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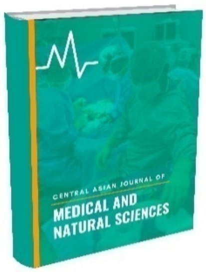

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Assessment of the Nutritional Status of Rocket Salad (Eruca Sativa) in Technogenically Affected Soils

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Abstract: In this article is studied Cinnamonic Forest soils and weakly developed soils (Regosols), technogenically affected by heavy metals, granulated and ungranulated coke powder from the industrial zone of Kremikovtsi metallurgical plant, as well as a natural Leached Cinnamonic Forest soil from the village of Seslavtsi, Sofia region. The technogenically affected soils are characterized by slightly alkaline pH, weak availability of nitrogen, very weak of phosphorous and normal of potassium. Organic matter content in these soils is high, 5.2%, 11.8% and 17.5% due to the coke additives. With the four soils a greenhouse experiment was set up with rocket salad (Eruca sativa Mill) as a test plant. In two of the variants, the soils were additionally contaminated with copper, 500 and 1000 mg/kg. On the three technogenically affected soils the yields are several times lower than on the control soil. There is a tendency of a decrease of the rocket salad yield with adding copper in all the soils, except in the technogenically affected leached Cinnamonic Forest soil (Profile 7). Phosphorous content in plants in the technogenically affected soils is lower than in the control soil and decreases in the variants with copper addition. Higher sodium contents in these soils are also observed in all the variants excluding the control soil. Pollution with copper has a different effect on the macroelement status in the natural Cinnamonic Forest soil and the weakly developed techno- genically affected soils.

Key words: Technogenically affected soils, Macroelements, Copper, Eruca sativa, Coal, Coke.

Introduction

Many human activities, such as industrial production, mining, large amounts of waste, etc., cause soil contamination with heavy metals. It is characteristic of heavy metals that they cause toxic effects in plants in low concentrations compared to those of macronutrients. Arugula is known as unsaturated omega-3 fatty acids, which are usually a component of nuts. Arugula was grown in Bulgaria about 30 years ago, and the wild form (Sisymbrium officinale L.) is found in our flora. It is a crop with a short biological cycle, quickly accumulates leaf mass and extracts nutrients from the soil - mainly nitrogen and potassium. Some authors recommend nitrogen fertilization with rates not higher than 10 kg / da due to nitrate accumulation (up to 4000 mg.kg-1 fresh mass) (Bianco et al., 1997). According to Regulation (EU) № 1258/2011, the maximum levels for nitrates in arugula leaves are 7000 mg.kg-1. A number of authors study different parameters in the cultivation of arugula on soils contaminated with various pollutants (heavy metals, municipal waste). When applying vermicompost from municipal waste, an increase in the content of copper and cadmium and a decrease in the content of manganese in arugula were found (Filho et al., 2011). Saleh (2001) found that arugula and radishes behave like hyperaccumulators. With an increase in the amounts of cadmium and lead in the soil, there is an increase in the intake of these elements in plants without toxic effects, and an increase in biomass, chlorophyll content and some enzymatic activities. In studies by Zhi et al. (2015) found that arugula is tolerant or moderately tolerant to Cu, Hg, Cr, and Cd and highly tolerant to Pb, Ni, and Zn, and can be used as an industrial oil crop in heavy metal contaminants. soil. Nitrogen and potassium are essential nutrients that are absorbed in large quantities compared to other elements. They are necessary for plants to form biomass and for the normal course of basic metabolic processes. An important condition for the absorption of nitrogen is the good supply of soil with potassium and phosphorus. The aim of the study was to determine the effect of man-made soils with physicochemical characteristics, favorable for the fixation of heavy metals in additional contamination with copper on the accumulation of biomass.

The Main Part

Leached Cinnamon forest soil (control) ; It is located on the land of the village of Seslavtsi, south of the village, 1-2 km north-northwest of the site of the Kremikovtsi plant. The soil is Cinnamon Forest with a normally developed profile, well-developed structural aggregates and total ironing. The structure of the profile is A1 - AB - B1 - B2 - B3 - BC - C. Horizon A1 is dark rust-brown, dry and compacted, with a mixed structure - powdery, small to coarse-grained and lumpy. There are unknown primary minerals (individual dark spots) and single rock fragments with a size of 0.1 - 5 cm. With the four studied soils - one control and three man-caused soils, a vascular vegetation experience was set in the vegetation house of IPAZR "N. Pushkarov".

There is no vegetation. The construction of the soil profile is AC Ipl. - AC IIpl. - AC IIIpl. - AC IVpl .. Horizon AC Ipl. has a rusty ash color, partial unhealthy granular-trochoid structure and a noticeable transition to the next horizon. Profile № 13. Leached Cinnamon Forest Soil (control); It is located on the land of the village of Seslavtsi, south of the village, 1-2 km north-northwest of the site of the Kremikovtzi plant. The soil is Cinnamon Forest with a normally developed profile, well-developed structural aggregates and total ironing. The structure of the profile is A1 - AB - B1 - B2 - B3 - BC - C.

Horizon A1 is dark rusty brown, dry and compacted, with a mixed structure - dusty, small to coarse-grained and lumpy. There are unweathered primary minerals (individual dark spots) and single rock fragments with a size of 0.1 - 5 cm. With the four studied soils - one control and three man-caused soils, a vascular vegetation experiment was set in the vegetation house of IPAZR “N. Pushkarov ”. The experiment was conducted in 12 variants. The first 4 variants are without additional added honey, in variants 5 ÷ 8 copper is added in the form of copper acetate in the amount of 500 mg / kg of soil, and in variants 9 ÷ 12 the added copper is in the amount of 1000 mg / kg of soil. After composting with the contaminant for 30 days, the experimental plants were planted - broadleaf arugula (Erusa sativa Mill), in containers of 1 kg - in each container three plants. All options are set in three repetitions. Nitrogen, phosphorus, potassium are imported as a background in all variants in the following quantities: nitrogen - 300 mg / kg, phosphorus - 300 mg / kg and potassium - 150 mg / kg soil. The plants were grown for 30 days, after which the yield in fresh biomass was reported. The following indicators in dry mass were reported: nitrogen - by the method of Keldal, phosphorus - by the aceto-lactate method of P. Ivanov (1986), potassium and sodium - by a flame photometer, calcium and magnesium - by atomic absorption spectrometer "Perkin Elmer" (Page et al., 1982). The analyzes of the soils were performed according to the following methods: mechanical composition - pipette method according to Kaczynski (1958); humus - by oxidation - according to Tyurin (Kononova, 1963); carbonates - according to Scheibler (Penkov et al., 1981); pH - potentiometrically in H2 O and KCl; min. N - modified method of Bremner and Kiney (Bremner, 1965); P2 O5 and K2 O - method of P. Ivanov (Ivanov, 1986). Results and discussion In table. 1 shows the values for pH, mineral content N, P, K, organic matter content, sorption capacity and electrical conductivity of soils. The reaction of the soils is slightly alkaline, which is a prerequisite for good fixation and immobilization of heavy metals. The stock with mineral N and P is weak and very weak, and with K - normal (Ninov et al., 1975). In all three technogenic soils there is an increased content of heavy metals compared to the control soil from the area of Seslavtsi, but the levels for the maximum allowable concentration for industrial terrains are not exceeded (Ordinance № 3, 2008). control leached Cinnamon soil, exceed several times the yields of man-made soils (Fig. 1). The young plants of the technogenic soils are visibly suppressed, difficult to catch and go through a long period of adaptation and formation of a root system. The soil from Profile 7 - Cinnamon forest with technogenic superficial layer of coal dust and high content of soluble salts (Table 1), has the strongest depressing effect on plants and its yields are the lowest, growth is almost not observed (plants remain the size of those planted in the seedling phase). In man-made soils, in addition to the presence of pollutants and salts, the poor water-air regime also has an impact. These soils are visibly destructured, which interferes with normal plant growth. With the introduction of additional pollutant copper (500 mg / kg) in the control soil from Seslavtsi the biomass of the plants decreases (from 37.02 to 34.05 g), while with the introduction of 1000 mg / kg the amount of biomass is significantly reduced - approximately twice and has been statistically proven (Nenova et al., 2015). In the first variant, without additional contamination with honey, the yield of plants from the soil from Profile 7 is the lowest, followed by Profile 6. The plants grow best on the technogenic soil from Profile 8 - several times higher than the yields from Profile 7 (Fig. 1). . The introduction of additional amounts of honey into the soil leads to plant suppression and lower yields. Contamination with more copper (1000 mg / kg soil) has no significant effect and no differences in yields have been demonstrated. The situation is different for plants grown on soil from Profile 7. Here there is even a slight increase in biomass in the variants with additional pollution, but the differences have not been proven (Nenova et al., 2015). Filho et al. (2011) found an increase in arugula yield as well as an increase in Cd and Cu content in plants when applying vermicompost from municipal waste, while Karimi et al. (2013) establish means reduction in yield and changes in macronutrient intake in beans and field mustard grown on soils contaminated with Cd, Pb and Ni. Nitrogen content in plants varies widely in different species, tissues or organs, stage of development, growing conditions and other factors. In general, the variation is between 0.3 - 7% in the dry mass, as in the case of

vegetable plants the values are lower than in the case of legumes. Nitrogen and copper interact in protein synthesis through Cu-containing complexes, with plants with a high N content usually showing symptoms of Cu deficiency, ie an antagonistic effect between the two elements (Kabata-Pendias, 2011). Cu2 + ions are involved in oxidation, photosynthesis and respiration, protein and carbohydrate metabolism, symbiotic N2 fixation, water permeability and other processes in the plant body (Woolhouse and Walker, 1981).

In the experiment, the content of total nitrogen in the leaves of arugula is high and varies between 4.06 and 5.59% in the dry matter. The lowest content is in the soil plants of Profile 7, and the highest - in Profile 6. In case of additional contamination with copper (1000 mg / kg) again the nitrogen content is the lowest in the soil plants of Profile 7. The amount of nitrogen in the plants on the control Cinnamon forest soil is lower than in the technogenic soils (Profiles 6 and 8) in the variants without additional contamination with honey, but in the variants with added honey there is no pronounced tendency. In our previous study (Atanasova et al., 2014) in two types of unpolluted soils (leached Smolnitsa and Alluvial-meadow soil) in the vegetation experiment was found a variation in the amount of total nitrogen in arugula between 5.04 and 5.66% in dry mass in variants with mineral fertilization and lower nitrogen content in organic fertilization (2.70 - 3.68%). Nurzyńska-Wierdak (2009) in a fertilizer experiment with mineral fertilization found a nitrogen content between 5.57 - 5.95% in arugula leaves, ie the nitrogen content in our experiment is close to that found by other authors. The phosphorus content in the dry mass 70 of different crops (expressed as P2 O5) does not exceed 0.5%, and in many cases is about 0.2 - 0.3% (Mengel, 2001). As with nitrogen, the differences depend on the type and organ of the plant. For some seeds, the values may exceed 2%. The soils we study have a low supply of phosphorus. The phosphorus content in the plants grown on the technogenic soils was also reduced in comparison with the control soil - almost twice (Fig. 3). The amount of phosphorus in the plants is the lowest in the variant of technogenic soils with 1000 mg / kg of added honey. The phosphorus content is lowest in the plants on the soil of Profile 7, ie here the entry of this element is blocked. Cu – P interactions show that high P-levels in the soil reduce the mycorrhizal absorption of Cu. On the other hand, high Cu levels inhibit the bioavailability and efficacy of P (Kabata-Pendias, 2011) due to their interaction in poorly soluble phosphates. With potassium in the plants there are no significant differences in the content of control and man-made soils with the exception of the two soils - Profiles 7 and 8, additionally contaminated with copper (1000 mg / kg), where potassium is lowest, ie pollution with honey does not affect the potassium regime of arugula (Fig. 2). Cu – Ca interactions are complex and dependent on the pH range during the growing season and appear to be antagonistic (Kabata-Pendias, 2011). In our study, no Cu – Ca antagonism was observed as a result of copper contamination, and differences in Ca-concentration at the plant level were not demonstrated. The reason for this may be due to the additional acidification of the soils as a result of the addition of Cu acetate and the reduction of the immobilization of calcium. Higher values of the electrical conductivity of the soil solution in technogenic soils are also an indication of a higher content of water-soluble salts of Na and Ca. Wyszkowski et al. (2009) also did not find an antagonistic effect, but an increase in the content of nitrogen, magnesium and especially calcium in the aboveground parts of oats with the addition of pollutant copper in the soil. Similar to calcium, in man-made soils the content of magnesium values in plants does not change significantly with different amounts of added pollutant. In the control soil we have a synergistic effect, also observed by other authors (Kabata-Pendias, 2011). In our research there is no decrease in the concentration of copper due to the so-called "dilution effect" as a result of accelerated growth and increase in arugula yield as a result of fertilization, and vice versa - phytoaccumulation effect (Nenova et al., 2015). . There are significant differences in the sodium content in the plants grown on the control soil and the technogenic soils (Fig. 3). The content of this element in the plants on the control soil is an order of magnitude lower than that of the plants on the technogenic soils, regardless of the amount of added copper and corresponds to the higher values of electrical conductivity reported in the technogenic soils.

Conclusion

The technogenic soils from the industrial zone of MK "Kremikovtsi", polluted with heavy metals and coke dust, have an unfavorable water-air regime. There is an imbalance in the nutrition of macronutrients in these soils in the absence and presence of additional amounts of honey compared to the natural uncontaminated leached Cinnamon forest soil. There was a decrease in yields in man-made soils compared to the control. Cu-P antagonistic interactions are observed due to phosphorus immobilization. No Cu-Ca and Cu-Mg antagonism was observed as a result of copper contamination. The high salt content in the technogenic soils leads to an increase in the levels of Na and Ca in the plants.

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