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INFLUENCE OF SOILLESS CULTURES ON SOIL ENVIRONMENT

WPŁYW UPRAW BEZGLEBOWYCH NA ŚRODOWISKO GLEBOWE

Abstract: Soilless culture is used for the growing of vegetables and ornamental plants. In this technology plants in inert medium are frequently cultivated. However, in order to stabilize the concentration and the pH value of the solution in the root zone and in order to adjust the substrate moisture, the volume of nutrient solution must be higher than the nutritional requirements of plants. In result, there are significant leakages of nutrient solution to the soil. The aim of the presented research was the investigation of chemical properties of soils in the greenhouses where soilless culture technology is used for ornamental plant cultivation.

In comparison with control soils, the 1:2 soil water extract from greenhouse soils showed a higher electrical conductivity. In result of nutrient solution leakages, in the soil increased the concentration of almost all nutrients and particularly of potassium, nitrates, magnesium, while the content of phosphorus, sulphates and of microelements decreased in a lesser degree. The highest threat results from the easy translocation of NO_3-N. The degradation rate of soil environment depended primarily on the length of greenhouse utilization.

Keywords: greenhouse, soil, degradation, soilless culture, leakage

Soilless culture represents a technology for plant growing in nutrient solutions that supply all nutrient elements needed for optimum plant growth with or without the use of an inert medium or organic growing medium to provide mechanical support. Hydroponics or soilless culture offers a means of control over soil-borne diseases and pests. Thanks to that fact, one can avoid the costly and time-consuming soil replacement or sterilization. Soilless culture in commercial ornamental plant production is used for the growing of roses, gerbera, carnations and even asparagus. However, in order to stabilize the concentration and the pH value of the solution in the root zone and in order to adjust the substrate moisture, the volume of nutrient solution must be higher than the nutritional requirements of the plants. In effect, there are significant leakages of the nutrient solution to the soil. Currently, for soilless culture, 30–50 % of overflow is recommended [1].

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The aim of the present paper was to investigate the chemical properties of soils in greenhouses where soilless culture technology is utilized for ornamental plants cultivation.

Material and methods

Studies were carried out in September 2008 in three horticultural farms localized in different regions of Wielkopolska. The first one specialize in the production of carnations in rockwool (8 years), in the second farm roses are cultivated in rockwool (10 years) and in the third one, gerberas are grown in perlite (12 years). In those objects, open fertigation systems are applied, ie the drainage water is leaking from the slabs directly to the soil. Overflow is not collected and nutrient recirculation is not applied. In each of the objects, one greenhouse was selected, where soil samples were taken every 20 cm to the depth of one meter. Samples were taken in three randomly selected places. Drilling was carried out under the rockwool slabs (rose and carnation), or under the containers with perlite (gerbera), where the plants were grown. For the sake of comparison, soil samples (0–100 cm) were taken as well from sporadically fertilized lawns growing near the greenhouses. The available forms of macroelements in the soil were extracted with 0.03 mol · dm^{-3} CH_3COOH [2]. For the extraction of microelements, the modified Lindsey solution was used [3]. The following elements were determined: NH_4-N and NO_3-N (by distillation method in modification of Starck), P, SO_4-S (by colorimetric analysis), K, Ca, Na (by spectrophotometric analysis), Mg, Fe, Cu, Zn, Mn (by atomic absorption spectrophotometry). Electrical conductivity and pH value were measured as well. Soil texture was determined by sedimentation method. Results of the determinations are given according to FAO classification [4].

Results and discussion

Drainage waters from typical agricultural areas are the beginning of the migration tracks of nutrients. Similar process takes place with the leakages from soilless cultures. They transfer mineral components first to the upper layer and then to the lower-layer of soil. Subsequently, the nutrients penetrate the surface waters or the groundwaters. The threat is significant, because of the high fertilizer doses used for vegetable and ornamental plants fertigation grown in greenhouses. For example, from 1 ha of roses cultivated in perlite or lapillus (volcanic rock) and with the average overflow about 40 %, the effluent of 2000 m^3 contained 700 kg of nitrogen [5]. During one growing season of gerbera in rockwool, together with the drainage waters, the monthly overflow to the soil was: 10–39 kg N, 13–52 kg K, 3–13 kg Mg and 3–12.5 kg Na · ha^{-1} [6].

During plant cultivation, the chemical composition of the leakages depending on the chemical composition of the nutrient supplied to plants, the plant age, course of climatic conditions (especially of temperature), time of the day and fertigation frequency. In consequence, there follows an uncontrolled leakage of solutions to the soil, and the concentration of the majority of components in the soil increases. These changes depended only in a small degree on the soil texture (Tables 1–3), but in a greater extent,

Table 1

Influence of nutrient solution leaching during 8 years of carnation cultivation in rockwool on chemical properties of greenhouse soil in comparison to garden soil

Layer [cm]	Soil text.*	NH_4–N	NO_3–N	P	K	Ca	Mg	Na	SO_4–S	Fe	Mn	Zn	Cu	pH	EC [$mS \cdot cm^{-1}$]
		[$mg \cdot dm^{-3}$]													
Greenhouse															
0–20	SL	7	74	338	657	2005	422	39	37	109	58	31	17	7.0	0.57
20–40	SL	14	77	299	719	1993	376	38	76	89	15	20	9	7.0	0.56
40–60	L	18	53	295	772	1250	315	39	78	83	16	10	6	7.0	0.48
60–80	L	18	49	57	778	5519	373	30	50	31	6	3	2	7.2	0.40
80–100	L	18	39	63	655	5850	350	27	36	19	4	2	2	7.7	0.50
Lawn															
0–20	SL	28	28	47	59	2497	183	44	123	50	2	2	1	7.6	0.50
20–40	SL	< 1	< 1	20	17	2220	170	30	94	64	2	2	1	7.9	0.44
40–60	L	< 1	< 1	8	5	2387	160	24	86	87	2	1	1	8.0	0.36
60–80	L	< 1	< 1	7	5	2863	187	23	82	64	2	1	1	8.0	0.30
80–100	L	< 1	< 1	9	5	6221	176	24	75	25	2	1	1	8.1	0.26

* Soil texture according to FAO [4]: S – sand, LS – Loamy sand, SL – Sandy loam, L – loam.

Table 2

Influence of nutrient solution leaching during 10 years of roses cultivation in rockwool on chemical properties of greenhouse soil in comparison with garden soil

Layer [cm]	Soil text.*	NH_4–N	NO_3–N	P	K	Ca	Mg	Na	SO_4–S	Fe	Mn	Zn	Cu	pH	EC [mS · cm^{-1}]
		[mg · dm^{-3}]													
Greenhouse															
0–20	LS	7	399	58	1098	461	163	110	95	160	7	8	1	6.2	0.99
20–40	LS	7	245	45	711	355	123	70	103	192	8	5	1	6.3	0.68
40–60	LS	21	91	23	536	254	80	48	30	197	8	4	1	6.3	0.48
60–80	LS	7	42	7	263	223	40	36	34	180	5	1	< 1	6.4	0.20
80–100	SL	7	35	12	205	281	52	41	9	180	3	< 1	< 1	6.5	0.25
Lawn															
0–20	LS	28	14	18	24	452	72	19	2	138	5	78	3	6.6	0.09
20–40	LS	11	< 1	13	19	542	28	22	2	155	7	49	2	6.3	0.03
40–60	LS	7	< 1	10	16	363	13	16	1	181	16	21	3	6.3	0.02
60–80	S	7	< 1	7	18	324	13	15	1	177	12	18	2	6.4	0.02
80–100	S	4	< 1	4	20	263	13	15	1	180	11	13	1	6.4	0.02

* Abbreviation: see Table 1.

Table 3

Influence of nutrient solution leaching during 12 years of gerbera cultivation in perlite on chemical properties of greenhouse soil in comparison with garden soil

Layer [cm]	Soil text.*	NH_4–N	NO_3–N	P	K	Ca	Mg	Na	SO_4–S	Fe	Mn	Zn	Cu	pH	EC [mS · cm^{-1}]
		[mg · dm^{-3}]													
Greenhouse															
0–20	SL	11	77	295	524	1937	379	63	42	119	13	32	18	6.4	0.64
20–40	SL	18	56	333	341	956	227	41	98	123	27	23	17	6.4	0.56
40–60	S	11	28	327	271	761	164	34	221	123	45	18	14	6.2	0.71
60–80	S	14	25	295	297	800	166	34	326	120	32	16	12	6.3	0.68
80–100	S	7	10	352	360	937	255	42	246	120	36	20	16	6.0	1.02
Lawn															
0–20	SL	7	7	139	30	638	59	24	4	84	2	7	2	6.8	0.07
20–40	SL	14	< 1	86	27	614	75	30	15	87	6	10	2	6.7	0.07
40–60	S	7	< 1	55	26	471	55	30	7	99	6	11	2	6.7	0.07
60–80	S	7	< 1	28	16	276	24	23	4	93	4	7	1	6.8	0.05
80–100	S	7	< 1	14	10	270	25	12	4	90	4	6	1	6.2	0.04

* Abbreviation: see Table 1.

they depended on the species of the grown plants and on the length of the greenhouse exploitation (8–12 years).

In comparison with the samples from control soils, the water extract from greenhouse soils showed a higher electrical conductivity, but a slightly lower pH value. The highest increment of EC in relation to the control soil was shown by the greenhouse with roses (to the depth of 60 cm), while the lowest increment of EC value was found in the greenhouse with carnation (Tables 1–3). Probably it is an effect of nutrient solutions concentration.

Electrical conductivity of the basic nutrient solution used for plants fertigation cultivated in soilless cultures were 2.2 for rose, 1.9 for gerbera and 1.7 mS · cm^{-1} for carnation. In the soils from greenhouses with roses, because of the scale of concentration in the soil, the elements can be arranged in the following order: K > NO_3-N > Mg > SO_4-S > Na > P > Fe. At the same time, there was found a decrease in the content of Mn, Zn and Cu. In the soil from greenhouses with carnations, the elements, regarding their concentration increase formed the following sequence: K > P > Mg > NO_3-N > Fe > Mn > Zn > NH_4-N > Cu. In the soil samples from greenhouses with gerbera, the order of elements was the following one: K > Ca ≈ P > Mg > SO_4-S > N-NO_3 > Fe > Na > Mn > Zn > Cu. A particularly high concentration increase was usually found in case of potassium (up to 1098 mg · dm^{-3}), magnesium (up to 422 mg · dm^{-3}) and in the nitrate(V) form of nitrogen (up to 399 mg · dm^{-3}). High concentration of Ca in soil from the greenhouse with carnations should be explained by the naturally high content of this element in loams.

An increase of the component content in the soil is connected with the exchange-adsorption of cations and chemisorption of cations and anions. Because of a negative charge of the sorption complex of soils, anions are not exchange-adsorbed. They migrate most easily into the depth of soil. In literature, attention is called to the rather significant speed of nitrates translocation in the soil – the presence of NO_3^- ions at the depth of 90 cm was found already several weeks after the application of mineral fertilizers in nurseries and in greenhouses [7, 8]. Utilization of the total applied nitrogen fertilizer by plants is not possible, even in field conditions where smaller doses of fertilizers are applied than in greenhouses. An example of a possible pollution effect caused by nitrogen application was quoted in a fertilization experiment with avocado grown in a field [9]. Four levels of N were applied over four years. Increasing the N applied from 80 kg · ha^{-1} to 640 kg · ha^{-1} increased the NO_3-N concentration in soil from 4.2 to 427.2 mg · kg^{-1} in the 0–30 cm layer and from 0.5 to 232.0 mg · kg^{-1} in the 60–90 cm layer.

Effect of long-term fertilization on the content of macro- and microelements in the profiles of greenhouse soils was evaluated already 14 years ago. However, the research referred to the conventional methods of plant fertilization grown in greenhouse soils [10, 11]. Traditional fertilization (organic plus mineral fertilizers) caused a significant increase of elements not only in the arable layer, but also in the deeper soil layers. The range of changes in the chemical properties of soils depended more on the time length of the greenhouse exploitation (20–40 years) and on the accepted production program than on the soil texture. Results of the above-mentioned studies [10, 11] were similar to those received in our actual studies shown in Tables 1–3. Differences refer to concentrations which in case of potassium were higher in soil samples taken from greenhouses with soilless culture. On the other hand, the concentrations of SO_4-S, Fe, Mn and Zn in soils with the conventional fertilization were significantly higher than in the greenhouses with soilless culture and fertigation. It indicates a quicker rate of soil degradation in greenhouse where the soilless cultures with open fertigation system are used.

The danger following from excessive doses of the applied fertilizers in greenhouse was noticed in Spain [12], Netherlands [13] and in Italy [14]. It was found that during plant cultivation in greenhouse soil, 83 % of NO_3-N originating from mineral fertilizers was translocated to the depth of 60–100 cm, while 77 % of NH_4-N was accumulated in the upper soil layer (0–60 cm). On the other hand, 90 % of N originating from organic fertilizers was found in the 0–10 cm layer [15]. The ion of NO_3^- can migrate both with water percolation and with the groundwater ascension. Therefore, the place of nitrate accumulation depends on the intensity of these two opposite water movements [16].

Conclusions

Leakages of nutrient in soilless cultures cause the accumulation of significant amounts of elements in soil. At the same time, the not absorbed ions migrate to groundwaters. The greatest threat results from the easy translocation of NO_3-N. Degradation rate of soil environment depends primarily on the length of greenhouse exploitation. A complete elimination of losses from soilless culture is unrealizable. A smaller application of nutrients and in consequence smaller losses to the soil can be obtained by the introduction of the closed system. However, because of increase of ions concentration in root environment, unending recirculation of the whole volume of nutrient solution is impossible. A significant part must be mixed with pure water. The rest constitutes an unusable post-production waste.

References

[1] Brajeul E., Pineau S., Guitton Y., Maillard E., Loda D. and Lesourd D.: Infos Ctifl. 2005, **210**, 31–34.
[2] Nowosielski O.: Zasady opracowywania zaleceń nawozowych w ogrodnictwie. PWRiL, Warszawa 1998.
[3] IUNG: Metody badań laboratoryjnych w stacjach chemiczno-rolniczych. Cz. IV. Puławy, Seria P, 1983.
[4] Brady N.C. and Weil R.R.: The nature and properties of soils. Prentice Hall Publishing 2001.
[5] Duchein M., Baille M. and Baille A.: Acta Hortic. 1995, **408**, 129–135.
[6] Breś W.: Polish J. Environ. Stud. 2009, **18**(3), 341–345.
[7] Brand M.H., McAvoy R.J. and Corbett E.G.: J. Environ. Hortic. 1993, **11**, 82–85.
[8] McAvoy R.J., Brand M.H., Corbett E.G., Bartok J.W., Jr. and Botacchi A.: J. Environ. Hortic. 1992, **10**(3), 167–171.
[9] Lahav E. and Kalmar D.: Austr. J. Agr. Res. 1977, **28**, 869–878.
[10] Breś W. and Roszyk J.: Biul. Warzyw. 1996, **XVL**, 51–57.
[11] Breś W. and Roszyk J.: Biul. Warzyw. 1997, **XLVI**, 25–30.
[12] Thompson R.B., Gallardo M. and Giménez C.: Acta Hortic. 2002, **571**, 243–248.
[13] Van Os E.A.: Water Sci. Technol. 1999, **39**(5), 105–112.
[14] De Pascale S. and Paradiso R.: Acta Hortic. 2001, **548**, 631–639.

[15] Thompson R.B., Martýnez-Gaitan C., Gallardo M., Gimenez C. and Fernandez M.D.: Agric. Water Manage. 2007, **89**, 261–274.
[16] Shücs M.: Roczn. Glebozn. 1991, **XLII**(3/4), 115–120.

WPŁYW UPRAW BEZGLEBOWYCH NA ŚRODOWISKO GLEBOWE

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Abstrakt: Uprawy bezglebowe wykorzystuje się do uprawy warzyw i roślin ozdobnych. W tego typu technologiach w celu ustabilizowania stężenia i pH pożywki oraz wilgotności strefy korzeniowej, ilość stosowanych roztworów musi być większa od rzeczywistych wymagań rośliny. Efektem tego są znaczne wycieki pożywki do gleby. Celem badań była ocena właściwości chemicznych gleb w szklarniach, w których są prowadzone uprawy bezglebowe roślin ozdobnych.

W porównaniu z próbkami gleb kontrolnych (trawnik), wyciąg wodny z gleb szklarniowych miał większą konduktywność elektryczną. Na skutek wycieków pożywek w glebie wzrastała koncentracja niemal wszystkich składników, a w szczególności potasu, azotu azotanowego i magnezu, w mniejszym stopniu fosforu, siarczanów i mikroelementów. Największe zagrożenie dla środowiska wynikało z łatwego przemieszczania się N-NO_3. Tempo degradacji środowiska glebowego zależało przed wszystkim od długości okresu eksploatacji szklarni.

Słowa kluczowe: szklarnia, gleba, degradacja, kultury bezglebowe, wyciek