ACCUMULATION OF ESSENTAL METALS IN LEAVES AND ROOTS OF CUCUMBER GROWN IN THE PRESENCE OF SOLID RESIDUES FROM A BIOGASS PLANT

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Abstract
Large amounts of solid residues (SR) remain after the process of energy production in a biogas plant. This material may be utilized directly or after composting (CSR) as organic fertilizers. The study was conducted to investigate the influence of various amounts of SR and CSR from biogas plant on growth, accumulation and distribution of essential metals in the leaves and roots of young cucumber plants. In both leaves and roots, concentration of K was the most responsive to treatments of macronutrients, and concentration of Mn of micronutrients. Overall, concentrations of all micronutrients, apart from Zn, were under optimal level in all treatments. Even though the concentration of nutrients in SR and CSR were limited, they significantly influenced content of essential metals and their distribution in leaves and roots of cucumber.

Introduction
The use of renewable sources in process of energy production is getting more attention over time due to the need to replace fossil fuels with renewable sources of energy. Therefore, the use of biomass of various origins (harvest residues, manure, municipal waste or plants produced to be used in biogas plants) has became favored and stimulated by policies. Since the features of input material in biogas plants may vary, the composition of residues after the usage of this material to produce biogas may vary as well. Apart from the nutritive value of residues from biogas plants, they can also contribute to improvement of the soil structure since they are rich in organic matter [1].
One of the biogas facilities on the territory of Vojvodina is “Mirotin-Energo” in Vrbas, which produces 36.000 t of fermented and composted fermented residues per year. Due to their chemical composition, solid and composted solid residues (SR and CSR, respectively) have the potential to be used as organic fertilizers in agriculture [2], [3]. Therefore, the main aim of the present study was to investigate the potential use of SR and CSR from biogas facility “Mirotin-Energo” as source of nutrients in cucumber production.

Experimental
The experiment was conducted in semi-controlled conditions of a greenhouse. Seeds of cucumber (*Cucumis sativus* L., cultivar “Tajfun”), were sown in pots V=750 mL, containing a mixture of 400 mL agroperlite (Agroperlit Extra, Termika Zrenjanin) and SR or CFR (either 5, 25 or 50 g), as described in Tab. 1. Each treatment was divided into two sub-treatments: one watered with deionized water (DW) and the other with ¼ strength solution after Hoagland and Arnon [4] (H) (Tab. 2). Additional two groups of plants were grown only in agroperlite (without addition of SR or CSR) and watered with either ¼ or ½ strength H (controls). The experiment was set in 3 replications, with 7 plants per replication.

Table 1. Composition of solid residue (SR) and composted solid residue (CSR) from biogas plant "Mirotin-Energo", Vrbas. Results are averages of six replications and refer to contents of ash and mineral elements in dry matter. DM, dry matter.

Residue from biogas plant	DM	Ash	K	Ca	Mg	Fe	Zn	Cu	Mn
	%					ppm			
SR	29.16	9.45	0.11	1.16	0.45	580	63.24	5.20	127.99
CSR	27.65	34.56	0.51	8.35	1.26	980	91.91	15.62	351.71

One month after sowing, plants were harvested, roots were briefly rinsed with deionized water (DI), excess liquid removed by blotting paper, and plant material dried at 70 ^{o}C until constant mass. Dry mass (DM) of leaves, stems and roots were measured. Concentrations of essential metals in leaves and roots were assessed by flame photometry (K and Ca) and by atomic absorption spectro-photometry (Mg, Fe, Zn, Cu and Mn).

Table 2. Nutrient treatments to which cucumber was exposed. To each pot containing 400 mL of agroperlite were added 5, 25 or 50 g of solid residue (SR) or composted solid residue (CSR). DW, deionized water; ¼H and ½H, ¼ and ½ strength nutrient solution after Hoagland and Arnon [4].

Composition of nutrient medium	Treatments													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
SR (g)			5	5	25	25	50	50						
CSR (g)									5	5	25	25	50	50
DW				*		*		*		*		*		*
¼ H (control)	*		*		*		*		*		*		*	
½ H (control)		*												

Results and discussion

Concentration of K increased in the presence of 25 and 50 g of SR and CSR in both leaves and roots, but it was about 10% higher in leaves (Tab. 3, Fig. 1). Cucumber has high requirements for K (higher than for N). According to [5], in leaves of treatments 6, 7, 8 concentration of K was optimal, in treatments 5, 12, 13 and 14 it was low and in 1-4 and 9-10 K was deficient. Concentration of Ca increased in the presence of SR and CSR in both leaves and roots, it was in the optimal range and its concentration in leaves varied less than concentrations of K and Mg (Fig. 1). The concentration of Mg in leaves increased in the presence of SR and CSR, whereas in roots 6-8 and 12-14 it was lower than in the ¼ H control. Overall concentration of Mg was in the optimal range, according to [5]. Concentration of Fe was suboptimal in all leaves except for those of treatment 13, where in was just above the threshold according to [5]. Interestingly, the treatments reduced concentration of Fe in both leaves and roots with respect to the ¼ H control, except in treatments 10 and 13 in leaves. The average reduction of Fe concentration in leaves of plants treated with SR was 30% and in the roots of both SR and CSR as much as 57% (Fig. 1). Concentration of Zn was in the optimal range. However, in the presence of SR it slightly increased and in the presence of SCR slightly decreased in leaves, whereas it significantly decreased in SR and especially in CSR treated roots. Concentration of Cu in all treatments was low, less affected by SR and CSR in leaves but about three times lowered in roots with the respect to the ¼ H control (Fig. 1). According to [5], concentration of Mn was low in treatments 2-4 and deficient in all the others (Tab.3, Fig. 1). In treatments 3 and 4 in leaves, however, and 3, 5, 8, 11, 13 and 14 in roots it was higher than in the respective ¼ H controls suggesting that both SR and CSR can serve as a source of Mn.

Table 3. Concentration of essential metals in dry matter of leaves and roots of cucumber, grown in the presence of SR or CSR. For reference to treatments, please see Table 2.

Plant part	**Treatment**	**K**	**Ca**	**Mg**	**Fe**	**Zn**	**Cu**	**Mn**
		%			ppm			
Leaf	**1**	1.3	4.2	0.6	36.6	46.9	5.6	12.9
	2	1.8	6.4	0.8	48.6	50.8	6.9	18.0
	3	1.4	5.2	0.9	29.9	45.9	4.7	16.0
	4	0.8	6.7	1.3	34.2	74.1	5.6	16.9
	5	2.4	5.6	1.1	20.4	42.8	4.5	5.6
	6	3.0	6.0	1.3	20.2	51.4	5.9	4.5
	7	3.1	6.4	1.3	20.3	42.4	4.9	6.0
	8	3.7	6.8	1.5	29.4	55.1	5.6	7.9
	9	1.5	6.6	0.9	37.0	33.7	4.4	9.6
	10	0.8	7.0	1.2	37.7	48.3	4.6	9.2
	11	1.6	6.6	1.1	32.9	34.4	4.5	8.7
	12	2.0	6.6	1.1	25.0	42.8	4.6	6.3
	13	2.7	6.6	1.1	53.9	49.0	6.7	10.0
	14	2.6	5.9	0.9	29.2	39.5	4.7	6.7
Root	**1**	2.3	2.5	0.3	129.3	95.4	24.4	3.3
	2	2.5	3.9	0.3	61.2	93.7	13.8	1.5
	3	2.7	3.6	0.5	54.9	72.9	7.0	6.6
	4	2.5	4.3	0.6	41.9	87.4	8.9	2.9
	5	4.1	4.1	0.4	81.3	67.7	7.1	6.0
	6	6.5	8.2	0.3	40.9	67.8	8.9	1.9
	7	5.7	3.6	0.3	48.4	65.0	7.6	3.2
	8	6.6	4.8	0.3	63.8	72.5	8.1	4.4
	9	2.3	3.6	0.4	50.8	60.5	7.5	3.4
	10	2.7	3.9	0.6	40.1	67.6	8.0	2.0
	11	3.9	3.6	0.4	67.3	54.2	7.1	5.3
	12	4.8	3.6	0.3	48.4	61.3	7.5	3.1
	13	4.1	4.2	0.3	65.8	70.0	9.0	5.0
	14	4.5	4.5	0.3	62.9	64.1	8.1	4.8

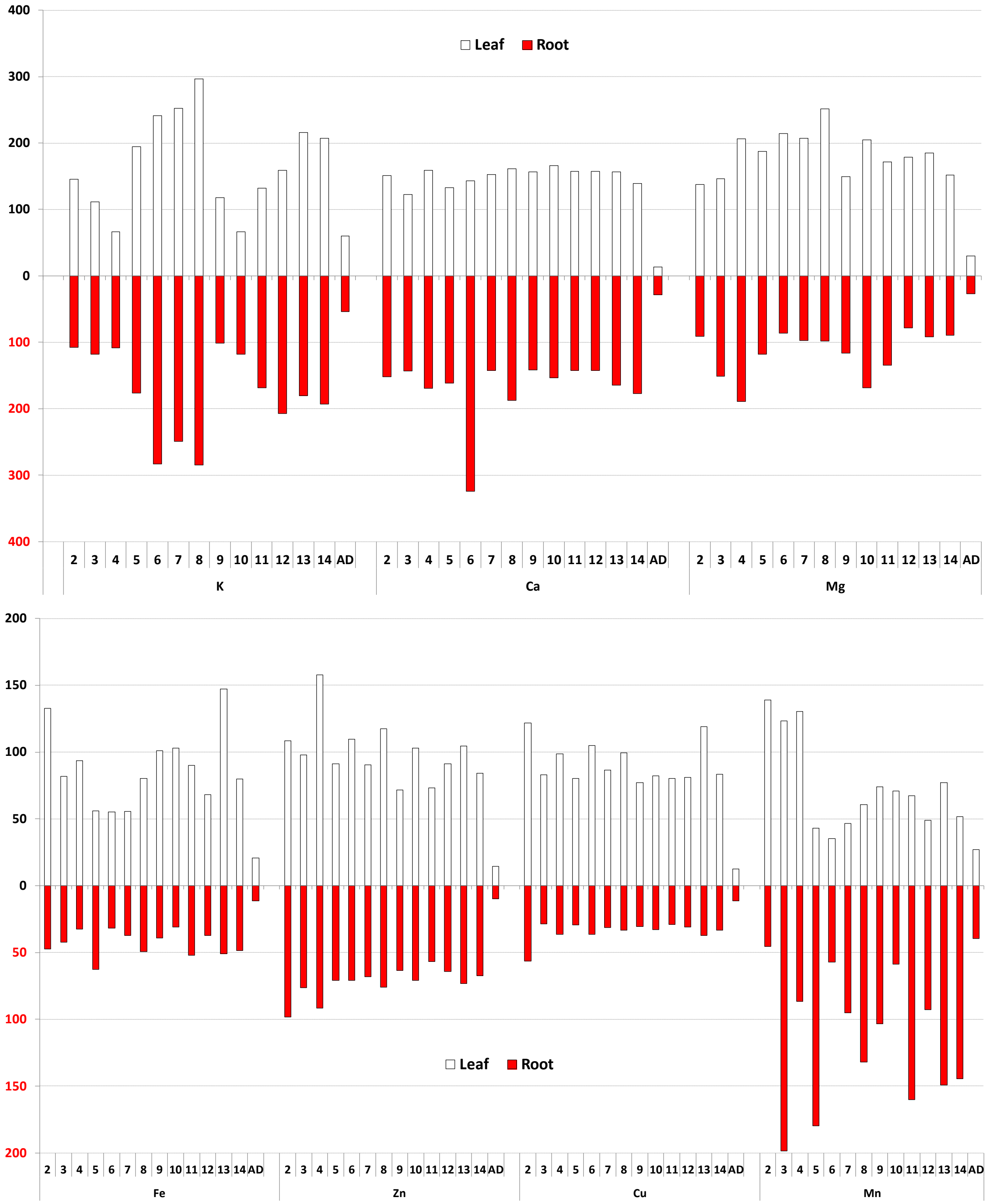

Figure 1. Concentration of essential metals in leaves and roots of cucumber, grown in the presence of SR and CSR, expressed in percents of the ¼ H control (100%). For reference to treatments, please see Table 2. AD, average deviation.

Conclusion

Even though in this experiment cucumber was not supplied with sufficient sources of all the analyzed essential metals, it was found that cucumber can utilize nutrients supplied by SR and CSR. The amounts of elements found in plants depended both on applied amount of residues and on their processing (composted or not). Besides concentration, the treatments influenced distribution of some elements between roots and shoots (e.g. Mg, Zn, Cu, and Mn) and reduced concentrations of the others (e.g. Fe and Cu). Therefore, application of solid residues in cucumber production has to be conducted carefully.

Acknowledgements

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