Journal of Elementology ISSN 1644-2296

Çolak Esetlili, B., Fırat, E., Seçim, A. and Toy, H. (2024) 'Zinc Biofortication of Brassicaceae Microgreens', *Journal of Elementology*, 29(1), 87-97, available: https://doi.org/10.5601/jelem.2023.28.3.3082

RECEIVED: 20 August 2023
ACCEPTED: 26 January 2024

ORIGINAL PAPER

Zinc enrichment of Brassicaceae microgreens*

Bihter Çolak Esetlili, Edanur Fırat, Ayşenur Seçim, Hasan Toy

Department of Soil Science and Plant Nutrition
Ege University, Izmir, Turkey

Abstract

Inadequate intake of zinc (Zn) by humans can lead to hidden health problems, especially in women and children of poorer regions with a high risk of malnutrition. Therefore, the enrichment of Zn in edible plant tissues through Zn fertilization is considered an effective approach in this regard. This study aims to investigate the biological enrichment of Zn in some of the microgreens belonging to the Brassicaceae family, and to evaluate their Zn uptake potential. Cauliflower, broccoli, and cabbage microgreens grown with the addition of different doses of $ZnSO_4$ (0, 5, 10, 20 mg kg^{-1}) in the nutrient solution were analyzed for their fresh and dry weights, as well as the nutrient element content (P, K, Ca, Mg, Fe, Mn, Zn, and Cu). The results show that enhanced Zn levels affect the varieties differently; therefore, the response to Zn enrichment was genotype-specific. The highest fresh weight (13.89 g) was determined in broccoli microgreens at 10 mg kg^{-1} Zn application, while the lowest (5.87 g) was found in cauliflower microgreens at the control treatment (Zn0). The highest Zn content was determined in cauliflower, broccoli, and cabbage microgreens treated with 20 mg kg^{-1} Zn. The application of 5 mg kg^{-1} Zn significantly affected the Ca, Mg, and Mn content of cabbage microgreens. The biological enrichment of Zn in cauliflower, broccoli, and cabbage microgreens from the Brassicaceae family is expected to have positive effects on human health and can be considered as an option, particularly for counteracting Zn deficiency.

Keywords: microgreens, zinc, cauliflower, broccoli, cabbage

Bihter Çolak Esetlili, Assoc. Prof. Dr, Department of Soil Science and Plant Nutrition, Ege Faculty of Agriculture, University, Izmir, Turkey, e-mail: bihtercolak@gmail.com
* This study is supported by the Ege University Scientific Research Projects Coordination Unit, Project Number: FLP-2021-23482.

INTRODUCTION

Zinc, which has antioxidant functions in the human body, is an essential micronutrient that should be included in daily dietary intake (Marreiro et al. 2017). Approximately 2 billion people worldwide are affected by Zn deficiency. The World Health Organization (WHO) has reported that 800,000 people, including 450,000 children under the age of 5, die due to Zn deficiency each year. The daily Zn requirement for adults and healthy individuals is 15-20 mg, and the total Zn content in the body should be around 2 g (Reider et al. 2020). Zinc deficiency is generally associated with the consumption of grain-based food products with low Zn content and bioavailability, as well as a lack of dietary diversity. Insufficient Zn intake during pregnancy and in preschool children can lead to various problems, including physical growth retardation, immune system disorders, reproductive disorders, and neurobehavioral development impairments (Wessells, Brown 2012, Miller, Welch 2013, Clemens 2014). It is known that Zn deficiency exists in 30% of agricultural production areas worldwide (Sillanpaa 1982, Barut et al. 2017). Although agricultural soils generally contain an abundance of total Zn, several factors (such as soil temperature, pH, lime, phosphorus, organic matter content, etc.) affect the availability of Zn to plants. Therefore, agronomic biofortification, which involves increasing the accumulation of target nutrients in edible plant tissues through fertilization or other triggering factors, is considered a simple and short-term approach to obtaining functional agricultural products and higher yields of Zn-deficient crops, as well as addressing Zn nutrient deficiency. The application of Zn to plants through foliar and root treatments can solve problems in plant production and provide an effective solution to Zn deficiency in humans (Çakmak 2008, Prasad et al. 2014, Barut et al. 2017). In particular, enrichment with Zn in microgreen production, which is a high-nutrient plant-based production approach without genetic modification, is considered an important consumption method that ensures high bioavailability of trace elements (Kyriacou et al. 2019, Nayak et al. 2021). Microgreens, which can be produced from various species including wild edible plants, can be easily grown in urban gardening in a relatively short time (7-21 days). Additionally, the consumption of microgreens can guarantee a rich and complete diet that provides various essential nutrients, including ascorbic acid and carotene, which characterize these plants, as well as high absorption of Fe and Zn (Di Gioia, Santamaria 2015, Xiao et al. 2016).

This study aimed to evaluate the effects of different doses of $ZnSO_4$ (0, 5, 10, 20 mg kg^{-1}) applied into the nutrient solution on the yield and content of Zn and other essential elements (K, P, Ca, Mg, Fe, Cu, Zn, Mn) during the production of microgreens from cauliflower, broccoli, and cabbage, all belonging to the Brassicaceae family.

MATERIAL AND METHODS

Experiment site and growing system

Microgreens of cauliflower, broccoli, and cabbage were grown under controlled conditions in a greenhouse of the Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ege University (22±5°C).

Three commonly consumed microgreen species, 'Igloo' cauliflower (*Brassica oleracea* L. var. *viridis*), 'The Atlantis' broccoli (*Brassica oleracea* L. var. *italica*) and 'The Bayraklı 85' cabbage (*Brassica oleracea* L. var. *capitata f. alba*) were selected for the study. Seeds were purchased from an Izmir seeds organization. Before setting up the microgreen experiment, the germination characteristics and capacity of the seeds were examined (Table 1).

Table 1

Germination characteristics and capacity of Brassica microgreen seeds

Common name	Botanical name	Seed (1 g)	Germination time (day)	Opt. germination temp. (°C)	Germination rate of seeds (%)		
					day 5	day 8	day 10
Cauliflower	*Brassica oleracea* L. var *viridis*	270-320	7-14	24-26	85	95	100
Broccoli	*Brassica oleracea* L. var. *italica*	300-350	3-4	20-22	25	40	65
Cabbage	*Brassica oleracea* var. *capitata f. alba*	280-350	10-15	20-25	60	75	100

Germination capacity; Fifty seeds of each cauliflower, broccoli, and cabbage were placed in Petri dishes prepared in triplicate and moistened with distilled water. The germinated plants in the Petri dishes, where moisture level was checked daily, were checked on the 5^{th}, 8^{th}, and 10^{th} day, and the germination capacities of the seeds were calculated (McCormac, Keefe 1990, Demir, Balkaya 2005, Arın, Balcı 2017). The highest germination percentage was observed in broccoli, while the lowest was found in cauliflower seeds.

Experimental design; Sixty grams of perlite were weighed into plastic pots, and seed sowing was performed on five designated rows in each pot. The experiment consisted of 36 pots, representing 3 different plants × 4 Zn levels × 3 replicates. The pots were monitored for moisture, and irrigation with distilled water was carried out every other day. After germination, a nutrient solution (modified Hoagland nutrient solution) containing different doses of $ZnSO_4$ (0, 5, 10, 20 mg kg^{-1}) was applied twice a week to all plants. Microgreens were harvested on the 20^{th} day after germination.

Mineral analysis

The fresh weights of the microgreens were recorded, and then the plants were dried at 60-65°C. After drying, the samples were ground and prepared for analysis. One gram of a sample was weighed into a porcelain crucible and incinerated at 350°C for 8 hours. The ashed samples were treated with 0.5 M HCl to prepare the extraction solution. The nutrient element content (K, P, Ca, Mg, Fe, Cu, Zn, and Mn) of samples prepared by the dry combustion method was determined using atomic absorption spectroscopy (Munter, Grande 1981, Kacar 2010) and flame photometry (Brown, Lilleland 1946).

Statistical analysis

The collected data were subjected to analysis of variance using the General Linear Models procedure in JMP Pro 16 (SAS Institute Inc. 2021) version. Significant differences between groups were analyzed using the Tukey post-hoc multiple comparison procedure at $p<0.01$ (Carver 2019).

RESULTS AND DISCUSSION

This study examined the effects of increasing Zn levels on fresh weight, dry weight, and nutrient element contents of microgreens from the Brassicaceae family, including broccoli, cauliflower, and cabbage. The dry weights of microgreens were found to be statistically significant with increasing Zn doses, while their fresh weights showed no statistically significant differences among the varieties (Table 2). When the fresh weights of microgreens were evaluated overall, it was observed that broccoli microgreens had higher weights compared to cauliflower and cabbage (Figure 1). No statistically significant difference in fresh weight was observed between cauliflower and cabbage. As expected, fresh weight is influenced by the seed density and germination rate of each species, and it was found that broccoli, which has the highest germination capacity, also had a higher fresh weight. On the other hand, cabbage, which has the lowest germination capacity, had a lower fresh weight compared to the other two varieties. When the dry weights of microgreens were examined, it was observed that cauliflower reached the highest value (0.67 g) at 5 mg kg^{-1} Zn application. The fresh and dry weights of microgreens in this study were lower compared to a rocket, red cabbage, and red mustard microgreens grown under a similar cultivation system. According to Di Gioia et al. (2019), increasing Zn applications did not have a significant effect on the yield of *Carum copticum*.

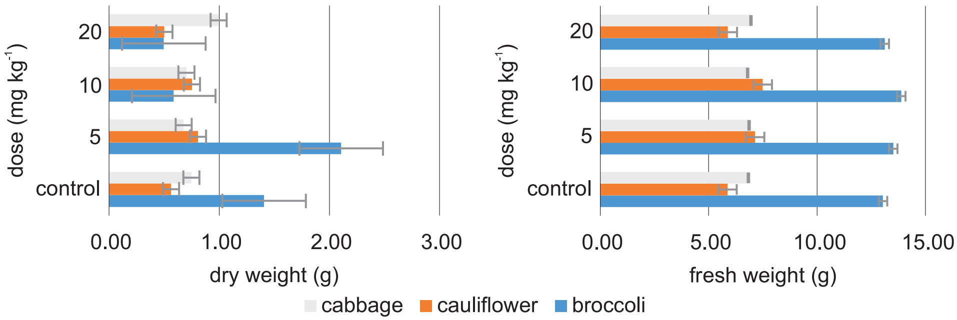

Fig. 1. Effect of increasing Zn applications on broccoli, cauliflower and cabbage microgreens on fresh and dry weight

Table 2

Effect of Zn applications on dry and fresh yield of microgreens

Species (S)	Zn (mg kg^{-1})	Dry weight (g)	Fresh weight (g)
Broccoli	0	0.450±0.040^{b}	13.04±0.400^{a}
	5	0.560±0.080^{a}	13.51±0.410^{a}
	10	0.470±0.030^{efg}	13.89±0.640^{a}
	20	0.470±0.030^{g}	13.12±0.400^{a}
Cauliflower	0	0.530±0.030^{fg}	5.870±0.410^{b}
	5	0.670±0.030^{d}	7.150±0.400^{b}
	10	0.580±0.060^{d}	7.500±0.400^{b}
	20	0.530±0.030^{g}	5.890±0.420^{b}
Cabbage	0	0.540±0.000^{de}	6.830±0.400^{b}
	5	0.590±0.000^{def}	6.870±0.490^{b}
	10	0.460±0.020^{def}	6.950±0.410^{b}
	20	0.480±0.020^{c}	6.860±0.130^{b}
p value	**		

Tukey post-hoc test was used. Means followed by different letters in each column are significantly different at $p<0.01$(**)

The effects of increasing Zn applications on the nutrient element content of microgreens were determined (Table 3). It is known that Zn triggers many metabolic activities in plants. The changes in the macroelement content of microgreens due to increasing Zn applications are shown in Figure 2. The phosphorus (P) content of microgreens reached the highest level at 5 mg kg^{-1} Zn application. In a study examining the effects of different Zn applications on maize growth, Çelik (2000) reported that the highest P content was found at 6 mg kg^{-1} Zn application and increasing Zn applications reduced the P content. Another study on rice by Taban (1995) indicated that rice P content decreased with increasing Zn doses. In this study, it was observed that the potassium (K) content of microgreens varied among the

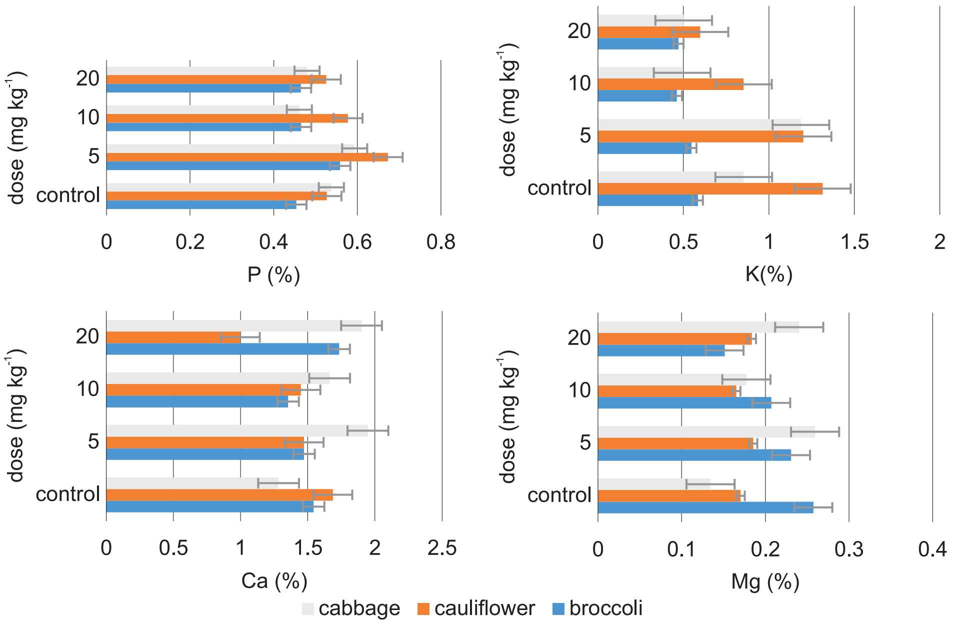

Fig. 2. Effect of increasing Zn applications on P, K, Ca and Mg contents of broccoli, cauliflower and cabbage microgreens

Table 3

Effect of increasing Zn applications on P, K, Ca and Mg contents of broccoli, cauliflower and cabbage microgreens

Species (S)	Zn (mg kg^{-1})	P (%)	K (%)	Ca (%)	Mg (%)
Broccoli	0	0.450±0.040^{d}	0.560±0.010^{de}	1.550±0.070^{bcde}	0.260±0.020^{a}
	5	0.560±0.080^{bc}	0.540±0.010^{ef}	1.480±0.070^{cde}	0.250±0.020^{ab}
	10	0.470±0.030^{d}	0.450±0.010^{g}	1.360±0.070^{def}	0.240±0.020^{abc}
	20	0.470±0.030^{d}	0.460±0.010^{g}	1.740±0.070^{abc}	0.170±0.020^{cd}
Cauliflower	0	0.530±0.030^{c}	1.350±0.010^{a}	1.690±0.070^{abcd}	0.170±0.020^{bcd}
	5	0.670±0.030^{a}	1.220±0.010^{b}	1.480±0.070^{cde}	0.170±0.020^{bcd}
	10	0.580±0.060^{b}	0.850±0.010^{c}	1.450±0.070^{cde}	0.170±0.020^{cd}
	20	0.530±0.030^{c}	0.610±0.010^{d}	1.000±0.070^{ef}	0.220±0.020^{abcd}
Cabbage	0	0.540±0.000^{c}	0.860±0.010^{c}	1.290±0.070^{f}	0.160±0.020^{d}
	5	0.590±0.000^{b}	1.190±0.010^{b}	1.950±0.070^{a}	0.280±0.020^{a}
	10	0.460±0.020^{d}	0.490±0.010^{fg}	1.670±0.070^{abcd}	0.180±0.020^{bcd}
	20	0.480±0.020^{d}	0.500±0.010^{efg}	1.900±0.070^{ab}	0.230±0.020^{abcd}
p value	**				

Tukey post-hoc test was used. Means followed by different letters in each column are significantly different at $p<0.01$ (**).

varieties. It is known that microgreens are generally rich in K (Singh et al. 2021). However, a decrease in the K content was also determined with increasing Zn applications. While cauliflower and broccoli microgreens reached the highest K content in the control treatment, cabbage had the highest K content at 5 mg kg^{-1} Zn dose. Taban and Alpaslan (1996) reported a decrease in maize K content with increasing Zn applications, while Çelik (2000) stated that the highest K content in maize was obtained with a 6 mg kg^{-1} Zn application. Weber (2017) found that the microgreens of broccoli had higher contents of P, K, Mg, and Ca compared to the mature stage of the plant.

In another study investigating the macro- and microelement content of Brassicaceae family microgreens, the order of macro-element quantities was reported as K>P>Ca>Mg (Aytemiş, 2021). Waterland et al. (2017) examined the nutrient element content of cabbage plants at the microfilial, baby leaf, and mature stages and found that nutrient element concentrations were higher during early leaf development. There is an antagonistic relationship between Zn and calcium, and it has been reported that calcium applications reduce Zn absorption (Sadana, Takkar 1985, Rietra et al. 2017). However, in our study, it is observed that the effects of increasing Zn applications on the microgreen calcium content varied among varieties. The highest calcium content was determined in cauliflower microgreens in the control treatment, while in broccoli, it was observed at 20 mg kg^{-1} Zn application, and in cabbage, it was found at 5 mg kg^{-1} Zn application. It is known that microgreen forms with short growth cycles covering early growth stages generally do not experience calcium deficiency (Gupta et al. 2016). Plants are known to have similar capabilities for calcium and magnesium accumulation (Broadley et al. 2004). When the magnesium contents of microgreens were examined, it was observed that the magnesium contents of the varieties were influenced by increasing Zn. The highest magnesium content was determined in broccoli in the control treatment, in cauliflower at 20 mg kg^{-1} Zn application, and in cabbage at 5 mg kg^{-1} Zn application.

The effects of Zn enrichment on the microelement content of microgreens are shown in Table 4. The copper content of broccoli was higher compared to cabbage and cauliflower, with the control treatment (8.90 mg kg^{-1}) having the highest concentration. Cabbage microgreens had the highest copper content (8.68 mg kg^{-1}) at 5 mg kg^{-1} Zn dose. The iron content decreased with increasing Zn applications in cabbage and broccoli, while it increased in cauliflower. The antagonistic relationship between Zn and copper and iron is known to be due to the shared plasma membrane carriers (P3A-type H-ATPases and P1B-Zn-ATPases, respectively) – Rietra et al. (2017). The zinc content of microgreens also increased with increasing Zn applications. It was determined that microgreen varieties had different Zn uptake potentials, with the highest Zn content being observed in cauliflower at 10 mg kg^{-1} Zn application and the lowest Zn content in cabbage in the control treatment. The manganese

Table 4

Effect of increasing Zn applications on the Cu, Zn, Fe and Mn contents of broccoli, cauliflower and cabbage microgreens

Species (S)	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
Brokoli	0	8.900±0.510^{a}	121.5±4.290^{e}	81.25±2.460^{efg}	38.00±1.630^{bcd}
	5	8.100±0.360^{abc}	242.3±3.490^{cd}	92.75±1.250^{cd}	40.75±1.250^{ab}
	10	7.380±0.170^{bcd}	254.5±4.290^{bc}	77.25±2.060^{fg}	38.75±2.060^{bc}
	20	6.980±0.170^{cd}	266.25±4.090^{b}	72.25±0.850^{g}	34.75±2.060^{bcd}
Cauliflower	0	7.480±0.210^{bcd}	65.25±4.090^{f}	92.75±0.850^{cd}	39.75±2.060^{ab}
	5	6.880±0.170^{cd}	137.8±4.300^{e}	88.75±1.250^{de}	32.25±0.850^{cd}
	10	6.330±0.130^{de}	290.8±4.110^{a}	115.5±2.250^{b}	21.75±1.650^{e}
	20	5.330±0.130^{e}	310.5±4.290^{a}	138.8±3.680^{a}	20.50±1.040^{e}
Cabbage	0	7.580±0.250^{bcd}	58.25±4.090^{f}	85.75±2.460^{def}	30.75±0.480^{d}
	5	8.680±0.290^{ab}	224.8±4.640^{d}	99.50±2.100^{c}	46.75±1.250^{a}
	10	7.780±0.330^{abc}	251.8±3.970^{bc}	87.25±1.250^{de}	33.75±1.650^{bcd}
	20	7.550±0.210^{bcd}	266.5±4.510^{a}	89.00±1.870^{de}	21.00±0.410^{e}
p value		**			

Tukey post-hoc test was used. Means followed by different letters in each column are significantly different at $p<0.01$ (**).

content of microgreens, like other microelements, decreased with higher Zn applications (>5 mg kg^{-1}). When the effect of varieties was evaluated, the highest manganese content was found in cabbage at 5 mg kg^{-1} Zn application. Xiao (2016) examined the microelement content of microgreens and found higher concentrations of iron in all species. The concentrations of iron (0.47-0.84 mg 100 g^{-1} FW), Zn (0.22-0.51 mg 100 g^{-1} FW), copper (0.04-0.13 mg 100 g^{-1} FW), and manganese (0.17-0.048 mg 100 g^{-1} FW) were reported to vary within these ranges. Weber (2016) stated that lettuce microfilial leaves contained 2 to 3 times more iron than mature vegetables, but cabbage microfilial leaves contained significantly higher amounts of microelements compared to lettuce. Lenzi et al. (2019) compared three wild leafy species harvested at the microgreen and baby leaf stages (Sanguisorba minor Scop., Sinapis arvensis L., and Taraxacum officinale Weber ex F. H. Wigg.). They found that Sanguisorba minor was richer in iron and copper during the baby leaf stage, while Sinapis arvensis and Taraxacum officinale microgreens were richer in microelements than the baby leaves. Changes in microelement contents by varieties are shown in Figure 3.

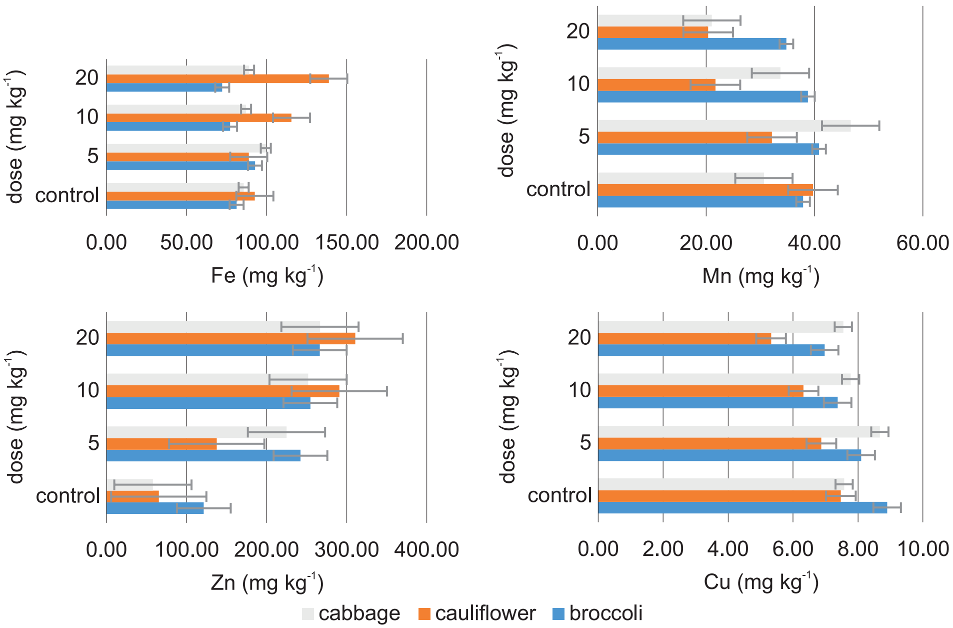

Fig. 3. Effect of increasing Zn applications on Cu, Zn, Fe and Mn contents of broccoli, cauliflower and cabbage microgreen

CONCLUSIONS

Food safety is one of strategically important issues in many countries. Especially, Zn deficiency in humans is very important since it impacts a great share of the world's population. In this regard, the main problem is inadequate Zn intake. Solutions should be developed to improve the health and life quality of billions of people. In this context, microgreens and their biofortification will provide a simple solution to a complex public health problem. The success of this strategy, which has the potential to easily, inexpensively, and quickly overcome Zn deficiency, relies on the sustainability of the production process, the selection of high-quality and reliable products, and the optimization and standardization of the biofortification process. The study demonstrates that microgreens from the Brassicaceae family, such as cauliflower, broccoli, and cabbage, can be produced through biological enrichment with Zn, and they can be evaluated as alternative products for improving Zn deficiency in humans. It is also believed that these microgreens can be consumed as fortified foods not only for Zn but also for their calcium, sodium, iron, and manganese. The highest Zn content is achieved in cauliflower, broccoli, and cabbage microgreens when 20 mg kg^{-1} Zn is applied. It is found that other nutrient elements (P, K, Ca, Mg, Fe, Cu, Mn) are at optimum levels in 5 mg kg^{-1} Zn treatment application. In the coming years, Zn enriched microgreens as well as their bioactive compounds, will be accepted as important healthy dietary intake. Therefore, it is suggested to conduct crucial, comprehensive and multidisciplinary studies for the benefit of human health.

REFERENCES

Arın, L., ve Balcı, H. (2017) 'The effect of some organic acid and plant-derived material treatments on the germination, emergence and seedling quality of broccoli', *Turkish Journal of Agriculture-Food Science and Technology*, 5(13), 1792-1795.

Aytemiş, Z. (2021) 'Disinfection of Salmonella enterica Typhimurium and Escherichia coli O157: H7 during Spray Irrigation with Chlorinated Water in Radish microgreens' (*Master's thesis, Institute of Science and Technology*).

Barut, H., Şimşek, T. and Aykanat, S. (2017) 'The effect of zinc application on yield and some agricultural characteristics of durum wheat cultivars', *Turkish Journal of Agricultural Research*, 4(1), 10-23.

Broadley, M.R., Bowen H.C., Cotterill HL, Hammond J.P., Meacham, M.C., Mead, A., White, P.J. (2004) 'Phylogenetic variation in the shoot mineral concentration of angiosperms', *Journal of Experimental Botany*, 55: 321-336.

Brown, J., Lilleland, O. (1946) 'Rapid determination of potassium and sodium in plant materials and soil extracts by flame photometry. In: Proceedings of the American Society for Horticultural Science', Amer Soc Horticultural Science 701 North Saint Asaph Street, Alexandria, Va 22314-1998, pp. 341-346.

Carver, R. (2019) 'Practical data analysis with JMP', *SAS Institute Inc*.

Clemens, S. (2014) 'Zn and Fe biofortification: The right chemical environment for human bioavailability', *Plant Science*, 225, 52-57.

Çakmak, İ., (2008) 'Enrichment of cereal grains with zinc: agronomic or genetic biofortification?' *Plant Soil*, 302: 1-17.

Çelik, H. (2000) 'The effects of different zinc fertilizers on dry matter yield and some nutrient content of corn plant' (*Doctoral dissertation, Bursa Uludag University Turkey*).

Demir, E., and Balkaya, A. (2005) 'Determination of seed maturation periods in leaf cabbage genotypes (Brassica oleracea var. acephala) in samsun ecological conditions', *Anatolian Journal of Agricultural Sciences*, 20(2), 52-56.

Di Gioia, F., Petropoulos, S. A., Ozores-Hampton, M., Morgan, K., & Rosskopf, E.N. (2019) 'Zinc and iron agronomic biofortification of Brassicaceae microgreens', *Agronomy*, 9(11), 677.

Di Gioia, F., Santamaria, P. (2015) 'Microgreens-novel fresh and functional food to explore all the value of biodiversity', *Ecologica Srl: Bari, Italy*, 2015; ISBN 9788890928932.

Gupta, N., Ram, H., & Kumar, B. (2016) 'Mechanism of Zinc absorption in plants: uptake, transport, translocation and accumulation', *Reviews in Environmental Science and Bio/Technology*, 15, 89-109.

Kacar, B., İnal, A. (2010) 'Plant Analysis', *Nobel*, Ankara.

Kyriacou, M.C., El-nakhel, C., Graziani, G., Pannico, A., Soteriou, G.A., Giordano, M., Ritieni, A., Pascale, S. (2019) 'Functional quality in novel food sources: Genotypic variation in the nutritive and phytochemical composition of thirteen microgreens species', *Food Chemistry*, 277, 107-118.

Lenzi, A., Orlandini, A., Bulgari, R., Ferrante, A., Bruschi, P. (2019) 'Antioxidant and mineral composition of three wild leafy species: A comparison between microgreens and baby greens', *Foods*, 8(10), 487.

Marreiro, D.D.N., Cruz, K.J.C., Morais, J.B.S., Beserra, J.B., Severo, J.S., De Oliveira, A.R.S. (2017) 'Zinc and oxidative stress: current mechanisms', *Antioxidants*, 6(2), 24.

McCormac, A.C., Keefe, P.D. (1990) 'Cauliflower (Brassica oleracea L.) seed vigour: imbibition effects', *Journal of Experimental Botany*, 41(7), 893-899.

Miller, B.D.D., Welch, R.M. (2013) 'Food system strategies for preventing micronutrient malnutrition', *Food Policy*, 42, 115-128.

Munter, R.C. and Grande, R.A. (1981) 'Plant tissue and soil exract analysis by ıcp atomic emission spectrometry. In: Developments in Atomic Plasma Spectrochemical Analysis', Ed. R.M. Barnes, Heydenand Song London, England, 653-672 pp.

Nayak, S.L., Dhami, K.S., Sahu, D. (2021) 'Microgreens: A potential source of energy', *Biotica Research Today*, 3;3(2), 098-9.

Prasad, R., Shivay, Y.S., Kumar, D. (2014) 'Agronomic biofortification of cereal grains with iron and zinc', *Advances in Agronomy*, 125: 55-91.

Reider, C.A., Chung, R.Y., Devarshi, P.P., Grant, R.W., Hazels Mitmesser, S. (2020) 'Inadequacy of immune health nutrients: Intakes in US adults, the 2005-2016 NHANES', *Nutrients*, 12, 1735, available: DOI:10.3390/nu12061735

Rietra, R.P.J.J., Heinen, M., Dimkpa, C.O., Bindraban, P.S. (2017) 'Effects of nutrient antagonism and synergism on yield and fertilizer use efficiency', *Communication Soil Science and Plant Analysis*, 48, 1895-1920.

Sadana, U.S., Takkar, P.N. (1985) 'Zinc equilibria in submerged sodic soils as influenced by application of amendments', *Fertilizer Research,* 6, 91-96.

SAS Institute Inc. (2021). JMP Pro ® Version 16.0, Cary, North Carolina, USA.

Sillanpaa, M. (1982) 'Micro Nutrients and the Nutrient Status of Soils', *A Global Study. FAO Soils Bulletin*, No. 48, FAO, Rome.

Singh, M., Choudhary, A., Kumar, A. (2021) 'Microgreens: A Nutritional Food', *Biotica Research Today*, 3(7), 612-613.

Taban, S. (1995) 'The effect of zinc given to the soil in ıncreasing amounts on nitrogen, phosphorus and potassium contents of rice plant', *TR. Journal of Agriculture and Forestry*, 19:119-125.

Taban, S., Alpaslan, M. (1996) 'The effects of zinc fertilization on zinc, ıron, copper, manganese and chlorophyll contents of maize', *Journal of Engineering Sciences*, 2(1), 69-73.

Waterland, N. L., Moon, Y., Tou, J. C., Kim, M. J., PenaYewtukhiw, E. M., Park, S. (2017) 'Mineral content differs among microgreen, baby leaf, and adult stages in three cultivars of kale', *HortScience,* 52(4), 566-571.

Weber, C.F. (2016) 'Nutrient content of cabbage and lettuce microgreens grown on vermicompost and hydroponic growing pads', *Journal Horticulture*, 3(4), 1-5.

Weber, C.F. (2017) 'Broccoli microgreens: a mineral-rich crop that can diversify food systems', *Frontiers in Nutrition*, 4, 7.

Wessells, K.R., Brown, K.H. (2012) 'Estimating the global prevalence of zinc deficiency: Results based on zinc availability in national food supplies and the prevalence of stunting', *PLoS ONE*, 7(11), e50568, available: doi.org/10.1371/journal.pone.0050568

Xiao, Z., Codling, E.E., Luo, Y., Nou, X. Lester, G.E. and Wang, Q. (2016) 'Microgreens of Brassicaceae: Mineral composition and content of 30 varieties', *Journal Food Composition and Analysis*, 49, 87-93.