na njihovo produktivnosti v gozdno-stepnem območju Ukrajine

Predstavljeni so rezultati triletne raziskave (2023–2025) 31 sort ajde (*Fagopyrum esculentum* Moench) različnih ekoloških in geografski virov v Vzhodni gozdno-stepni Ukrajini. Avtorji so preučevali višino rastlin, število listov in socvetij, produktivnost rastlin, maso tisoč semen, število semen na rastlino in nastavitev semen. Ugotovljen je bil odločilen vpliv tipa rasti pri oblikovanju arhitekture rastlin in produktivnosti.

Ugotovljeno je bilo, da je produktivnost odvisna predvsem od števila semen na rastlino in nastavitve semen (r = 0.95). Masa tisočih semen je relativno stabilna lastnost (V = 7.5 %).

Sorte 'Pidmoskovna T', 'M NF-84B', 'Mariia', 'Sumchanka', 'Roksolana', 'Krupynka', 'Selianochka' in 'Simka' so bile prepoznane kot obetavni viri pomembnih lastnosti za nadaljnje križanje z namenom izboljšanja produktivnosti in teže tisoč zrn.

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Short communication

A Slovenian Water-driven Device for Hulling Buckwheat "Stope" is in the Process of Being Registered as Cultural Heritage.

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ABSTRACT

A traditional Slovenian water-powered device for hulling buckwheat grain and producing groats is described. According to the traditional Slovenian process mentioned in literature as early as the year 1689, buckwheat grains were quickly boiled in water, drained, and partially dried. This way, the dry husks became brittle, while the inner part of the grains remained firm and elastic enough to not get damaged during the process. In other parts of Slovenian territory, the grain-hulling device was powered by foot (just like in many other places around the world) or with a hand pestle, while in southeastern Slovenia they used a water-driven device. One of the few standalone devices for hulling buckwheat is in Gorenje Vrhpolje near Šentjernej. Because of the significance of this unique device, a process for monument protection has been initiated with the relevant office at the Ministry of Culture of the Republic of Slovenia.

INTRODUCTION

In Slovenia, there is a long tradition of producing buckwheat groats (hulled buckwheat), which was already described by Valvasor (1689). The process has basically remained the same over time. The buckwheat grains are boiled in water until the insides swell and the hulls crack, then the grains are taken out of the water and partly dried in the shadov place. Making buckwheat groats used to be an important source of income for Slovenian farmers households (Pšajd, 2024; Kozar – Mukič, 2024). Even now, buckwheat and buckwheat groats have a sense of food that brings back memories of the 'good old days' (Vombergar and Gostenčnik, 2001).

In parts of Slovenia where there are not many suitable water streams, especially in northeastern Slovenia (Podravje and Pomurje), foot-operated threshers are used. This is described and illustrated with pictures in the articles by Pšajd (2024) and Kozar – Mukič (2024). On one side, in the middle of the supported beam, the farmer steps on the beam and then lets it drop so that on the other side, the tip freely falls into the prepared cooked and partially dried grain. The device got its Slovenian name 'stope' from this alternating stepping. In western Slovenia (Primorska, near Šempeter pri Gorici), we found a simple hand-operated stope: the farmer placed the prepared grain into a hole in a large stone and pounded it with a wooden mallet to husk the grain. According to the user, the stone is supposedly from the Roman era.

Buckwheat grains are an important source of antioxidants and other nutritionally important metabolites (Kreft et al., 2008; Vombergar and Luthar, 2018; Vombergar et al., 2025). After husking, the nutritionally important substances remain in the groat, as they are mostly located in the embryo, endosperm, and aleurone layer, not in the husk (Kreft et al., 2017; 2023; Vombergar et al., 2020).

The husks were not thrown away after hulling; in Europe, they were once used as extra insulation for houses, and in Italy (Teglio), even for storing dried sausages. The husks are also useful for pillows since they're comfortable and vent heat and moisture well (Vombergar et al., 2024). They are less suitable for fertilizing fields, probably because soil microorganisms temporarily lock up the minerals, which can then be released only in the following years after the decomposition of husk, and become available to crops again.

DEVICE DESCRIPTION

The water-powered device for hulling buckwheat is located at the Cerkovnik farm. Owner Andrej Cerkovnik maintains it in its original condition. The water wheel of the device is at risk of degradation due to alternating exposure to water and air. A description of original state of this device was published with a photograph in 2003 in an international publication in South Korea (Kreft 2003). The owner thoroughly restored the water wheel in the summer of 2013 so that it would be ready for visits from participants of the 12th International Buckwheat Research Association (IBRA) symposium. The inside of the device, housed in a wooden shed set on stone foundations, has remained unchanged, original. It consists of a horizontal beam with big holes, into which pre-cooked and partially dried buckwheat grain (about one kilogram or more into each hole) is poured.

Other essential components are vertically mounted beams, each with an iron tip at the bottom. The third

Figure 1. *Stope in Gorenje Vrhpolje during the visit of participants of the 12th IBRA conference in 2013.*

Figure 2. *Water wheel on "mlinščica" water stream to run stope.*

Figure 3. *Inside view to stope.*

Figure 4. *Inside view to stope under action.*

component of the inner part of the device is a spindle with moving levers. When the spindle turns, the levers alternately lift the vertical beams and let them drop so that they freely fall into a groove in the lower beam for threshing. The lifting and dropping of the vertical beam is repeated as needed, sometimes up to about fifty or more times. The processed grain is taken out of the device, and by winnowing in the wind, the husks are removed. Some grains remain unhulled. On long winter evenings, families used to pick out the unhulled grains from the mixture.

In the Dolenjska region, there were several water-powered stope (stamping mills). Some of them were and still are preserved as parts of regular stone mill sets. The Cerkovnik stamp mills on the Kobila stream, however, are unique, as far as is known, the only preserved standalone water-powered stamp mills, with a millwheel that is powered from a water stream (mlinščica) from below. As such a landmark, stope were recognized on the initiative of Fagopyrum Slovenian Association for the buckwheat promotion by the Department for the Protection of Cultural Heritage in Novo Mesto, which initiated the process to protect these stope as a unique technical heritage and a cultural monument of special importance at the Ministry of Culture of Slovenia.

There used to be about 18 mills or stope on the Kobila stream (Anton Rangus, personal communication), but so far only Cerkovnik's stope in the village of Gorenje Vrhpolje and his cousin Anton Rangus' mill in the village of Dolenje Vrhpolje remain. Rangus is still involved in husking common and Tartary buckwheat groats, but now with modern equipment.

CONCLUSION

Following the infortmation from miller Anton Rangus and the initiative of FAGOPYRUM – Society for buckwheat promotion, has Dušan Štepec, M.SC. a conservator-advisor and head of the Novo mesto regional unit at the Slovenian Authority for the Protection of Cultural Heritage, Cultural Heritage Service, carried out an assessment of the stope and determined that it is an extraordinary and valuable technical structure. Based on this, he shared the information with the planners of the Kobila stream regulation and submitted a proposal to register the Cerkovnik stope in the register of immovable cultural heritage to the Ministry of Culture of Slovenia.

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IZVLEČEK

Slovenske vodno gnane stope za luščenje ajde v postopku registracije kot kulturna dediščina.

V delih Slovenije, kjer ni mnogo primernih potokov, to je zlasti v severnovzhodni Sloveniji (Podravje in Pomurje) uporabljajo stope na nožni pogon. To je opisano in ilustrirano s slikami v člankih Pšajd (2024) in Kozar – Mukič (2024). Na eni strani v sredini podloženega trama kmet stopa na tram in nato spusti, da na drugi strani s konico prosto pade v pripravljeno kuhano in delno posušeno zrnje. Od tega izmeničnega stopanja je naprava dobila slovensko ime »stope«. V zahodni Sloveniji (Primorska, v bližini Šempetra pri Gorici) smo našli preproste stope na ročni pogon: kmet je namestil pripravljeno zrnje v vdolbino v velikem kamnu in tolkel z lesenim batom, da se je zrnje oluščilo. Po navedbi uporabnika naj bi bil kamen domnevno še iz časa Rimljanov.

Ajdova zrna so pomemben vir antioksidantov in drugih v prehrani pomembnih metabolitov (Kreft et al., 2008; Vombergar and Luthar, 2018, Vombergar et al., 2025). Po luščenju ostanejo prehransko pomembne snovi v kaši, saj so večinoma locirane v embriju, endospermu in alevronskem sloju in ne v luščini (Kreft et al., 2017; 2023; Vombergar et al., 2020).

Luščin se po luščenju ni zavrglo, v Evropi se jih je nekoč uporabljalo za dodatno izolacijo hiš, v Italiji (Teglio) pa celo za shranjevanje posušenih salam. Luščine so uporabne tudi za vzglavnike, saj so prijetni in lepo odvajajo toploto in vlago (Vombergar et al., 2024). Za gnojenje njiv so manj primerne, verjetno ker mikroorganizmi tal začasno vežejo mineralne snovi, ki pa se lahko sprostijo naslednja leta in postanejo ponovno dostopne posevkom.

Vodno gnana naprava za luščenje ajde je locirana na domačiji Cerkovnik. Gospodar Andrej Cerkovnik jo vzdržuje v prvotnem stanju. Vodno kolo naprave je ogroženo s preperevanjem zaradi izmenične izpostavljenosti vodi in zraku. Opis prvotnega stanja teh stop je bil s fotografijo objavljen leta 2003 v mednarodni publikaciji v Južni Koreji (Kreft 2003). Lastnik je vodno kolo stop temeljito obnovil poleti leta 2013, da je bilo pripravljeno za obiske udeležencev 12. simpozija Mednarodnega združenja za raziskave ajde (IBRA). Notranji del naprave je v leseni hiški, postavljeni na kamnite temelje in je ostal nespremenjen, originalen. Sestavljen je iz vodoravnega trama z vdolbinami, v katere se nasuje prekuhano in delno posušeno zrnje ajde. Drugi bistveni sestavni deli so vertikalno nameščeni tramovi, vsak ima železno konico na spodnjem delu. Tretji sestavni del notranjega dela naprave je vreteno z odmičnimi ročicami. Med vrtenjem vretena ročice izmenjaje dvigajo vertikalne tramove in jih spuščajo, da prosto padajo v vdolbino v spodnjem tramu, na zrnje za luščenje. Dviganje in padanje vertikalnega trama se ponovi, dokler je potrebno, navadno je okoli petdesetkrat. Obdelano zrnje se vzame iz naprave in s prepihavanjem na vetru se odstrani luščine. Nekaj zrn ostane neoluščenih. V dolgih zimskih večerih je nekdaj družina ob mizi odbirala neoluščena zrna iz kaše.

Na Dolenjskem je bilo več stop na vodni pogon. Nekatere so bile in so še ohranjene v sklopu mlinov. Opisane Cerkovnikove stope na potoku Kobila so edinstvene, kolikor je znano so edine take ohranjene samostojne stope na vodni pogon, z mlinščico, ki poganja vodno kolo od spodaj. Kot tako znamenitost jih je na pobudo Fagopyrum – društva za promocijo ajde prepoznal tudi območni zavod za varstvo kulturne dediščine v Novem mestu, ki je sprožil postopek za zaščito teh stop kot edinstveno tehnično dediščino in kulturni spomenik posebnega pomena.

Na potoku Kobila naj bi bilo nekoč okoli 18 mlinov ali stop (Anton Rangus, osebna informacija), do sedaj so ostale samo Cerkovnikove stope v vasi Gorenje Vrhpolje in mlin njegovega bratranca Antona Rangusa v vasi Dolenje Vrhpolje. Rangus se še vedno ukvarja z luščenjem navadne in tatarske ajdove kaše, vendar s sodobnimi napravami.

Na opozorilo mlinarja Antona Rangusa in na pobudo FAGOPYRUM – društva za promocijo ajde je pri Zavodu za varstvo kulturne dediščine Slovenije, Služba za kulturno dediščino, ***konservatorski svetnik in vodja območne enote Novo mesto mag. Dušan Štepec izvedel valorizacijo stop in ugotovil*** da gre za izjemen in dragocen tehniški objekt. Na tej osnovi je posredoval informacije načrtovalcem regulacije potoka Kobila in sprožil predlog za vpis Cerkovnikovih stop v register nepremične kulturne dediščine pri Ministrstvu za kulturo Republike Slovenije.

Zahvala: Zahvaljujemo se konservatorskemu svetniku mag. Dušanu Štepcu za razumevanje pomena Cerkovnikovih stop in za predlog za vpis stop v register nepremične kulturne dediščine pri Ministrstvu za kulturo Republike Slovenije.

Liangshan Initiative of the 16th International Buckwheat Symposium

The 16th International Buckwheat Symposium was held in Xichang City, Liangshan Yi Autonomous Prefecture, Sichuan Province, China, from June 25 to 27, 2026. With its extensive Tartary buckwheat cultivation base, strong industrial foundation, and relatively complete industrial chain, Liangshan is widely recognized as the "World Capital of Tartary Buckwheat."

As a distinctive crop originating in China, Tartary buckwheat has significant nutritional value as well as ecological, industrial, and health-related importance. Over time, a shared understanding has gradually taken shape among the global buckwheat research and industry communities regarding the importance of Tartary buckwheat germplasm conservation, scientific research, product development, and sustainable utilization. At the same time, growing attention from consumers and food specialists highlights the role of Tartary buckwheat in enriching portfolios of high-value crops, alongside the rising popularity of common buckwheat, its closely related species, in international cuisines.

Based on this long-standing and widely recognized consensus, participants and stakeholders are encouraged to further strengthen the conservation and innovative use of Tartary buckwheat germplasm resources, promote coordinated development of basic research, applied research, and industrial transformation, and enhance the role of the Tartary buckwheat industry in supporting human health, ecological protection, and regional specific industries.

The conservation and sustainable utilization of Tartary buckwheat genetic resources require international collaboration among researchers, breeders, farmers, industry, and policymakers. Promotion of open sharing of scientific data, genomic resources, and research findings is encouraged whenever appropriate.

This initiative is intended to bring together the shared attention and continued efforts of the global buckwheat community, encouraging open, voluntary, and cooperative exchanges to jointly advance high-quality development in Tartary buckwheat research and industry. Participants are encouraged to establish long-term collaborative networks, organize regular scientific exchanges, and develop joint research projects.

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Report on 16th International Conference on Buckwheat in Xichang, Sichuan, China

The 16th International Conference on Buckwheat took place on June 25-27, 2026 in Xichang, Sichuan, China. It was devoted to Buckwheat Science and Technology Innovation for Human Nutrition and Health. More than 300 participants from China and 15 other countries joined the scientific sessions and other meetings, including the visits to Liangshan Huiqiao Biotechnology Co., LTD; Tartary buckwheat experimental fields, Liangshan Yi people Museum, and performances by Liangshan Yi peoples show.

On the evening of June 24, IBRA (International Buckwheat Research Association) Board session took place, discussing the venue of the 17th International Conference on Buckwheat in 2029. Crop Germplasmics publication (Xu Liu, Editor-in-Chief and Yunbi Xu, English Editor-in-Chief) on Plant Genetic Resources was presented.

During the closing ceremony Liangshan Initiative of the 16th International Buckwheat Symposium was accepted. Liangshan initiative is intended to bring together the shared attention and continued efforts of the global buckwheat community, encouraging open, voluntary, and cooperative exchanges to jointly advance high-quality development in Tartary buckwheat research and industry. Participants are encouraged to establish long-term collaborative networks, organize regular scientific exchanges, and develop joint research projects.

At IBRA Assembly on June 27, Prof. Dr. Meiliang Zhou, Institute of Crop Sciences, Chinese Academy of Agricultural Sciences (CAAS), Beijing, China, is elected for the president of IBRA for the period of next three years (June-27-2026 to June-26-2029). As the venue of the 17th International Conference on Buckwheat in 2029 was confirmed Udine, Italy.


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The 16th International Buckwheat Symposium
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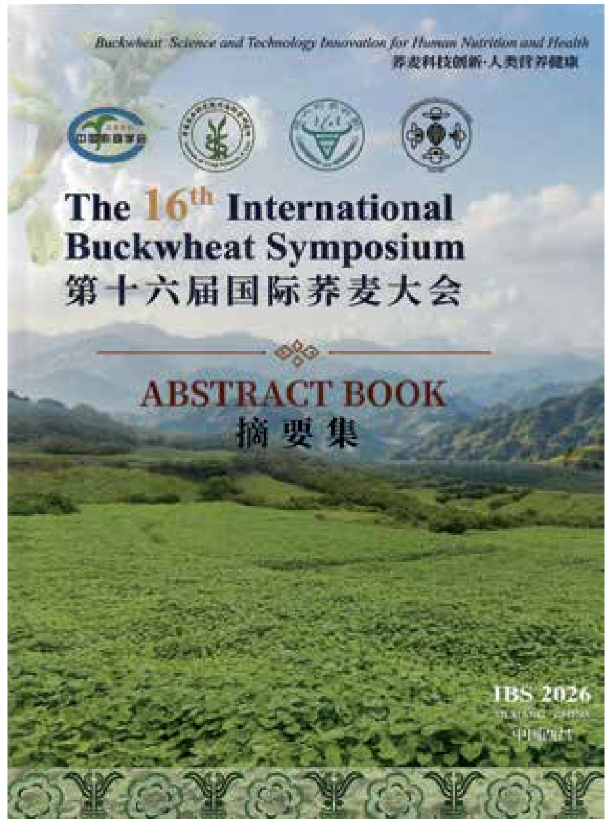
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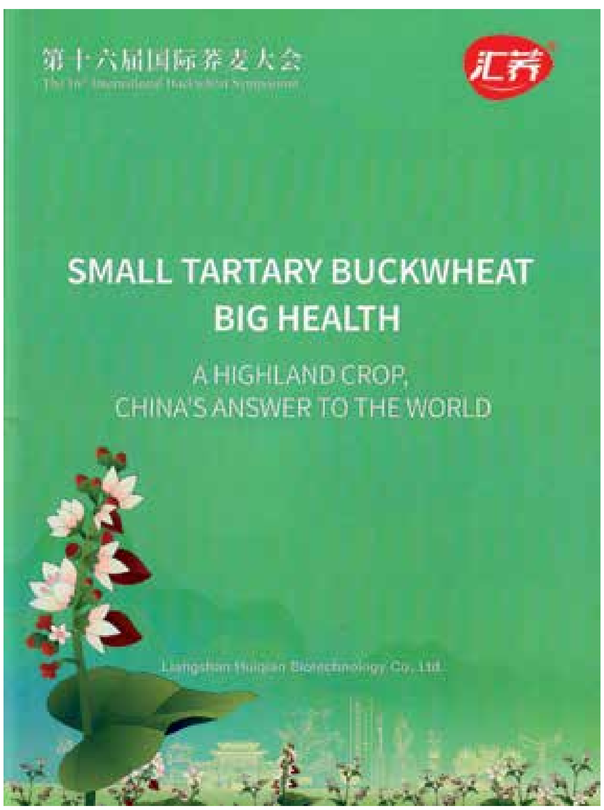
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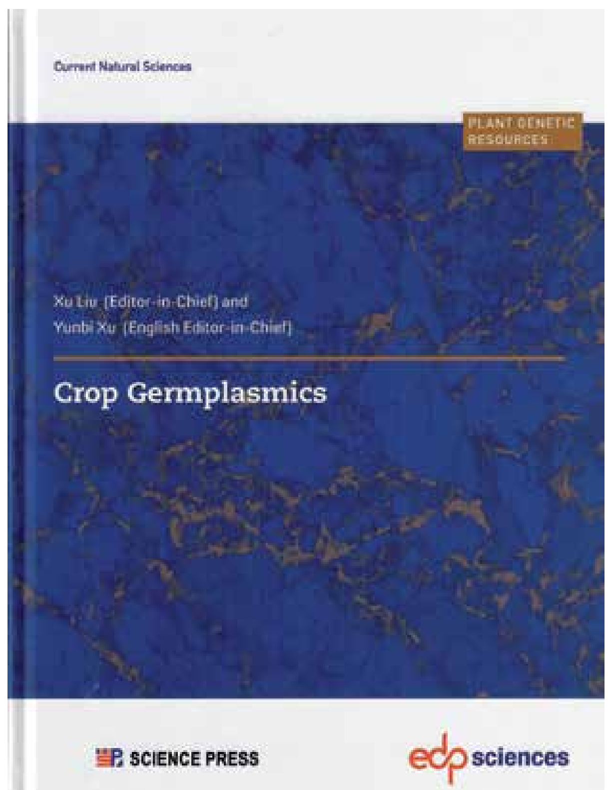
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After reviewing by two reviewers and accepting the paper, the editorial office will ask the authors to provide the original figures if the submitted ones will not be adequate. Your manuscript should be sent to the Editor-in-Chief (Prof. Ivan Kreft). E-mail: **ivan.kreft@guest.arnes.si**

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Manuscripts should be typed in one column (we will transfer later the text to two columns). All pages, including the tables, legends and references, should be numbered consecutively. The manuscript should be arranged in the following order, or other suitable similar order:

1. Title page (page 1)
   - Title (the title should be as short as possible, but should contain adequate information to indicate the contents)
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   - Key words (maximum of 8, in alphabetical order, suitable for indexing)
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4. Main text
   - Introduction, Material and Methods, Results, Discussion
   - The relative importance of headings and subheadings should be clear.
5. The approximate location of figures and tables could be indicated in the margin or in the text.
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Abstract in Slovenian will be for foreign authors made by the editors.
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The papers received by editor latest on **November 30**, **2026**, if accepted, will be published in the spring issue 2027 of FAGOPYRUM (probably in January 2027).

In FAGOPYRUM journal it is for now no charge of publication fee for authors.

Best regards,
Ivan Kreft