Elemental composition of the stems of *Beta vulgaris* L. var. *conditiva* Alef. as an indicator of increasing the profitability of functional products

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**Abstract.** The features of the elemental composition of seeds (stems) of beet (*Beta vulgaris* L. var. *conditiva* Alef.) of three varieties of selection of ARRIVG – branch of FSBSI FSCVG. The largest share of mineral elements is potassium (more than 1% of dry matter), as well as calcium, sodium, magnesium, and phosphorus (more than 0.4-0.5% each element). The seeds of the Karina variety accumulate the maximum amount of potassium, calcium, chlorine, and sulfur. According to the content of sodium and phosphorus in the seeds, a variety of Zhukovchanka, magnesium and iron – Demetra is distinguished. Of the microelements, zinc and manganese predominate. A significant variability in the accumulation of elements by seeds of different beet varieties is shown. Significant varietal differences were observed in the accumulation of titanium, aluminum (variability of more than 70%), silicon, manganese, nickel, rubidium (more than 60%). The accumulation of sulfur, chromium, lead, zirconium, and zinc is more stable in varieties. It is noted that when seeds germinate in the seed skin, the content of sodium and chlorine increases sharply (by 3.4-7 times) in comparison with the original seeds.

1. Introduction

Human nutrition requires at least 22 mineral elements [1,2]. They can be provided with an appropriate diet. However, it is estimated that more than 60% of the 6 billion people in the world are deficient in iron (Fe), more than 30% in zinc (Zn), 30% in iodine (I), and 15% in selenium (Se). In addition, calcium (Ca), magnesium (Mg), and copper (Cu) deficiencies are common in many developed and developing countries [3-7]. This situation is explained by the production of products in areas with low mineral phyto availability and/or consumption of (main) crops with low mineral content, as well as a lack of fish or animal products in the diet [2,4,5,8,9]. Therefore, the introduction of vegetable products with high nutritional value into the diet is the important factor in maintaining human health.

Beet (*Beta vulgaris* L. var. *conditiva* Alef.), widely used among the population, has a rich fiber structure, facilitates digestion. It is very rich in B vitamins (B1, B2, B3 and B6) and folic acid [10]. Root crops contain phenolic compounds, both dissolved and located in the structure of the cell wall, and betalain compounds [11]. The pigments that give the root crop a red color are biologically active compounds and provide antioxidant activity of the product [12,13].
For beet, it is typical to form clusters of 2-6 closely fused fruits on the inflorescences [14-16]. Inside each fruit, as a rule, there is a single kidney-shaped seed, which is surrounded by a pericarp formed from overgrown flower bed and perianth [17].

The accumulation of mineral elements, in addition to its role in human nutrition, is also important for germinating plant seeds. The mineral nutrients of seeds are a source of essential elements for sprouts and developing plants. A comparative study of the concentrations of 13 macro- and microelements (K, Rb, Mg, Ca, Mn, Fe, Co, Cu, Zn, Mo, B, P and S) in the seeds and leaves of 35 major species of herbaceous vascular plants growing on both limestone and silicate (non-calcic) soils showed that the concentrations of Rb and Co in plant seeds originating from limestone soils were on average about half of the silicate soils. Concentrations of Mn, Mg, Zn, and P in seeds were or tended to be lower or slightly lower in limestone soil plants, whereas average concentrations of Ca and Mo were higher [18].

However, studies on the elemental composition of beet seeds, especially taking into account varietal characteristics, are not enough to produce micro-green and seedlings. Therefore, the purpose of this work is to determine the elemental composition of stems of various Beta vulgaris L. var. conditiva Alef. varieties.

2. Materials and methods
Beet seeds of new promising varieties developed in ARRIVG – branch of FSBSI FSCVG – Zhukovchanka, Karina and Demetra are taken as the object of research.

Zhukovchanka and Demetra varieties were obtained by crossing Aya varieties (Russia) and Larka (the Netherlands) with further individual and family selection based on the uniformity of the rounded shape of root crops. Karina is obtained by individual-family selection from the population of sample K1 (Canada).

Determination of the content of chemical elements in seeds was performed by x-ray fluorescence analysis (RFA) at the Institute of Geochemistry SB RAS (Irkutsk, Russia) on an x-ray spectrometer S8 Tiger, Bruker (Germany). The procedure for preparing plant samples for RFA is as follows: grinding in an agate mortar; taking a sample – 0.5 g; pressing the emitter tablet from the sample plant on a substrate of boric acid.

3. Results
The content of macro-and microelements is one of the important characteristics of the nutritional value of plants, including functional food products [19].

Our research has shown that beet is an accumulator of such important macronutrients as K (more than 1% of dry matter in all varieties), as well as Na, Ca, Mg and P (more than 0.4-0.5%). The accumulation of silicon and iron in beet seeds is estimated at no more than tenths of a percent (table 1).

Varietal differences in the accumulation of microelements in seeds are well expressed. The seeds of the Karina variety accumulate the maximum amount of potassium, calcium, chlorine, and sulfur. According to the content of sodium and phosphorus in the seeds, a variety of Zhukovchanka, magnesium and iron – Demetra is distinguished.

From microelements in the largest amount (more than 20 ppm) manganese, zinc, barium, strontium accumulate, in the minimum (up to 2-3 ppm) - zirconium, lead, chromium, Nickel.

Significant varietal differences were observed in the accumulation of titanium, aluminum (variability of more than 70%), silicon, manganese, nickel, rubidium (more than 60%). The accumulation of sulfur, chromium, lead, zirconium, and zinc is more stable in varieties.

Previously, we studied the elemental composition of seeds of 5 varieties of different types of cabbage crops. It is shown that there is a wide variability of indicators for the microelements silicon, aluminum and titanium [20]. It is shown on seeds of 6 onion varieties that a wide variability of indicators is also observed for the microelements silicon, aluminum and the microelement titanium.
Mainly for the majority of macro-and microelements in onion seeds and various types of cabbage crops, the values of their concentrations are in the narrow range.

Table 1. Elemental composition of seeds (compound fruits) of various varieties of table beet.

| Elemental composition | Zhukovchanka | Demetra | Karina | Range of variation, % |
|-----------------------|--------------|---------|--------|-----------------------|
| **Macroelements, % on dry matter** |             |         |        |                       |
| Na                    | 0.561        | 0.499   | 0.463  | 17.5                  |
| Mg                    | 0.554        | 0.805   | 0.696  | 31.2                  |
| Al                    | 0.0205       | 0.0254  | 0.0073 | 71.3                  |
| Si                    | 0.110        | 0.113   | 0.039  | 65.5                  |
| P                     | 0.64         | 0.47    | 0.72   | 34.7                  |
| S                     | 0.27         | 0.26    | 0.28   | 7.1                   |
| Cl                    | 0.37         | 0.26    | 0.39   | 33.3                  |
| K                     | 1.51         | 1.10    | 1.49   | 27.2                  |
| Ca                    | 0.65         | 0.82    | 1.11   | 41.4                  |
| **Microelements, ppm** |             |         |        |                       |
| Fe                    | 0.0171       | 0.0192  | 0.0084 | 56.3                  |
| Ti                    | 23           | 19      | 4      | 82.6                  |
| Cr                    | < 2          | 2       | < 2    | 0                     |
| Mn                    | 37           | 114     | 38     | 67.5                  |
| Ni                    | 1.3          | 2.8     | 1      | 64.3                  |
| Cu                    | 12           | 14      | 7      | 50.0                  |
| Zn                    | 46           | 52      | 45     | 13.5                  |
| Br                    | < 2          | 7       | < 2    | 71.4                  |
| Rb                    | 6            | 7       | 15     | 60.0                  |
| Sr                    | 33           | 34      | 53     | 37.7                  |
| Zr                    | < 1          | < 1     | < 1    | 0                     |
| Ba                    | 24           | 37      | 23     | 37.8                  |
| Pb                    | < 2          | < 2     | < 2    | 0                     |

The experiment compared the elemental composition of the initial seeds (stems) and the seed rind after seed germination and emergence (table 2).

Table 2. Elemental composition of the initial seeds of various varieties of beet and seed rind after germination of seeds in the darkness.

| Elemental composition | Zhukovchanka | Demetra | Karina |
|-----------------------|--------------|---------|--------|
| **Macroelements, % on dry matter** |             |         |        |
| Na                    | 0.504        | 0.144   | 0.509  |
| Mg                    | 0.542        | 0.574   | 0.764  |
| Al                    | 0.007        | 0.024   | 0.025  |
| Si                    | 0.031        | 0.103   | 0.120  |
| P                     | 0.655        | 0.450   | 0.442  |
| S                     | 0.267        | 0.228   | 0.253  |
| Cl                    | 0.391        | 0.060   | 0.315  |
| K                     | 1.61         | 0.29    | 1.07   |
| Ca                    | 0.67         | 1.65    | 0.88   |
| Fe                    | 0.01         | 0.026   | 0.040  |

The experiment compared the elemental composition of the initial seeds (stems) and the seed rind after seed germination and emergence (table 2).
The following changes in composition were recorded in the seed rind after germination compared to the original seeds (before sowing): the amount of sodium, chlorine, potassium, phosphorus (except for the Demetra variety), rubidium increases; the content of calcium, strontium (except for the Carina variety), as well as titanium, iron and nickel (except for the Demetra variety) decreases; the accumulation of magnesium, sulfur, chromium, lead, zirconium, and partly zinc changes slightly. The sharpest differences were observed in sodium and chlorine. The accumulation of sodium in the seed rind is higher than in the original seeds by 3.4-4 times for different varieties, and the accumulation of chlorine is by 4.4-7 times.

4. Summary

The data obtained in this paper allow obtaining additional information about the quantitative content of macro - and microelements in the seeds (stems) of beet. Of the macronutrients in stems, potassium accumulates in the largest amounts - more than 1% of the dry matter for all varieties, more than 0.4-0.5% of the dry mass is calcium, sodium, magnesium and phosphorus. Of the microelements in the largest amount (more than 20 ppm), manganese, zinc, barium, strontium accumulate. Significant varietal variability in the accumulation of elements by different varieties of beet was noted.

It is shown that after seed germination, the content of sodium and chlorine in the seed rind increases sharply compared to the original seeds.

5. References

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