ACTA Acta Sci. Pol., Hortorum Cultus 10(1) 2011, 123-130

EFFECT EXERTED ON SOIL PROPERTIES BY APPLE-TREE CULTIVATION FOR MANY YEARS AND BY REPLANTATION. PART II. CONTENT OF MINERAL COMPONENTS IN SOIL AND LEAVES

Zofia Zydlik[1], Eugeniusz Pacholak[1], Katarzyna Styła[2]

[1]Department of Pomology, Poznań University of Life Sciences

[2]Department of Agricultural and Forest Environment Studies, Polish Academy of Sciences

Abstracts: Studies were carried out in the years 2008–2009 in the Experimental Orchard of Fruit Growing Department, on the area of RSGD in Przybroda. Apple-trees of 'Topaz' cultivar on M.26 rootstock were planted in five soil localities: 1 – directly in grubbed up rows of an apple-tree orchard, 2 – in herbicide fallow belts of grubbed up apple-tree orchard, 3 – in turf belts of grabbed up apple-tree orchard, 4 – in a locality after a four-year break in apple-tree cultivation, without any preparatory treatments and 5 – in a soil after previous agricultural use – virgin soil. During the realization of studies, the mineral soil content (P, K, Mg) was identified, the total content of nitrogen and the pH value of soil were determined. In order to recognize the nutritional status of trees, the mineral contents of leaves (N, P, K, Mg and Ca) were investigated. Obtained results indicated that the content of mineral components in the soil depended on the earlier applied cultivation methods and on the soil layer from which the samples were taken. The highest mineral content was found in the soil which had been earlier use for agricultural purposes. The content of total nitrogen in the soil was significantly differentiated, depending on the soil locality where the apple-trees were planted and on the term of sampling. In summer season, the total nitrogen content in the soil was on the lowest level. Soil locality and the content of mineral components in the soil exerted an influence on the mineral composition in the leaves of 'Topaz' cultivar apple-trees.

Key words: replantation, mineral components, soil, leaves

Corresponding author – Adres do korespondencji: Zofia Zydlik, Departament of Pomology, Poznań University of Life Sciences, ul. Dąbrowskiego 159, 60-594 Poznań, Poland, tel. (+48) 61 848 79 48, e-mail: zydlik@up.poznan.pl

INTRODUCTION

Orchard plants grown on an exhausted soil can show some disease symptoms caused by negative actions of different factors. Literature data report that the factors which evoke replantation disease are divided into biotic factors such as bacteria, actinomycetes, fungi, nematodes and by abiotic factors including the absence of nutritional balance, incorrect soil structure, absence or excess of moisture [Utkhede and Smith 1994].

Absence or shortage of macro- and micro-elements lead to plant weakness and thereby to a decreased plant resistance, to the presence of pathogens and other abiotic factors in the soil [Mai and Abawi 1981; Merwin and Stiles 1989]. According to Pacholak et al. [1996], the absence of soil fertilization for a period of 17 years contributed to the impediment of apple-tree growth in the first year after plantation and it increased the number of dry trees in the successive years.

Another abiotic reason causing soil fatigue is its pH value. Acidification of soil can decrease or remove the problem of apple-tree replantation disease [Jonkers and Hoestra 1978], because a soil with low pH is less susceptible to replantation disease than a soil with pH value close to an indifferent level [Savory 1966; Hein 1972; Sewell et al. 1992]. In England, no replantation disease was found in a soil showing 4.0–4.5 pH [Utkhede and Smith 1994], and the majority of mineral components in situations of a low pH value are not accessible to plants limiting the growth of trees [Li and Utkhede 1991]. Acid soils usually are characterized by a decreased microbiological activity [Strączyński 1999].

The objective of our studies carried out in the years 2008–2009 was the investigation of the effect of soil locality and of replantation application exerted on the content of mineral components in the soil (P, K, Mg) as well as on the content of total nitrogen and the general nutritional status of apple trees.

MATERIAL AND METHODS

The present paper contains the second part of our studies on the effect of apple-tree cultivation for many years and of the application of replantation exerted on the soil properties and on the content of mineral components in soil and leaves of apple-trees 'Topaz' cultivar. A detailed description of the studied material has been presented in Part I of our studies.

Soil samples were taken in the year of tree plantation (2000), while in the year 2008, in the term of 15–20 July, soil was sampled in four replications in herbicide belts from two soil layers: 0–20 cm (arable layer) and 21–40 (sub-arable layer) and the following determinations were made:

a. content of P, K – by Egner-Riehm method and Mg content – by Schatchabel's method [Breś et al. 1991],

b. soil pH in H_2O and KCl – by potentiometric method [Drozd et al. 199].

Content of total nitrogen in soil was determined in years 2008–2009, in the soil samples taken in term: in the spring season, two weeks after tree blooming; in summer, after the termination of intensive tree growth and in autumn, one week after fruit harvest-by Kjeldahl method N_{org}. in g·kg^{-1} [Lityński et al. 1976].

Leaf samples were taken in mid-July 2008 and 2009. Combustion process was carried out in "wet conditions" in the presences of sulphuric acid and hydrogen peroxide solution in a mineralized Turbotherm of Gerhardt Co., after a mineralization analysis according to the method given by Ostrowska et al. [1991]:

a. nitrogen – by Kjeldahl method on Vapodest apparatus of Gerhard Co.,

b. phosphorus – by vanadomolibden method on Specol 1100 spectocolorimetr,

c. potassium, calcium and magnesium – by atomic absorption method (ASA)

Obtained results were compared with the valid critical values elaborated for orchard soils and leaves [Sadowski et al. 1990].

Results were analyzed by the analysis of variance using STATISTICA program. Significance of differences was estimated on the basis of Duncan's test for the confidence interval $\alpha = 0.05$.

RESULTS AND DISCUSSION

Soil analysis carried out in the year of orchard establishment (2000) and in the ninth year of orchard cultivation (2008) showed a significant differentiation in the contents of the analyzed mineral components, depending on the locality on which the apple-trees had been planted (tab. 1) Estimation of the effect of locality on the contents of phosphorus, potassium and magnesium in the soil showed the highest concentration in the soil of orchard planted in the locality after previous agricultural use, while the lowest concentration of these elements was shown in the orchard, where apple-trees were planted directly in the rows of the grubbed up trees (tab. 1).

In comparison with the initial analysis from the year 2000, it was found that the content of the analyzed mineral components in soil decreased in all localities in the arable soil layer. An exception was the soil sampled from the locality where apple-trees were planted in the belts of the grubbed up orchard, where an increased magnesium content was found. Similarly, in the sub-arable layer, the content of the analyzed components was decreased as well, with the exception of the combination where apple-trees had been planted directly in the grubbed up rows of trees. There, an increased amount of phosphorus was found. A similar situation was also found in the combination where apple-trees were planted in herbicide fallow and on the turf belts of the grubbed up orchard, where an increased content of magnesium was shown in the sub-arable soil layer. A comparison of the obtained results of chemical analyses with the critical values of the component contents for orchard soils indicated that the amounts of phosphorus, potassium and magnesium in both soil layers sampled from different soil localities were high. An exception was the soil sampled from the orchard planted directly in the rows of the grubbed up trees, where the potassium content in both the arable and sub-arable layers was on a medium level. It must be stressed that the proportion of potassium to magnesium in the soil from different localities, both in the year when our studies had begun and in the ninth year of orchard cultivation showed a regular level [Sadowski et al. 1990].

Table 1. Content of mineral components in the soil of apple orchard
Tabela 1. Zawartość składników mineralnych w glebie sadu jabłoniowego

Year Rok	Locality Stanowisko	pH (KCl)		P		K		Mg		Rotatio K/Mg Stosunek K/Mg	
				mg·100 g^{-1} soil – mg·100 g^{-1} gleby							
		0–20	21–40	0–20	21–40	0–20	21–40	0–20	21–40	0–20	21–40
2000	1	4.8 a*	5.2 a	11.7 a	5.7 a	16.8 a	10.4 a	8.9 a	7.7 a	1.9	1.4
	2	5.3 ab	5.3 a	12.7 a	4.4 a	16.6 a	13.2 a	8.7 a	7.7 a	1.9	1.7
	3	5.6 ab	5.7 ab	13.1 a	6.8 a	17.3 a	15.3 a	7.3 a	6.8 a	2.4	2.3
	4	5.4 ab	5.6 ab	17.8 b	8.3 a	16.1 a	19.1 ab	12.0 b	11.9 b	1.3	1.6
	5	6.0 b	6.1 ab	16.8 b	13.0 b	28.8 b	27.5 b	13.6 b	14.8 b	2.1	1.9
2008	1	6.0 a	6.3 a	7.1 a	6.1 a	6.4 a	4.9 a	5.7 a	5.8 a	1.1	0.8
	2	5.5 a	5.9 a	7.9 ab	4.3 a	9.7 a	5.9 a	7.4 a	7.9 a	1.3	0.7
	3	5.9 a	5.7 a	8.9 b	4.8 a	15.9 c	10.6 b	7.6 a	9.5 b	2.1	1.1
	4	6.3 a	5.9 a	8.1 ab	7.4 ab	11.9 b	8.4 ab	7.6 a	10.4 b	1.6	0.8
	5	6.3 a	6.9 a	9.0 b	9.7 b	15.6 c	11.5 b	12.7 b	13.6 c	1.2	0.8
Changes in relation to initial analysis Zmiana w porównaniu do analizy wyjściowej	1	+1.2	+1.1	-4.6	+0.4	-10.4	-5.5	-3.2	-1.9	-0.8	-0.6
	2	+0.4	+0.4	-4.8	-0.1	-6.9	-7.3	-1.3	+0.2	-0.6	-1.0
	3	+0.3	+0.6	-4.2	-2.0	-1.4	-4.7	+0.3	+2.7	-0.3	-1.2
	4	+0.9	+0.3	-9.7	-0.9	-4.2	-10.7	-4.4	-1.5	+0.3	-0.8
	5	+0.3	+0.8	-7.8	-3.3	-13.2	-16.0	-0.9	-1,2	-0.9	-1.1

*mean values marked with the same latter do not differ significantly at $\alpha = 0.05$
*średnie oznaczone tymi samymi literami nie różnią się istotnie na poziomie $\alpha = 0,05$

Similarly, also the content of mineral components and the soil reaction showed a differentiation between the analyzed soil layers and the localities, but only in the first year of studies (tab. 1). In comparison with the initial analysis from 2000, there was an increase of the pH value in both analyzed soil layers, while, the value was the highest in the soil of the orchard planted directly in the rows of the grubbed up trees (tab. 1).

The locality, where apple-trees were planted, exerted a significant influence on the total nitrogen content in the soil (tab. 2). On the average, the highest total nitrogen content was found in the soil of the orchard planted directly in the rows of the grubbed up trees and in the orchard planted in the soil which earlier was used for agricultural purposes. The lowest content of total nitrogen was shown in the locality which had a 4-year break in the cultivation of apple-trees. According to literature data [Ciecko et al. 2006; Gorlach and Grzywowicz 1989], the reserves of soil nitrogen amount from 0.2 to 3.5 g · kg^{-1}, depending on soil type and on the depth of soil profile. Mineral content in soil profile depends on many factors, among others on the cultivation method, on the dose and from of fertilizer, on the content of organic substances and on climatic conditions [Chmielewska and Dechnik 1987]. This fact explains the high differentiation between the particular terms of sampling. Our 2-year studies have shown that the total nitrogen content in soil also depended on the term of sampling (tab. 2). The lowest total nitrogen content soil was found in the samples taken in the summer period, while the highest N content was found in autumn. This agrees in part with the results obtained by Styła [2006], who also reported a differentiation in total nitrogen content in soil depending on the term soil sampling.

The earlier method of soil use exerted a significant influence on the level of mineral components in leaves o 'Topaz' cultivar apple-trees (tab. 3). Plantation of trees directly in the rows of grubbed up trees contributed to a poorer nutrition of trees with nitrogen which was shown by the lowest content of this component in leaves. The highest con-

Table 2. Total nitrogen content in the soil of apple orchard
Tabela 2. Zawartość azotu ogólnego w glebie sadu jabłoniowego

Locality Stanowisko	$N_{org.}$ in g · kg^{-1} d.m. soil – $N_{org.}$ w g · kg^{-1} s.m.gleby			Mean value for locality Średnia dla stanowiska
	spring wiosna	summer lato	autumn jesień	
Old row of trees Stary rząd drzew	1.79 d*	1.57 b	2.39 g	1.92 d
Old herbicide fallow Stary ugór herbicydowy	1.57 b	1.65 c	1.78 d	1.67 b
Old turf Belt Stary pas murawy	1.65 c	1.67 c	1.79 d	1.70 c
4-year break 4-letnia przerwa	1.43 a	1.56 b	1.57 b	1.52 a
Virgin soil Nowina	2.02 e	1.65 c	2.09 f	1.92 d
Mean value for terms Średnia dla terminów	1.69 b	1.62 a	1.92 c	

*mean values marked with the same latter do not differ significantly at α = 0.05
*średnie oznaczone tymi samymi literami nie różnią się istotnie na poziomie α = 0,05

Table 3. Content of mineral components in the leaves of apple trees of 'Topaz' cultivar
Tabela 3. Zawartość składników mineralnych w liściach jabłoni odmiany 'Topaz'

Locality Stanowisko	% d.m. – % s.m.				
	N	P	K	Mg	Ca
Old row of trees Stary rząd drzew	1.82 a*	0.18 b	1.62 d	1.48 c	0.26 b
Old herbicide fallow Stary ugór herbicydowy	2.16 d	0.18 b	1.12 b	1.98 e	0.34 c
Old turf Belt Stary pas murawy	2.25 e	0.17 a	0.94 a	1.80 d	0.37 d
4-year break 4-letnia przerwa	2.07 c	0.22 d	1.90 e	1.15 a	0.25 a
Virgin soil Nowina	2.02 b	0.20 c	1.49 c	1.35 b	0.26 b

*mean values marked with the same latter do not differ significantly at $\alpha = 0.05$
*średnie oznaczone tymi samymi literami nie różnią się istotnie na poziomie $\alpha = 0,05$

centration of nitrogen was recorded in the leaves of apple-trees planted in the turf belts of the grubbed up orchard. In reference to critical values, nitrogen content ranged on a low level in the locality after the old row of trees, in the locality with 4-year break in apple-tree cultivation and in the virgin soil. Nitrogen optimal level was shown in the orchard planted in the herbicide fallow belts and in turf belts of the grubbed up orchard (tab. 3). The content of phosphorus in leaves also showed significant differentiation between the particular soil localities, however, in relation to the critical values, in all studied leaves, it was on the optimal level (tab. 3). The highest differentiation between the localities was found in the potassium content in leaves. In comparison with the critical values, potassium content was low in leaves of trees planted in the turf belts of the grubbed up orchard, while it was optimal in trees planted in herbicide fallow belts of the grubbed up orchard and in the virgin soil. A high level of potassium in leaves was collected from trees planted directly in the rows after grubbed up trees and in the locality after a 4-year break in apple-tree cultivation. Magnesium content in leaves was on the optimal to high levels in trees planted in herbicide fallow belts and in turf belts of the grubbed up orchard. A high differentiation in the content of nutritive components in leaves was explained by Ugolik [1994] and Kurlus and Ugolik [1999], who stated that the concentration of the particular nutritive components in leaves depends on the component content in the soil, on the course of climatic conditions, on the yielding level and on the age of trees.

CONCLUSIONS

1. Content of mineral components in soil depended on the earlier method of soil use, as well as on the soil layer from which the sample was taken. After 8 years of cultivation of the apple trees of Topaz cultivar a significant higher content of P, K and especially Mg was indicated in the soil samples collected from virgin soil in comparison with samples from rows of the old orchard.

2. Total nitrogen content in soil was significantly differentiated, depending on the soil locality on which apple-trees were planted and on the term of sampling. In summer season, the total nitrogen content in soil was the lowest. The higher average content of total nitrogen was indicated in the samples from virgin soils and from locality were apple trees was planted directly in the rows of grubbed up trees.

3. Soil locality exerted an effect on the mineral composition in the leaves of 'Topaz' cultivar apple-trees. Planting apple trees directly in rows of grubbed up trees significantly decreased P and K content and 4-year break in apple tree growing decreased content of Mg in leaves.

REFERENCES

Breś W., Golcz A., Komosa A., Kozik E., Tyksiński W., 1991. Nawożenie roślin ogrodniczych. Cz. I. Diagnostyka potrzeb nawozowych, Wyd. AR Poznań, 105.

Ciećko Z., Zołnowski A.C., Krajewski W., 2006. Wpływ nawożenia NPK stosowanego w uprawie ziemniaka na zwartość N-NO_3 oraz NH_4 w glebie. Zesz. Probl. Post. Nauk Roln., 513, 55–62.

Chmielewska B., Dechnik J., 1987. Wpływ nawożenia mineralnego na zawartość niektórych form azotu w brunatnej glebie lessowej. Rocz. Nauk Roln., Ser. A 106 (2), 197–205.

Drozd J., Licznar S. E., Weber J., 1997. Gleboznawstwo z elementami minerologii i petrografii, Wrocław.

Gorlach E., Grzywnowicz J., 1989. Distribution of various nitro gen forms in the soil profile and their relationship with nitrogen taken up by plants. Pol. J. Soil Sci., 23, 43–49.

Hein K., 1972. Beitrage zum problem der Bodenmudigkeit. Gardenbau-Wissenschaft 35, 47–71.

Jonkers H., Hoestra H., 1978. Soil pH in fruit trees in reclamation to specific replant disorder of apple. I. Introduction and review of literature. Scientia Hort. 8, 113–118.

Kurlus R., Ugolik M., 1999. Wpływ podkładki na zawartość składników mineralnych w liściach jabłoni odmiany Šampion. Zesz. Nauk. AR im. H. Kołłątaja w Krakowie, 351, Sesja Naukowa 66, 205–123.

Li T. S. C., Utkhede R. S., 1991. Effect of soil pH and nutrients on growth of apple seedlings grown in apple replant disease soils of British Columbia. Can. Plant. Dis. Surv. 71, 29–32.

Lityński T., Jurkowska H., Gorlach E., 1976. Analiza chemiczno-rolnicza gleby. PWN. Warszawa, 135–143.

Mai W. F., Abawi G. S., 1981. Controlling replant disease of pome and stone fruits in Northeastern United States by replant fumigation. Plant Disease, 65 (11), 859–864.

Merwin I.A., Stiles W.C., 1989. Root-lesion nematodes, potassium deficiency and prior cover crops as factors in apple replant disease. J. Amer. Soc. Hort. Sci. 114, 724–728.

Ostrowska A., Gawliński S., Szczubiałka Z., 1991. Metody analizy i oceny właściwości gleb i roślin. Katalog. Warszawa, Instytut Ochrony Roślin, 245–279.

Pacholak E., Cwynar M., Zydlik Z., 1996. Wpływ siedemnastoletniego nawożenia i nawadniania na wzrost jabłoni odmiany Szampion na podkładce P 60 w drugim roku po replantacji. XXXIV Ogólnopol. Nauk. Konf. Sadownicza. ISiK, Skierniewice 28–30 sierpnia, 96–99.

Sadowski A., Nurzyński J., Pacholak E., Smolarz K., 1990. Określanie potrzeb nawożenia roślin sadowniczych. II. Zasady, liczby graniczne i dawki nawożenia. Instrukcja Upowszechnieniowa nr 3. SGGW, Warszawa, 25.

Sadowski A., Ścibisz K., Tomala K., Kozanecka T., Kępka M., 1988. Negative effects of excessive nitrogen and potassium fertilization in a replanted apple orchard. Acta Hort. 233, 85–94.

Savory B. M., 1967. Specific replant disease of apple and cherry. East Malling Res. Stn Ann. Rep. 1966, 205–208.
Sewell G. W. F., Roberts A. L., Elsey R. F., 1992. Apple replant disease: the assessment and result of seedling bio-assays of growth responses to soil fumigation with chloropicrin. Ann. Appl. Biol. 121, 199–209.
Strączyński S., 1999. Stan zakwaszenia i potrzeby wapnowania gleb w Polsce. Zesz. Probl. Post. Nauk Roln. 467, 527–532.
Styła K., 2006. Stan mikrobiologiczny gleby w sadzie jabłoniowym po replantacji. Praca dokt. wykonana w Katedrze Mikrobiologii Rolnej AR w Poznaniu pod kier. A. Sawickiej.
Ugolik M., 1994. Wpływ podkładek wegetatywnych i ich pochodzenia na zawartość składników mineralnych w liściach jabłoni. XXXIII Ogólnopol. Nauk. Konf. Sadownicza Cz. 1, ISiK Skierniewice, 32–33
Utkhede R. S., Smith E. M., 1994. Biotic and abiotic causes of replant problems of fruit trees. Acta Hort. 363, 25–32.

WPŁYW WIELOLETNIEJ UPRAWY JABŁONI I STOSOWANIA REPLANTACJI NA WŁAŚCIWOŚCI GLEBY. CZĘŚĆ II. ZAWARTOŚĆ SKŁADNIKÓW MINERALNYCH W GLEBIE I W LIŚCIACH

Streszczenie. Badania przeprowadzono w sadzie doświadczalnym w latach 2008–2009. Jabłonie odmiany Topaz posadzono na pięciu „stanowiskach glebowych": 1 – bezpośrednio w rzędach wykarczowanego sadu jabłoniowego, 2 – w pasach ugoru herbicydowego wykarczowanego sadu jabłoniowego, 3 – w pasach murawy wykarczowanego sadu jabłoniowego, 4 – na stanowisku z czteroletnia przerwą w uprawie jabłoni, bez zabiegów przygotowawczych i 5 – glebie po uprawach rolniczych – nowina. W trakcie realizacji badań dokonano oceny składu mineralnego gleby (P, K, Mg), zbadano zawartość azotu ogólnego i określono odczyn gleby. W celu poznania stanu odżywienia drzew wykonano ocenę składu mineralnego liści (N, P, K, Mg i Ca). Otrzymane wyniki wskazują, że zawartość składników mineralnych w glebie była zależna od wcześniejszego sposobu użytkowania gleby jak też warstwy, z której została pobrana. Najwyższą zawartość stwierdzono w glebie sadu posadzonego na stanowisku wcześniej użytkowanym rolniczo. Zawartość azotu ogólnego w glebie była istotnie zróżnicowana w zależności od stanowiska glebowego, na którym posadzono jabłonie oraz od terminu pobierania prób. W okresie letnim zawartość azotu ogólnego w glebie była najniższa. Stanowisko glebowe i zawartość składników mineralnych w glebie miały wpływ na skład mineralny liści jabłoni odmiany Topaz.

Słowa kluczowe: replantacja, składniki mineralne, gleba, liście

ACKNOWLEDGEMENTS

Studies were partially financed within the research project 44/2008/GW

Accepted for print – Zaakceptowano do druku: 27.12.2010