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Improvement of buckwheat production in conditions of climate change

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Abstract: Buckwheat‘s hight nutritional and pharmacological qualities make this pseudo cereal, a potential functional food and a symbol of a healthy lifestyle. The demand for buckwheat grain has grown because of its excellent nutritional value, balanced amino acid content, and abundance of lysine and arginine. Proteins, dietary fiber, vitamins, flavonoids, fagopyrins, d-fagomine, and phenolic acids are among the bioactive components of buckwheat that have promising therapeutic effects against chronic illnesses. Every year, there are noticeable changes in the climate, increasing temperatures and decreasing precipitation. The productivity of plants, including buckwheat, is impacted by rising temperatures. All of the aforementioned factors make it necessary introduction of agrotechnical measures in order to increase buckwheat production, i.e. yield. The Novosadska buckwheat variety, was examined in this study, grown in four repetitions, in two variants: the control, which was without application of foliar nutrition, and the variant that included foliar nutrition, with Phyto Complex, phytocereals nutrition, in Bački Petrovac, Serbia. The following criteria were examined of ten plants from each repetition: plant height, leaf mass, grain yield, protein and oil content, ash content, starch, water and phenol content. Grain yield and yield parameters were statistically considerably higher in the foliar nutrition variant than in the control variant. It is necessary to promote the introduction of agrotechnical measures to increase buckwheat production, aimed at increasing buckwheat yield. Improving productivity will be an important trade-off between food security, population growth, better land use in the face of climate change, and increased production.

Keywords: buckwheat; climate change; variety Novosadska; foliar nutrition; therapeutic effects against chronic illnesses

INTRODUCTION

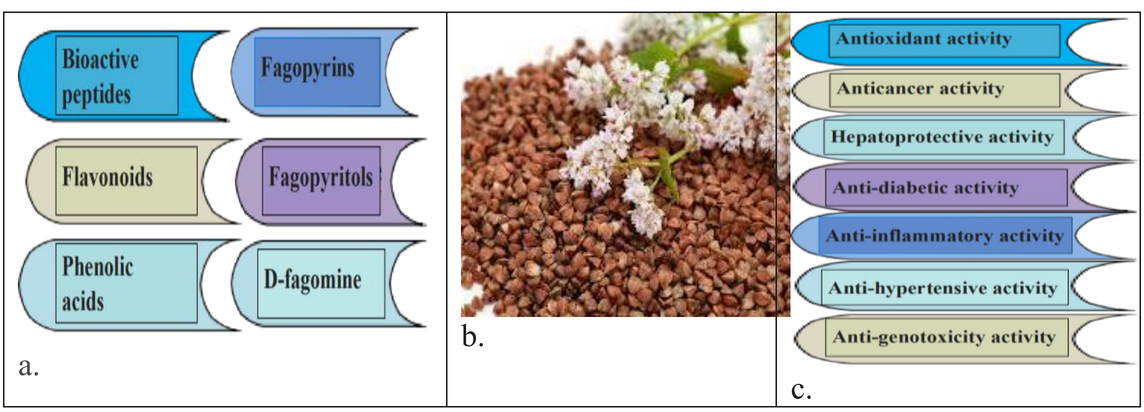
Buckwheat is a pseudocereal that is a member of the *Polygonaceae* family. Although pseudocereals are taxonomically distinct, their endosperm-rich starch components cause them to resemble members of the *Poaceae* family, which includes wheat, rice, and barley. Buckwheat comes from Central Asia and China (Zhang et al., 2012). An annual herbaceous plant, buckwheat can grow in any type of habitat, even infertile terrain (Rodríguez et al., 2020), and mountain areas are most suitable for it (Popović et al., 2017). Buckwheat has been divided into two species: annual and multiannual. While *Fagopyrum suffruticosum* Fr. Schmidt, *Fagopyrum ciliatum* Jaegt, and *Fago-*

pyrum cymosum Meissn are multiennual kinds, *Fagopyrum tataricum* L, *Fagopyrum giganteum* Krotov, and *Fagopyrum esculentum* Moench are annual species (Jing et al., 2016). Most Tartary buckwheat varieties are produced in the Himalayan regions, and *Fagopyrum esculentum* and *Fagopyrum tataricum* are also common (Popović et al., 2017; 2022; Sofi et al., 2022). The mountainous regions of China and Russia are home to the majority of buckwheat cultivars (Begemann et al., 2021; Yilmaz et al., 2020; Zou et al., 2021). Buckwheat, amaranth, and quinoa are the primary pseudocereals that have health advantages (Ferreira et al., 2022). A functional food with several health benefits, pseudocereals are one of the health-related foods (Astrini et al., 2020; Mir et al., 2014; 2018; Xu et al., 2022). Functional foods containing bioactive substances have become more common in consumers' diets in recent years. These functional meals offer end users health and nutritional advantages.

According to Giménez-Bastida et al. (2015) and Małgorzata et al. (2018), buckwheat seeds are mostly utilized as morning cereals in the form of groats, flour for baked goods, and other enhanced products like bread, tea, honey, and sprouts.

Buckwheat and its by products have been linked to a number of health benefits, including hypocholesterolemic, hypoglycemic, anticancer, and anti-inflammatory properties. These benefits increase their potential for use in the formulation of functional foods (Mondal et al., 2021) and expand their applications in agriculture, industry, and medicine (Fotschki et al., 2020). One of the useful pseudocereals with nutraceutical ingredients to combat celiac disease, malnutrition, and health-related illnesses is buckwheat. Buckwheat-related food products with good sensory and techno-functional properties have been appealing to the food industry in recent years. They are also helpful for people who are gluten intolerant and have health benefits. Adding buckwheat to product formulation might help reduce a number of health issues and create gluten-free products. Buckwheat has the potential to be used in gluten-free product development. Buckwheat was declared the medicinal plant of the year in Germany in 1999 (Popović et al., 2017; 2022; Kolarić et al. 2021). The buckwheat grain's properties, nutritional components, and bioactive elements are depicted in Picture 1.

Proteins, dietary fiber, vitamins, flavonoids, fagopyrins, d-fagomine, and phenolic acids are among the bioactive components of buckwheat that have promising therapeutic effects against chronic illnesses (Zhou et al., 2015; Zhou, Wen et al., 2015). Buckwheat seeds contain albumins, globulins, prolamins, and glutelins, and are a rich source of proteins with well-balanced amino acids (Jin et al., 2022). Because buckwheat proteins don't contain gluten, those with celiac disease can tolerate them better (Bobkov, 2016). Buckwheat's proteins are abundant in cysteine, asparagine, phenylalanine, lysine, threonine isoleucine,



Picture 1. Buckwheat bioactive components, a., grain, b., and nutraceutical properties, c.

and leucine (Bhinder et al., 2020). Although the biological benefits of buckwheat proteins are exceptional, their protein digestibility is decreased by antinutritional components (tannins and proteases) (Mattila et al., 2018). Buckwheat's bioactive components, polyphenolic chemicals (flavonoids and phenolic acids), enhance the grain's potential as a nutraceutical. Flavonoids including rutin, isoorientin, quercetin, isovitexin, vitexin, and orientin are abundant in buckwheat (Raguindin et al., 2021). Only buckwheat has rutin, a pseudo -cereal with superior anti-inflammatory, anti-cancer, and antioxidant qualities (Zhu, 2016). Buckwheat contains flavonoid chemicals that have pharmacological and other health advantages (Lee et al., 2016). According to Ahmed et al. (2014), buckwheat is also a good source of fagopyrins, plant sterols, tannins, and resistant starch.

Celiac disease and IgE-mediated wheat allergy are two well-known conditions that are associated with gluten intake. Celiac disease, an autoimmune disorder that can seriously damage the intestines, is largely caused by genetic risk factors. 0.5% to 1% of the general population has celiac disease (Giménez-Bastida et al., 2015; Manikantan et al., 2022; Rafiq et al., 2021). In contrast, IgE antibodies that recognize epitopes from specific proteins, referred to as allergens, trigger a series of events that culminate in allergic inflammation, causing gluten sensitivity and/or other wheat proteins. Between 0.33% and 1.17% of people have a wheat allergy (Ballini et al., 2021; Brand et al., 2022; Srisuwatchari et al., 2020).

Only patients with celiac disease are advised to follow a strict, gluten-free diet for the remainder of their lives. Those who have been diagnosed with IgE-mediated wheat allergy are subject to similar limitations. In recent years, there has been increased focus on nonceliac gluten sensitivity, a third condition that is characterized by discomfort following gluten consumption and is not related to celiac disease or IgE-mediated allergies (Aksoy et al., 2021; Srisuwatchari et al., 2020; Vassilopoulou et al., 2021). Although it is grown on rainfed marginal terrain and has low production, buckwheat is a crucial crop for mountainous regions. Its productivity must be increased by using scientific knowledge and improved farming techniques. In rainfed conditions, the crop requires 30 to 45 kg of nitrogen per hectare in order to achieve a greater yield. Despite a higher biomass yield, too much nitrogen reduces grain yield. The correlation of grain yield with plant population was found significant at P = 0.05. The regression analysis showed the relation between grain yield and nitrogen levels was not linear with low coefficient of determination ($R_2 = 0.16$), (Gaithe et al., 2015).

The aim of the research was to analyze the productivity of *Fagopirum esculentum* in the world and in Serbia and tested productivity and quality parameters Novosadska buckwheat in changing climatic conditions and to determine the effect of foliar nutrition on buckwheat productivity.

MATERIAL AND METHODS

The production trials were carried out on the trial plots of the Institute of Field and Vegetable Crop, in Bački Petrovac, with buckwheat variety "Novosadska" grown on chernozem, 2022. The trial was set up in a randomized block design with four replications, on an area of 10 m^2, at the optimal time, in mid-April. Cultivation technology applied in the crop was varietal. Autumn ploughing was carried out to a dept of 30 cm, with application of 300 kg/ha of NPK fertilization. Per ha sowing 60 kg buckwheat seed. This investigation included: foliar nutrition and control without nutrition. Foliar fertilization was applied with Phyto cereals preparation, by Phyto complex. Phyto cereals preparation is a cocktail with micro and macro elements, vitamins, amino acids, and growth stimulants. Nutrition was applied in three times, with 1 l/ha: 1. after forming 3 leaves; 2. after 7 leaves and 3. before flowering plants.

Crop care: Mechanical and Chemical (Dual Gold 960 EC, Corrective treatment with Fusilade forte – 1.5 l/ha; Desication: Reglon forte, 4l/ha).

The harvest was done at technological maturity. Next parameters were analyzed: plant height (cm), leaf mass (cm), grain yield (g), protein and oil content, ash content, starch (%), water and phenol content.

The water content was determined according to the standard (AACC International, 2000), total ash according to Kaluđerski and Filipović (1998), while the protein level was determined by the Kjedahl method with a conversion factor of 6.25 (ISO, 20483:2013). Content of the total of lipids was determined by Soxhlet with petroleum ether as a solvent. The percentages were determined by the volumetric method. And the phenol content spectrophotometrically. Before harvesting, 10 buckwheat randomly plants were taken from each plot for morphological analysis. The yield was taken after harvest from each plot and converted to 13% moisture. The obtained results were processed using descriptive statistics and presented tabularly and graphically.

Meteorological condition

In the examined year of 2022, the average air temperature was 20.8 °C and the total amount of precipitation was 155.8 mm (long term 314.4 mm), Table 1, Figure 1.

The production year was very unfavorable for buckwheat production. Total precipitation in the 2022 vegetation period amounted to 155.8 mm. A deficit of precipitation was 158.6 mm was recorded. Average vegetation temperatures in 2022 were 20.8°C and were higher by 1.9°C compared to the reference period (18.9 °C), 1987-2021, Figure 1.

Table 1. Average temperature (°C), and total precipitation (mm) in 2022

Parameter	**Temperature, 2022 (°C)**			**Precipitation, 2022 (mm)**		
Mounts	**sdT 2022.**	**1987-2018.**	**□sdT**	**□P 2022.**	**1987-2018.**	**□□P**
IV	12.2	12.0	0.2	42.1	46.5	-4,4
V	19.4	17.1	2.3	30.8	69.6	-38,8
VI	23.0	20.8	2.2	44.2	81.1	-36,9
VII	24.8	22.5	2.3	14.0	66.5	-52,5
VIII	24.8	21.9	2.9	50.9	50.7	0,2
Average	**20.8**	**18.9**	**1.9**	**155.8**	**314.4**	**-158,6**

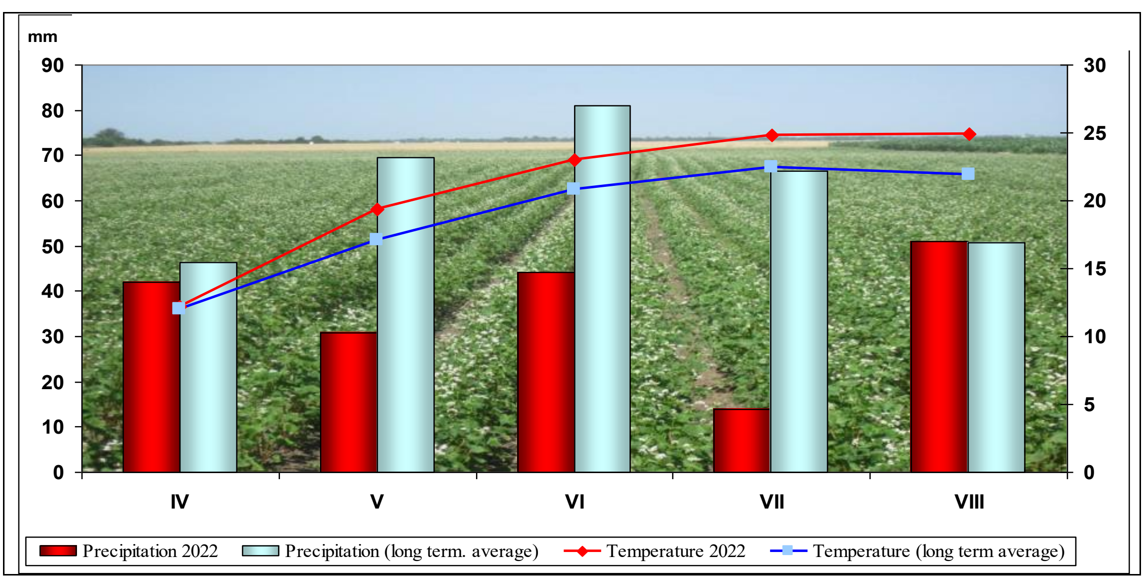


Figure 1. Temperature (°C), and total precipitation (mm) in the 2022 vegetation period

RESULTS AND DISCUSSION

Buckwheat world production

Due to its great economic importance, buckwheat areas have seen a growing trend in recent years. Areas of buckwheat is 2.86 mill. ha, the average grain yield was 975 kg ha^{-1} and world production is about 2.0 mill. t. The largest areas under buckwheat are in: Europe (52%), Asia (40%), America (6%) and Africa, with share in the world production of 0.5% (Popović et al., 2022), Figure 2.

About 3.8 million tons of buckwheat are produced worldwide, with Russia leading the pack with 1.5 million tons and China coming in second with 0.9 million tons (FAOSTAT statistics, 2019). Additionally, buckwheat is grown in Brazil (3.5%), Poland (5.4%), the USA (5.7%), France (8.3%), and Japan (1.0%).

Novosadska Buckwheat production in Serbia

"Novosadska buckwheat" variety showed that it has excellent genetic potential and achieved excellent performances in an unfavorable year for production. Average yield was 1.52±0.19 t ha^{-1}, and varied from 1.38 t ha^{-1} (V1 variant) to 1.65 t ha^{-1} (V2 variant). Average plant height was 146.95±8.7 cm and varied from 140.8 cm (V1 variant) to 153.1 cm (V2 variant). Average plant

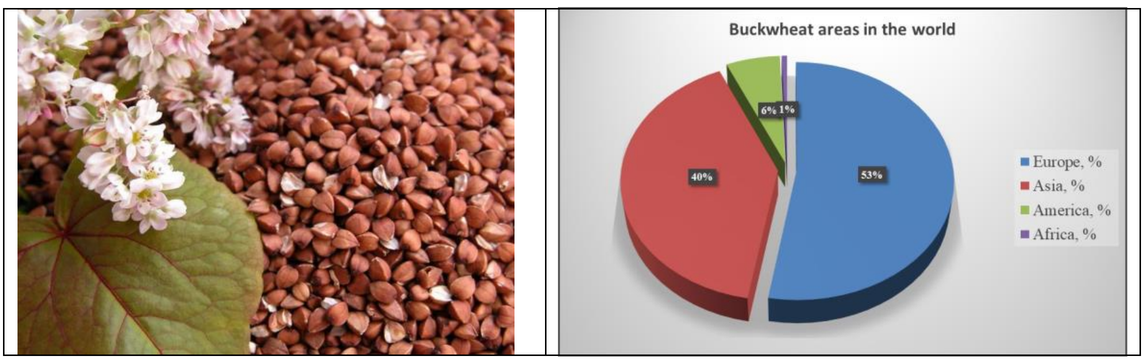


Figure 2. a) Buckwheat grain; **b)** Buckwheat areas have in the world, ha

Table 2. Novosadska buckwheat productivity parameters, B. Petrovac, Serbia, 2022

Parameter	V1-Control	V2- Foliar Nutrition	Average value	Std. Dev.	IV
Grain yield, t/ha	1.38	1.65	1.52	0.19	0.27
Planth height, cm	140.8	153.1	146.95	8.70	12.3
Plant height until first inflorescence,cm	35.1	23.1	29.10	8.49	12
Stem Thickness, cm	0.88	1.1	0.99	0.16	0.22
Leaf mass, g	1.0	1.2	1.10	0.14	0.2
Nutritional composition					
Carbohydrate, %	62.10	66.80	64.45	3.32	4.7
Protein content, % DM	18.10	18.30	18.20	0.14	0.2
Oil content, % DM	2.90	3.10	3.00	0.15	0.2
Ash content, % DM	2.91	3.90	3.40	0.71	1.0
Total phenols, %	0.14	0.15	0.15	0.01	0.1
Wather, %	10.30	10.10	10.20	0.06	0.2
IV- Interval variation; Std. Dev. - Std. Deviation					

height to 1st inflorescence was 29.10±8.49 cm and varied from 23.1 cm (V1 variant) to 35.1 cm (V2 variant), Table 2, Figure 3a-4d.

Average stem thickness was 0.99 ±0.16 cm, and varied from 0.9 cm (V1 variant) to 1.1 cm, in V2 variant. Average leaf mass was 1.1±0.14 g, and varied from 1.0 cm (V1 variant) to 1.2 cm (V2 variant), which shows that buckwheat can be successfully grown in plain areas and that in dry years it is desirable to apply foliar feeding in order to increase yield, Table 2, Figure 3a-4d.

In the dry year, foliar feeding had a statistically significant effect on the tested traits. The average grain yields of "Novosadska buckwheat" variety were significantly higher than the average world yields, on the basis of which we can conclude that buckwheat can be successfully grown in Serbia. Buckwheat green biomass yields are 25-35 t ha^{-1}. Under favorable conditions, about 300 kg ha^{-1} of honey can be obtained (Ikanović et al., 2013; Popović et al., 2017; 2022; Kolarić et al. 2021).

When fertilizer is applied, it reacts less strongly than other crops (White et al., 1941). In rich, nitrogen-rich soils, the crop is likely to lodge poorly (Sando, 1956). When the climate is right, it will yield a higher crop than other grain crops on unproductive and badly tilled soil. The effects of climate change, such as rising temperatures and unpredictable rainfall, are particularly dangerous for the agriculture industry. According to Thomson et al. (2005), the yield of food crops is expected to decline over the next 50 years due to changes in soil moisture and rising temperatures brought on by global climate change (Popović et al., 2020).

In their study, Gairhe et al. (2015) discovered that the interaction impact between priming and nitrogen level was not significant, and that 18 hours of seed priming with 45 kg N/ha produced the highest grain yield (2091 kg ha^{-1}). The buckwheat plot with nitrogen application had an greater rate of phosphorus consumption. Moderate potassium consumption was also noted, while is the soil's nitrogen content to stay constant. It would be advantageous to apply phosphatic fertilizer when growing buckwheat.

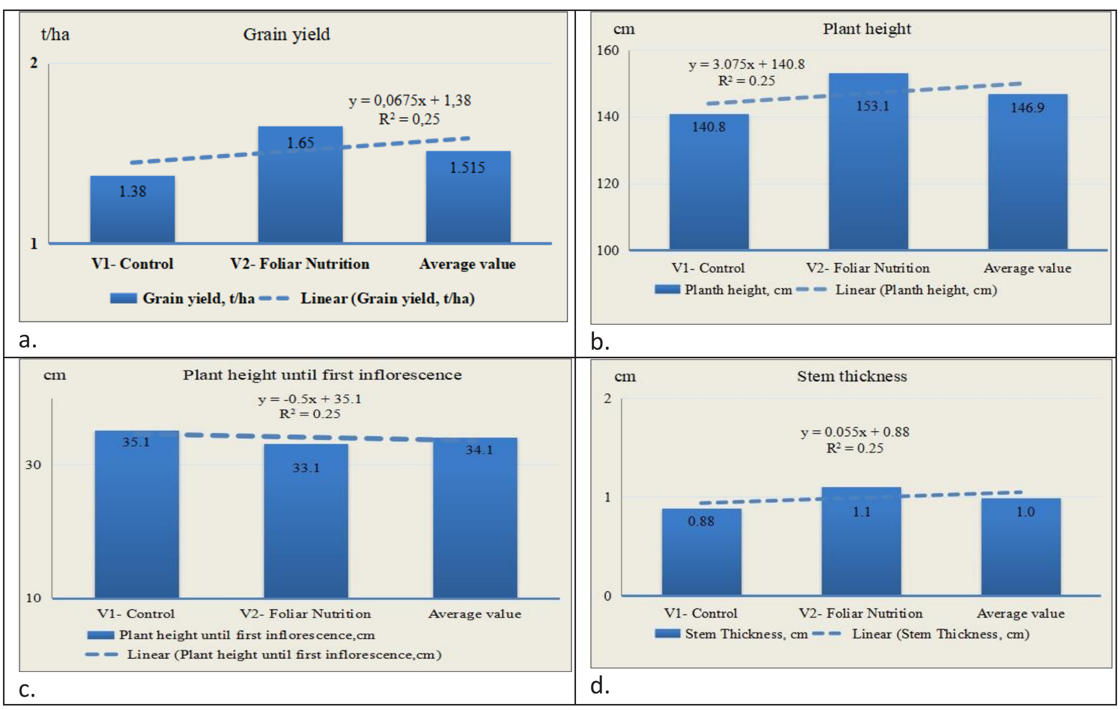


Figure 3. a) Buckwheat grain yield, t ha^{-1}; **b**) plant height, cm; **c**) plant height to the 1st inflorescence, cm; and **d**) stem thickness, cm, in arid 2022

Quality parameters of Novosadska buckwheat

Novosadska buckwheat" showed that it has excellent quality parameters. Average carbohydrates was 64.45±3.32% and varied from 62.1 (V1 variant) to 66.8% (V2 variant). Average protein content was 18.2±0.14% and varied from 18.1 (V1 variant) to 18.3% (V2 variant). Average oil content was 3±0.15% and varied from 2.9 (V1 variant) to 3.1 % (V2 variant). Average ash content was 3.4 ±0.71%, and varied from 2.9 (V1 variant) to 3.9% (V2 variant). Average total phenols was 0.15±0.1% and varied from 0.14 % (V1 variant) to 0.15% in V2 variant, Table 2, Figure 4a-4d.

Average water was 10.20±0.06% and varied from 10.10 % (V1 variant) to 10.3% in V2 variant which shows that buckwheat can be successfully grown in plain areas.

Protein content was 12.7%, carbohydrates 55.5%, lipid 3.9%, dietary fiber 7.7 %, ash 2.3%. According to Dziadek et al. (2016), buckwheat has a significant protein content ranging from 8.5% to 18.8%, depending on the cultivar, source, and climate. Buckwheat grains have a higher protein content than cereal grains (Bobkov, 2016).

Buckwheat proteins are rich in arginine, lysine, and aspartic acids and have well-balanced amino acid compositions (Bhinder et al., 2020).

Buckwheat's protein digestibility is reduced by the presence of tannins and protease inhibitors. However, buckwheat proteins have higher protein digestibility-corrected amino acid scores than cereal proteins due to the inclusion of lysine amino acid (Zhang et al., 2012; Sofi et al., 2022). Starch is the available carbohydrate source in buckwheat grains that varies from 60% to 70% (Vojtiskova et al., 2012).

Buckwheat health benefit

Buckwheat's nutritional components, bioactive components, and potential make it a great choice for creating gluten-free products that target celiac disease, which affects 1.4% of the world's population, as well as other health-related

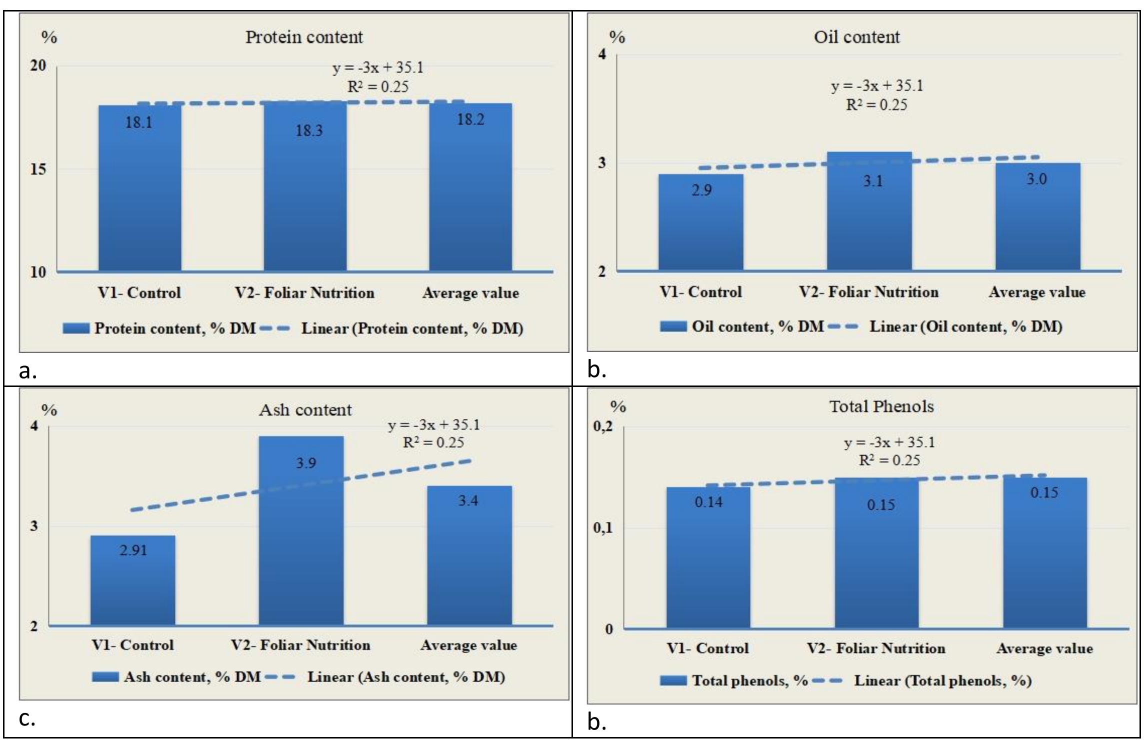


Figure 4. **a**) Buckwheat protein content; %; **b**) oil content, %; **c**) ash content, %; and **d**) protein content, in arid 2022

conditions, Picture 2a. Buckwheat's nutritional components, bioactive components, and potential make it a great choice for creating gluten-free products that target celiac disease, which affects 1.4% of the world's population, as well as other health-related conditions (Bastida et al., 2015).

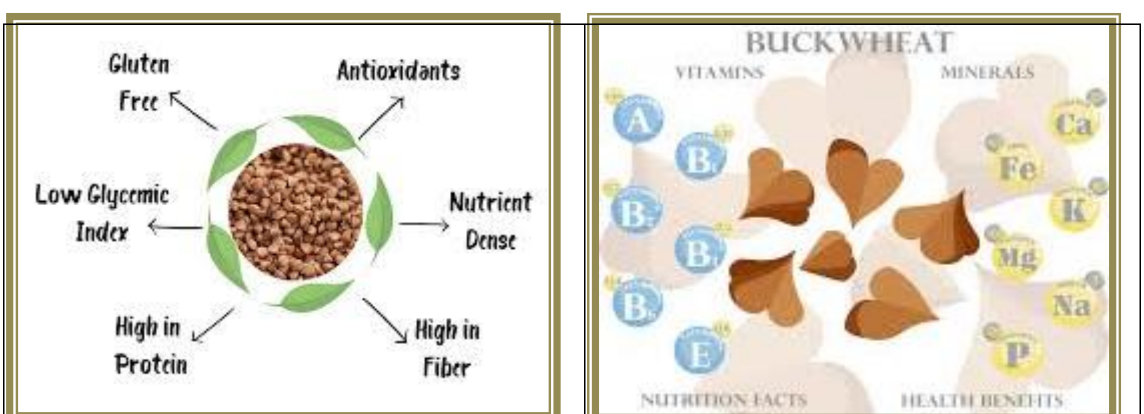
The typical buckwheat grain has the following important micronutrients: B, Cu (0.01%), Mn (0.01%), Bi (0.001%), Fe (0.01%), Ca (0.03%), P (0.3%), and Mg (3%). It also contains 73% carbohydrates, 11% crude protein, 1.9% fat, 1.3% crude fiber, and 1.5% ash, Picture 2b. According to Rajbhandari and Bhatta (2008) and Martin et al. (1976), tartary buckwheat grain has more than 68% carbohydrates, 13% crude protein, 2% fat, 1.5% crude fiber, 1.95 ash, Ca (0.04%), P (0.2%), and Fe (0.01%). Its biological, medicinal, and nutritional qualities make it an important agricultural plant, but so does its appropriateness for both commercial farming systems and low-input mountain farming (Rajbhandari and Bhatta, 2008).

Buckwheat grain is a very nutritious food ingredient that has been shown to have a wide range of positive health impacts. In addition to having some highly nutritious components, it may also have other qualities as a functional food. Unlike popular cereals, buckwheat protein is of exceptional quality and contains a lot of lysine, an essential amino acid. These plants have anti-inflammatory, neuroprotective, anti-cancer, anti-diabetic, and anti-plasma cholesterol properties. They also improve the symptoms of hypertension. Helps people with celiac disease follow a gluten-free diet. Buckwheat's prebiotic and antioxidant properties have been identified (Popović et al., 2022).

CONCLUSION

With a high nutritional profile and a wealth of vitamins, minerals, and phytochemicals, buckwheat is the important pseudocereal. The bioactive components in buckwheat have important health and nutraceutical implications. The pharmaceutical industry can cure a variety of illnesses by using the bioactive ingredients that were separated from buckwheat. Creating functional foods with health advantages is the most appealing trend in the food sector. The food market has been drawn to buckwheat-related goods with good sensory and technofunctional properties in recent years. These products are suitable for persons with gluten intolerance and have health benefits.

Serbia has favorable conditions for growing buckwheat. In Serbia, buckwheat is grown on small areas. The Novosadska variety grown on chernozem in a dry year achieved good morphoproductive properties. Foliar feeding had a high statistical significance for increasing grain yield.



a. b.

Picture 2. Buckwheat's health benefit, a, minerals and vitamins in grain, b.

The average grain yields of the buckwheat variety - Novosadska, in trials conducted in Bački Petrovac, near Novi Sad, varied from 1.38 t ha^{-1} (V1 variant) to 1.65 t ha^{-1} (V2 variant). In a dry year, yields were largely determined by the climatic and soil conditions that prevailed during the growing seasons.

The yields it achieved were significantly higher than the average world yields, on the basis of which we can conclude that buckwheat can be successfully grown in our country and in the plains. In dry years it would be advantageous to apply foliar fertilizer when growing buckwheat.

Buckwheat is becoming more and more important in the world and in our country in the economic, ecological and social sense. A growing trend for gluten-free buckwheat based products highlights the need for development of new products in functional food. These plants have anti-inflammatory, neuroprotective, anti-cancer, anti-diabetic, and anti-plasma cholesterol properties. They also improve the symptoms of hypertension.

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