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ABUNDANCE IN MACRONUTRIENTS OF SOILS UNDER VEGETABLE CULTIVATION IN OPEN GROUNDS AND UNDER FOIL TUNNELS

ZASOBNOŚĆ W MAKROSKŁADNIKI GLEB POD UPRAWAMI WARZYW W TUNELACH FOLIOWYCH I W GRUNCIE

Abstract: Production of vegetables and fruits in Poland is most often quite intensive, thus it is basing on introducing into soil large doses of mineral fertilizers, little manuring and without or with the limited crop rotation. Producers of vegetables apply high amounts of fertilizers leading often to their exaggerated accumulation in the soil. The aim of the work was to evaluate the abundance of nutrients, and determine changes in the soil environment resulting from agro-technological treatments applied in the intensive growing of vegetable in foil tunnels and open ground. Results of studies indicated the acidification of soils under the vegetable growing, especially in foil tunnels as a result of intensive mineral fertilizing which have increased the hydrolytical acidity, reducing the share of alkaline cations in the soil sorption complex in comparison with the agriculturally unused soil of the region. In the soil under open ground and foil tunnels vegetable cultivation a decrease of the organic carbon and accumulation of available forms of potassium and phosphorus were observed when comparing with the unused soil. The accumulation of available phosphorus and potassium in the soil under the vegetable cultivation was so significant that it can adversely affect uptaking of other nutrients by vegetables, thus lowered their ability to supply plants with nutrients, as well as affect adversely the environment.

Keywords: vegetable growing, soil reaction, organic carbon, macronutrients

The production of vegetables and fruits in Poland usually is intensive, basing on large doses of mineral fertilizers and without, or with limited manuring and crop rotation [1, 2]. The soil under the vegetable growing is depleted of nutrients taken up with every crop. Their uptake must be compensated with mineral and organic fertilizers. Producers of vegetables, in concern of delivering to the soil appropriate amounts of crop forming elements, introduce into soil exaggerated amounts of fertilizers, causing rather

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their accumulation in the soil than depletion [3]. In field cultivation mineral elements applied in large doses, exceeding the real demand of plants, can undergo surface flows in the result of violent rainfalls, or filtering deep into the soil profile [2, 4, 5]. Applying large doses of fertilizers is also aimed at precipitating cropping which is for the producer the most important since an easiness of the market, a price and a profitability of the production depend on the date of the harvest [3, 6].

The commune Igolomia-Wawrzenczyce is located in the Malopolska province in the Krakow district. It belongs to typically agricultural communes, specializing in the vegetable production, with the long-standing tradition. In its area fertile soils – chernozems – are found determining the intense vegetable growing, which surface of cropping occupies over the half of the arable land of the commune [7].

The purpose of the work was to evaluate abundance in nutrients, and determining changes in the soil environment resulting from agro-technological treatments applied in the intensive vegetable growing in foil tunnels and open ground.

Materials and methods

The commune Igolomia-Wawrzenczyce is located in the distance of about 10 km to the east of Krakow (N50^o 07′ , E20^o 21′). It is characterized by a wavy, wavy-hilly and flat lie of the land, and in the majority is covered with loess deposits. The average annual temperature is from +6 to +8 ^{o}C, and the sum of rainfalls is of 600 mm a year. Favourable physiographic, lithographic and climatic conditions of the commune and the proximity of markets are supporting the development of the vegetable gardening both in open ground and foil tunnels [7].

For examinations soil material was taken up from 13 objects located in the Igolomia-Wawrzenczyce commune, from the depth of 0–25 cm. From every object 3 individual soil samples were taken. Six objects constituted soils under open ground cropping: of onion (G2 and G3), cauliflower (G4 and G5), cabbages (G6) and celery – G7. Next six objects were soil under foil tunnels cropping of: peppers (T8, T9 and T10), of tomato (T11 and T12) and cucumber (T13). A soil of the extensively used, occasionally mown meadow, described in the work as unused soil constituted the referential object – N1.

In the studied soil material following properties were determined:

– pH values in 1:2.5 solutions of H_2O potentiometrically [8];

– composition of sorption complex through determination of exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ cations in the 1 mol · dm^{-3} NH_4Cl solution for non-calcareous soils and in 0.5 mol · dm^{-3} NH_4Cl solution for calcareous soils;

– contents of available forms of phosphorus and potassium with Egner–Riehm's method and magnesium with Schachtschabel's method [8].

Contents of (Ca^{2+}, Mg^{2+}, K^+ , Na^+) exchangeable forms and (P, K, Mg) available forms in obtained in this way solutions were determined with the *spectrometer of atomic emission with inductively induced argon plasma* ICP-AES JY 238 ULTRACE of Jobin Yvon:

– hydrolytic acidity by Kappen's method, using 1 mol · dm^{-3} CH_3COONa [8];

– level of total nitrogen, total and inorganic carbon with the use of automatic analyzer of these elements: TOC-TN 1200 Thermo Euroglas apparatus. The level of organic carbon was calculated as a difference between total and inorganic carbon levels;

– contents of available phosphorus by Olsen method, with the use of 0.5 mol · dm^{-3} $NaHCO_3$ with pH = 8.5 as an extractor. Phosphorous was measured colorimetrically with spectrometer UV-VIS, Aquamate at the wavelength of 720 nm [9].

Statistical analysis of results was carried out with the method of ANOVA unifactor variation analysis in the random arrangement. To estimate the significance of differences between mean values homogeneous groups were appointed using the test *a posteriori* of Fisher. *Standard deviations* (SD) and for some parameters coefficients of *variation* (V %) and values of the Pearson's linear correlation coefficient (r) were calculated. All calculations were performed using the Statistica package v. 10 PL. Graphs were prepared using Excel 2003 package.

Results

Examined soils were derived from loess and they had silty texture. Soil reaction under the open ground vegetable growing and of agriculturally unused soil was slightly acid to neutral, pH values measured in H_2O suspension were placed within the limits of 5.7–7.0. Soils of vegetables tunnel cultivations had acid to slightly acid reaction (pH_{H_2O} 4.8–6.2). Diversification of the pH values of the examined soils resulted from differences in saturation of sorption complex with alkaline cations. In sorption complex of studied soils cations of calcium prevailed. Their participation was associated with the way of soil using, and it was set in the order: unused soil > soil of open ground cultivations > soil of tunnel cultivations and on average it took out appropriately 82.9, 76.7 and 68.2 %, when differences in saturation of sorption complex with discussed cation between the unused soil and the soils under the vegetable growing were statistically significant (Table 1, Fig. 1).

Average participation of cations of magnesium in sorption complex was set inversely towards the participation of cations of calcium that is: soils of tunnel cultivations > soils of open ground cultivations > unused soil, and took out appropriately: 11.4, 9.1 and 8.4 %. Statistically significant differences appeared between the average participation of Mg cations in sorption complex in soils of open ground and tunnel vegetables. Participation of sodium and potassium cations in sorption complex of discussed soils were not statistically significantly diversified in relation to the way of soil use and was located in a limit appropriately: 1.2–2 % and 0.6–2.5 % (Table 1, Fig. 1). However a participation of the hydrolytic acidity in the capacity of sorption complex in soils of tunnel cultivations (16 %) was statistically significantly greater comparing with the soil of open ground cultivations (10 %) and of unused soil (6.8 %) (Fig. 1).

The way of using affected also the accumulation of organic carbon and total nitrogen in the examined soils. Indicated average contents of these elements placed in the order: unused soil > soils of tunnel cultivations > soils of open ground cultivations, differences in C and N contents between soil from the open ground and tunnel cultivations of vegetables were small. In spite of intensive fertilizing in the soils under vegetable

Table 1

Values of pH and sorption properties of studied soils (arithmetic mean of three individual samples ± standard deviation)

Soil	pH H_2O	Exchangeables cations mmol(+)/kg soil				Ha**	CEC***
		Ca^{2+}	Mg^{2+}	K^+	Na^+	mmol(+)/kg soil	
N1*	6.6	141.7 ± 0.1	14.4 ± 0.6	1.10 ± 0.08	2.02 ± 0.02	11.6 ± 0.2	170.9 ± 0.1
Open ground vegetable cultivation							
G2	5.7	79.0 ± 0.1	12.8 ± 0.2	1.04 ± 0.04	2.96 ± 0.03	19.5 ± 0.5	115.4 ± 0.1
G3	6.1	99.8 ± 0.9	9.94 ± 0.02	0.86 ± 0.03	1.33 ± 0.07	13.5 ± 0.3	125.5 ± 0.4
G4	5.9	114.8 ± 0.4	7.65 ± 0.02	2.27 ± 0.08	2.76 ± 0.01	15.6 ± 0.7	143.2 ± 0.1
G5	6.2	86.6 ± 0.7	16.1 ± 0.1	4.79 ± 0.05	1.57 ± 0.01	18.4 ± 0.1	127.5 ± 0.1
G6	7.0	113.8 ± 0.6	13.9 ± 0.3	4.12 ± 0.02	1.42 ± 0.02	6.76 ± 0.06	140.0 ± 0.2
G7	7.0	117.5 ± 0.2	12.3 ± 0.2	6.61 ± 0.03	3.39 ± 0.01	6.24 ± 0.01	146.0 ± 0.9
Foil tunnels vegetable cultivation							
T8	4.8	49.5 ± 0.2	11.2 ± 0.1	1.21 ± 0.02	0.73 ± 0.08	61.1 ± 0.2	123.8 ± 0.2
T9	5.7	80.9 ± 0.3	13.9 ± 0.1	1.32 ± 0.02	1.98 ± 0.04	21.7 ± 0.1	119.8 ± 0.1
T10	6.3	143.7 ± 0.2	20.5 ± 0.2	1.24 ± 0.07	2.56 ± 0.02	17.4 ± 0.3	185.4 ± 0.4
T11	6.1	85.7 ± 0.1	11.2 ± 0.2	6.00 ± 0.01	4.38 ± 0.01	17.6 ± 0.3	124.9 ± 0.1
T12	6.4	146.3 ± 0.3	19.6 ± 0.2	4.23 ± 0.06	3.41 ± 0.03	11.8 ± 0.3	185.3 ± 0.5
T13	6.2	127.9 ± 0.7	29.6 ± 0.2	8.17 ± 0.01	5.32 ± 0.05	19.1 ± 0.3	190.2 ± 0.6

* N1 – unused soil, G2 and G3 – onion open ground growing, G4 and G5 – cauliflower open ground growing, G6 – cabbage open ground cultivation, G7 – celery open ground cultivation, T8, T9 and T10 – pepper foil tunnel cultivation, T11 and T12 – tomato foil tunnel cultivation, T13 – cucumber foil tunnel cultivation; ** Hydrolytical acidity; ***CEC – cation exchangeable capacity.

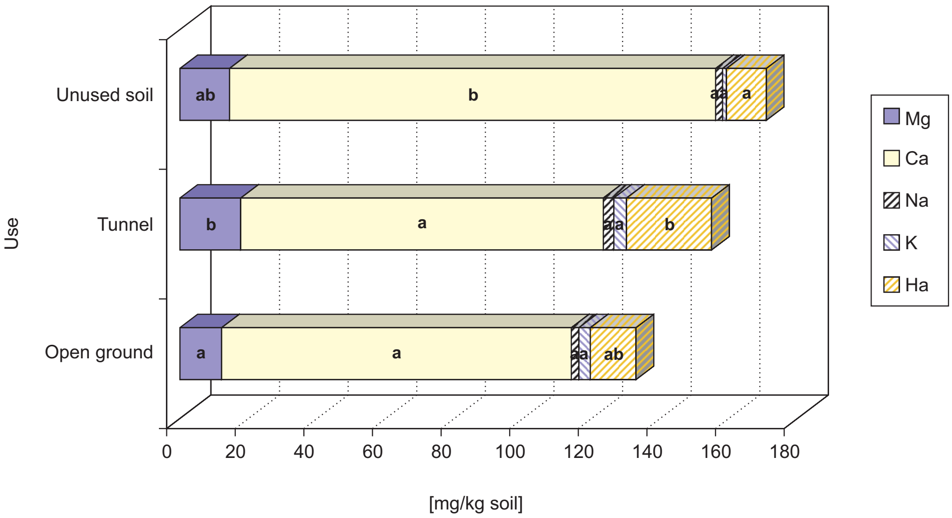

Fig. 1. Mean composition of sorption complex of differently used soil, the same letters mean the lack of statistically significant differences at the significance level $\alpha \leq 0.05$

growing the accumulation of organic carbon and total nitrogen were appropriately 2-fold and about 1.5-fold lower than in the unused soil, the last one was characterized by a little bit broader average C : N ratio (12.3), comparing with the soil of the vegetable growing, in which it took out about 10 (Table 2).

Intensive vegetables fertilizing influenced the accumulation of available forms of phosphorus and potassium in the soil under their crops in the strongest way. Average content of available phosphorus determined with Egner-Riehm's method in the unused soil was definite in "Materials worked up for fertilizer recommendations on arable lands" [10] as very low, and in the soil from the vegetable growing: open ground and tunnel, as very high, a little bit higher in the soil under tunnels than open ground cultivation but this difference was statistically insignificant (Table 2, Fig. 2). Statistically significantly lower was indeed an average content of phosphorus, extracted with $NaHCO_3$ (Olsen's method) in the unused soil when comparing with the soil, in which vegetables were growing. Average contents of this element determined with Olsen's method in the soil from open ground and tunnel cultivations of vegetables, amounted to appropriately: 248.3 and 228.6 mg P_2O_5/kg of the soil. Average amounts of phosphorus extracted with solution of the calcium lactate (with method of Egner–Riehm) from the soil of the vegetable growing were about 3-fold higher than extracted with $NaHCO_3$ (Olsen's method), while in the unused soil contents of phosphorus extracted with both reagents were identical and amounted about 43 mg P_2O_5/kg of the soil. Average contents of available potassium extracted with the calcium lactate from the soil under vegetable growing were very high [10] and statistically significantly higher than in the unused soil, in which the low content of this element was determined. Agro--technological treatments applied at the vegetable growing did not affect the content of

Table 2

Selected chemical properties of studied soils (arithmetic mean of three individual samples ± standard deviation)

Soil	C	N	C:N	MgO	K_2O	P_2O_5	Olsen-P_2O_5
	[g/kg]			[mg/kg]			
N1*	31.4 ± 0.9	2.31 ± 0.07	13.5	220.0 ± 1.7	85.1 ± 0.0	43.2 ± 4.3	43.5 ± 0.6
Open ground vegetable cultivation							
G2	12.9 ± 0.1	1.4 3± 0.03	9.0	244.2 ± 5.8	109.8 ± 2.3	387.1 ± 3.2	345.5 ± 1.3
G3	21.3 ± 2.2	1.47 ± 0.02	14.5	174.2 ± 2.5	97.7 ± 3.7	108.8 ± 0.3	282.1 ± 2.0
G4	11.3 ± 0.1	1.50 ± 0.06	7.5	143.3 ± 6.6	219.8 ± 3.5	602.6 ± 37.4	195.7 ± 2.0
G5	11.9 ± 0.5	1.60 ± 0.10	7.4	240.0 ± 1.6	568.3 ± 2.3	728.1± 23.3	201.3 ± 1.3
G6	16.7 ± 0.2	1.48 ± 0.04	11.3	206.7 ± 15.0	510.9 ± 3.3	968.4 ± 46.2	219.7 ± 2.1
G7	18.7 ± 0.1	1.51 ± 0.03	12.4	180.0 ± 1.6	860.9 ± 13.3	1077.6 ± 95.5	245.1 ± 1.0
Foil tunnels vegetable cultivation							
T8	16.1 ± 0.4	1.65 ± 0.06	9.8	190.8 ±1 0.8	159.3 ± 1.6	528.3 ± 15.3	154.7 ± 1.1
T9	11.7 ± 0.4	1.50 ± 0.10	7.8	169.3 ± 0.9	358.2 ± 9.4	1137.2 ± 17.7	253.4 ± 3.4
T10	16.6 ± 0.4	2.10 ± 0.08	7.9	315.0 ± 6.6	99.2 ± 0.7	151.3 ± 7.5	118.5 ± 0.8
T11	13.9 ± 0.1	1.80 ± 0.09	7.7	160.0 ± 1.6	731.5 ± 12.5	1308.2 ± 99.8	262.6 ± 2.2

* See explanation under Table 1.

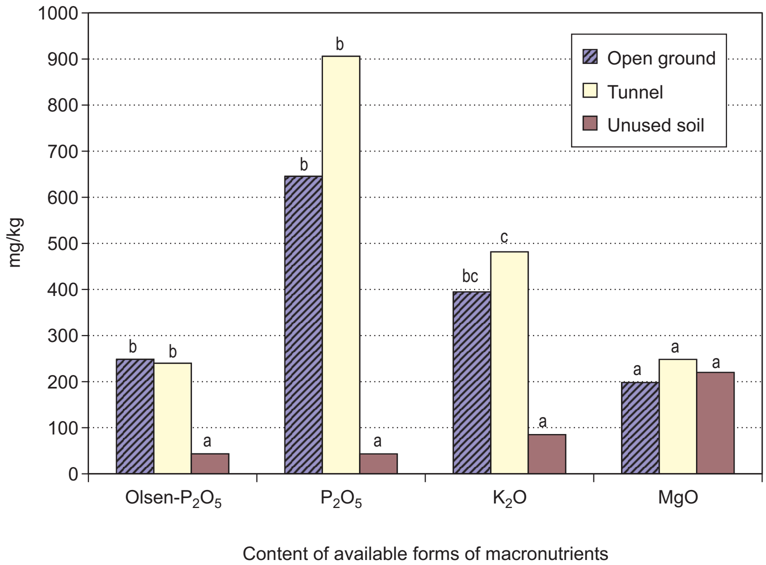

Fig. 2. Mean content of macronutrients in examined soils of different use, the same letters mean the lack of statistically significant differences at the significance level $\alpha \leq .05$

available magnesium, in all examined soils very high contents of this element were indicated and differences between contents of this form of magnesium extracted from the differently used soils were statistically insignificant (Table 2, Fig. 2).

Discussion

In Poland in the last years the area of vegetable growing under covers have reduced, while harvests of vegetables cultivated under protections have slowly but systematically grown [1, 2, 11]. Extremely crucial factor in the production of vegetables is an appropriate supplying with nutrients. Vegetables belong to cultivations with high nutritional requirements, especially with reference to phosphorus and potassium. These needs of plants are satisfied mainly with mineral fertilizers, applied in large doses. The accumulation of macroelements in parts of edible vegetables is determined by their presence in the soil in forms available to plants. Correctly run production, even intensive, in compliance with agro-technological principles should not lead to the decline of the soil. Nevertheless there are often made mistakes leading to the decrease of qualities of crops and of soil production capacities or threatening the environment [3, 6].

Agro-technological treatments, applied in the vegetable growing contributed to changes of physical and chemical properties of examined soils comparing with the unused soil located in the same region. These changes consisted above all in the considerable accumulation of some nutrients in the soil under the vegetable growing, often in amounts exceeding the demand of plants. Amounts of phosphorus and available potassium determined with Egner-Riehm's method exceeded very much recommended contents of this element in the soil under growing of given vegetable. Contents of phosphorus in case of the soil, from the tunnel cultivation of the cucumber were above 3-fold higher than contents recommended by Chemical-Agricultural Stations for the cultivation of this vegetable under tunnel, that is they crossed the border of harmfulness [6]. As such it is regarded the content of the given element twice as bigger than recommended [6]. However the excess of phosphorus and potassium are not directly harmful for plants, their exaggerated accumulation in soils hinders taking up of other nutrients and plants can manifest the deficiency of other elements. Contents of available phosphorus extracted with both solutions: the calcium lactate and the acid calcium carbonate were strongly positively correlated with the content of exchangeable and available potassium, Pearson's coefficients of simple correlation took out appropriately 0.81 and 0.50 (exchangeable potassium) and 0.88 and 0.53 (available potassium), ($\alpha < 0.05$) which proves the intensive fertilizing with these elements. Content of phosphorus determined with Olsen's method in the examined soils under vegetable growing in all cases exceeded a threshold value (100 mg P_2O_5/kg of the soil) determined as one of criteria of the hortic horizon. Appearing of this horizon indicates an advanced anthropogenic processes going on in the soil [12].

The exaggerated content of phosphorus can have also negative environmental effects associated with phosphorus getting to waters. Examinations conducted in the Research Rothamsted Station in Great Britain indicated significant increasing in the content of phosphorus in drainage waters to above 2 mg/dm^3, when content of determined phosphorus with Olsen's method crossed 60 mg P/kg (274 mg P_2O_5/kg) [4]. In the examined soils of open ground and tunnel vegetable cultivation the content of this element in some cases was close or even exceeded this amount.

There was not ascertained, expected, significant relation between pH values of the soil and the content of available phosphorus extracted with both methods Egner--Riehm's ($r = 0.048$, $\alpha > 0.05$) as well as Olsen's (-0.005, $\alpha > 0.05$). The fact can be explained by the low changeability of pH among the examined soils. The variation coefficient amounted to 8.61 %. Besides the content of available phosphorus was undoubtedly connected with a high inputs of this element into the soil and not fully taken up by plants [13].

Changes of physical and chemical properties of soils under the vegetable growing, resulting from conducted agro-technological treatments particularly intensive fertilizing, such as a decrease in the content of organic carbon and accumulation of phosphorus and potassium, were observed in soils of both the open ground and under foil tunnel vegetable cultivations. Moreover in soils of tunnel cultivations of vegetables a decrease in the pH values was also noticeable. Similar effects of intensive mineral fertilizing Lin et al [14] have observed in the soil under the vegetable growing in plastic tunnels in north China. According to Authors' the long-term vegetable growing in tunnels in the monoculture can lead to the increase of the soil acidity, when exaggerated accumulations of nutrients influences negatively a biological soil life and in consequence leads to lowering of its fertility.

Conclusions

1. Intensive applying of mineral fertilizers into soils under the vegetable growing, especially under foil tunnels increased the soil hydrolytical acidity, by reducing the participation of alkaline cations in sorption complex and finally acidified soils.

2. In the soil of open ground and tunnel vegetable cultivations a lowered content of organic carbon and accumulation of available forms of phosphorus and potassium were observed in comparison with the unused soil.

3. The accumulation of available phosphorus and potassium in soils under the vegetable growing is so high that it can adversely affect taking of other nutrients by vegetables, thus lower their ability to supply plants with nutrients, as well as pose environmental problems.

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ZASOBNOŚĆ W MAKROSKŁADNIKI GLEB POD UPRAWAMI WARZYW W TUNELACH FOLIOWYCH I W GRUNCIE

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Abstrakt: Produkcja warzyw i owoców w Polsce ma najczęściej charakter intensywny, czyli polega na wprowadzaniu do gleby dużych dawek nawozów mineralnych, niewielkim nawożeniu nawozami organicznymi i bez lub z ograniczonym płodozmianem. Producenci warzyw wprowadzają do gleb duże ilości nawozów, prowadząc często do ich nadmiernej akumulacji w glebie. Celem pracy było ocena zasobności w składniki odżywcze oraz określenie zmian właściwości środowiska glebowego zachodzących na skutek zabiegów agrotechnicznych stosowanych w intensywnej uprawie warzyw w tunelach foliowych i gruncie. Rezultaty przeprowadzonych badań wskazały na zakwaszenie gleb pod uprawą warzyw, szczególnie w tunelach foliowych w wyniku intensywnego nawożenia mineralnego, w efekcie którego wystąpiło zwiększenie kwasowości hydrolitycznej, zmniejszenie udziału kationów zasadowych w kompleksie sorpcyjnym tych gleb w porównaniu z glebą nieużytkowaną rolniczo tego regionu. W glebach upraw gruntowych i tunelowych warzyw zaobserwowano również zmniejszenie zawartości węgla organicznego i nagromadzenie przyswajalnych form fosforu i potasu w porównaniu do gleby nieużytkowanej. Akumulacja fosforu i potasu przyswajalnego w glebach pod uprawą warzyw była tak znaczna, że może mieć niekorzystny wpływ na pobieranie innych składników pokarmowych przez warzywa, a zatem obniżyć ich zdolność do zaopatrywania roślin w składniki pokarmowe, a także niekorzystnie wpływać na środowisko.

Słowa kluczowe: uprawa warzyw, odczyn gleb, węgiel organiczny, makroskładniki