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EFFECT OF SOIL POTASSIUM LEVELS AND DIFFERENT POTASSIUM FERTILIZERS ON YIELD, MACROELEMENT AND CHLORIDE NUTRION STATUS OF APPLE TREES IN FULL FRUITION PERIOD

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Abstract. The experiment was established in the spring 1999 on lessive soil developed from light boulder clay. Apple trees of Golden Delicious cv. on M.26 rootstock were planted in 3.5 × 1.2 m (2381 trees·ha^{-1}) spacing. Research involved the effect of diversified levels of potassium fertilization: 12, 16 and 20 mg K 100 g^{-1} d.m. of soil and three types of potassium fertilizers: potassium chloride (KCl), potassium sulfate (K_2SO_4) and potassium nitrate (KNO_3) on trees yielding and nutrition, as well as nutrient contents in the soil. Potassium fertilization using potassium chloride, potassium sulfate and potassium nitrate resulted in increased content of available potassium both in arable (0–20 cm) and in subarable (20–40 cm) layers of an apple orchard. Increase of available potassium content from 12 to 20 mg K·100 g^{-1} f. m of soil, due to fertilization with potassium chloride, potassium sulfate and potassium nitrate did increase soil pH (in H_2O) in arable and subarable layers as a result of higher contents of available calcium. Alkalizing effect of potassium sulfate and potassium nitrate, generally assumed as physiologically acidifying, occurred on neutral and alkaline soils [pH (in H_2O) over 6.90]. Fertilization with potassium chloride, potassium sulfate and potassium nitrate increased the content of sulfates in arable and subarable layers. The same result was observed in the case of chlorides in subarable layer. Application of potassium fertilization with potassium nitrate brought about decreased values of available magnesium content only in subarable layer. Due to the use of high rates of potassium nitrate, on the level 20 mg K·100 g^{-1} of soil, there was observed increased soil salinity (EC) both in arable and subarable layers. Introduction of potassium fertilization and increasingly higher rates of potassium fertilizers did not influence on the content of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and chlorine in apple tree leaves. Increasing potassium levels in the soil and potassium fertilizers did not affect the yield of Golden Delicious apple trees after coming them into full fruition period.

Key words: chlorides, sulfates, nitrates, orchards, soil analysis, plant analysis

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INTRODUCTION

Nutrition state of apple trees does considerably influence on their growth and yielding. One of the elements playing an important role in mineral nutrition of trees is potassium. It directly affects water relations of plants, enzymes activation and apple trees resistance to stresses, e.g. increase in flower buds frost tolerance [Zygmuntowska and Jadczuk-Tobjasz 2008, Sadowski et al. 1988].

Apple trees feature the highest potassium content in leaves, lower – in fruits and the lowest one in roots and branches. Potassium amount in leaves is a cultivar property. Potassium is easily translocated from leaves to fruits [Jarociński 2005]. This element can be absorbed in luxury or excessive amounts. The latter case can lead to reduced uptake of magnesium and calcium as a result of K : Mg and K : Ca antagonism [Lipecki and Jadczuk 1998, Jadczuk et al. 2003, Jarociński 2005]. The symptoms of diminished absorption of magnesium can occur as its deficit symptoms on leaves. As far as worse calcium uptake is concerned, it can result in decreased quantity of this element in fruits which brings about the occurrence of bitter pit. Potassium to calcium ratio in apple fruits is an important indicator regarding prediction of their storage properties [Tomala 1997]. Maintaining high state of apple trees nutrition with potassium can be justified in orchards characterizing high content of calcium in the soil [Szücs 2005].

Optimum trees fertilization should take into account their vigor, yielding capability, soil fertility and nutrition status [Sadowski 2000]. The basis of modern diagnosing of fertilization needs of orchard plants is determination of macro and microelements contents in soil and leaves. Komosa and Stafecka [2002] proved high usability of the universal method [Nowosielski 1974] for determination of macro and microelements in soils used for orchard purposes. The mentioned method was also applied in this investigation.

Apple trees nutrition with potassium is significantly connected with their nutrition of nitrogen, sulfur and chlorine. This status results from application of different potassium fertilizers including nitrates (KNO_3), sulfates (K_2SO_4) or chlorides (KCl) anions. It is especially important in the case of potassium sulfate, because it is a source of sulfur. Recently, there has been observed a considerable decrease of sulfur content in agricultural and orchard soils [Jakubus 2001, Szwonek 2006]. In practice, relatively cheap potassium chloride is used for fertilization of apple trees orchard soils instead of more expensive potassium sulfate. Chlorine, an essential element accompanying potassium fertilizers, is of a significant importance when considering plant nutrition [Heckman 2007].

Therefore, there has emerged a need of investigation dealing with efficiency of orchard soils fertilization and apple trees potassium nutrition introducing different doses and sources of potassium [Komosa and Szewczuk 2002, Szewczuk et al. 2008]. The aim the research was the assessment of the effect of increasing potassium levels in the soil, maintained by application of potassium nitrate, potassium sulfate and potassium chloride, on changes in macroelements and chlorine in soil and leaves, as well as on yield of Golden Delicious apple trees.

MATERIAL AND METHODS

The experiment was established in the spring 1999 in Research Station of Wroclaw University of Environmental and Life Sciences, on lessive soils developed from light boulder clay. The subject of investigation were apple trees of Golden Delicious cultivar on M26 rootstock, in their full fruiting period. Trees were planted in 3.5 × 1.2 m – 2381 trees·ha^{-1} spacing. In trees rows there was maintained herbicide fallow, while sward in inter-rows had been growing since the first year after planting trees.

In the experiment conducted in the years 2002–2004 there was assessed nutrition state and yielding of apple trees in their fourth – to sixth year after planting. Research was continuation of the experiment aiming at the assessment of the effect of diversified potassium fertilization on nutrition status of young apple trees regarding macro and microelements. Results obtained for the years 1999–2001 were published in the work by Komosa and Szewczuk [2002], and those referring to the years 2002–2004, involving examination of microelements content, were included in the work by Szewczuk et al. [2009]. The mentioned elaboration also contained data connected with macro and microelements content in the soil before planting trees, as well as potassium rates for the examined forms of potassium fertilizer in relation to determined potassium level in the soil and to research period, the years 1991–2001 and 2002–2004.

Investigation was carried out as two – factorial experiment. The first factor was potassium level in the soil, amounting: 12, 16 and 20 mg K·100 g^{-1} d.m. of soil. The kind of potassium fertilizer: potassium salt (KCl), potassium sulfate (K_2SO_4) and potassium nitrate (KNO_3). All treatments were fertilized with nitrogen and phosphorus on the basis of chemical analyses. Nitrogen was applied in the form of ammonium nitrate (34%) and potassium nitrate (13% N, 39% K only in the treatment with KNO_3), phosphorus in superphosphate (20% P), and potassium in potassium chloride (50% K), potassium sulfate (41% K) and potassium nitrate. Nitrogen, phosphorus and potassium single rates were: 60 kg N, 30 kg P and 100 kg K·ha^{-1} Fertilization was applied each year in three terms: half of March, April and May.

The experiment was conducted as an independent design, in four replications with 4 trees in particular replication. Experimental plot was of 67.2 m^2 area. Apart from apple trees subjected to examination, the plot featured 12 trees forming an insulating screen (there were 16 trees on the plot).

Soils samples for analysis were collected in the second half of July, from the middle of trees rows in herbicide strips, separately from two layers : 0–20 cm and 20–40 cm, with the use of a soil auger.

Soil analysis was done using the universal method by Nowosielski [1974], modified for orchard soils [Komosa and Stafecka 2002]. The samples were dried at room temperature, ground in a mortar and through a sieve with 1 mm mesh diameter. Extraction of N-NH_4, N-NO_3, P, K, Ca, Mg, S-SO_4 and Cl was done in 0.03 M CH_3COOH at soil : extract solution = 1 : 10 (w/w), i.e. 20 g of soil dry matter and 200 cm^3 0.03 M CH_3COOH, at 30 minutes lasting extraction. After the process had been completed, there were determined, according to IUNG [1983], the following elements: N-NH_4 – using microdistillation by Bremner's method, modified by Starck, N-NO_3 – applying an ion selective electrode ORION, P –according to colorimetric method with vanadiummolybdenum ammonium, K, Ca, Mg and Na – by atomic spectrometric absorption (ASA), $S\text{-}SO_4$ – nephelometrically with $BaCl_2$, Cl – nephelometrically with $AgNO_3$ and B – colorimetric method with curcumin.

The samples of leaves were collected in the second half of July. One sample, containing about 100 leaves originating from the middle part of long-shoots was collected from each plot. A single long-shoot provided 3–4 leaves which were taken to determination of total contents of N, P, K, Mg, Ca, S and Cl. Leaves were dried at the temperature of 45–50°C and ground. To determine total forms of P, K and Mg leaves were subjected to „wet" mineralization in sulfuric acid, while Cl was assayed by „dry" mineralization. Nitrogen content was determined by mineralization leaves in sulfosalicilic acid. Total N was determined after mineralization using Kjeldahl method, in Parnas-Wagner distillation device, P – by colorimetric method with ammonium molybdate, K, Ca, Mg – according to ASA method and Cl – colorimetrically with $BaCl_2$, while sulfur – due to a Butters-Chenery method.

Obtained results were statistically elaborated using analysis of variance for two – factorial experiments and Duncan test at significance level α 5%.

RESULTS AND DISCUSSION

Considering results show in table 1, it is possible to state that increased potassium content in 0–20 cm soil layer of herbicide strips did not significantly affect the content of nitrogen ($N\text{-}NH_4$ and $N\text{-}NO_3$), phosphorus, magnesium and chlorides in the soil. Yet it significant influenced on the increase of soil pH (in H_2O). The mentioned effect was especially evident between the levels 12 and 20 mg $K \cdot 100\ g^{-1}$ soil d.m. Elevated pH values occurred not only when potassium nitrate, classified to soil as alkalifying fertilizers was used, but also was present for application of potassium chloride and potassium sulfate, which feature acidifying properties [Marschner 2006]. The increase in pH (in H_2O) resulted from the content of calcium available to plants in the soil (tab. 1). Due to application of increasing potassium fertilization calcium was exchanged from a sorption complex into soil solution. Intensity of this process was higher than the accumulation of acidifying anions SO_4^{2-} and Cl^-. Conducted investigation prove that potassium, sulfate and chloride fertilizers (K_2SO_4 and KCl), applied into soils of high pH (in H_2O) values, over 6.9 and high calcium content, can characterize alkalifying properties.

There was recorded significant increase of $S\text{-}SO_4$ content in 0–20 cm soil layer as a result of using high rates of K_2SO_4 to reach the level of 20 mg $K \cdot 100\ g^{-1}$ soil d.m. (tab. 1). Sulfur content was maintained within optimum range of 1.8–2.9 mg $S\text{-}SO_4 \cdot 100\ g^{-1}$ soil d.m. According to Komosa and Stafecka [2002], optimum content of sulfur in orchard soils amounts 1.0–3.0 mg $S\text{-}SO_4 \cdot 100\ g^{-1}$ d.m of soil.

At KNO_3 application at the level of 20 mg $K \cdot 100\ g^{-1}$ d.m. of soil there could be noticed a tendency the increase of $N\text{-}NO_3$ content in 0–20 cm soil layer (tab. 1). There was not observed any increase in chlorides content in 0–20 cm soil layer under the influence of KCl (tab. 1). Application of high rates of KCl, K_2SO_4 and KNO_3 contributed to elevated values of soil salinity (EC). The highest increase in soil salinity took place at maintained level of 20 mg $K \cdot 100\ g^{-1}$ soil d.m. with the use of KNO_3, lower for KCl and

Table 1. Content of $N-NH_4$, $N-NO_3$, K, $S-SO_4$, Cl, P, Ca and Mg in the soil layer of 0–20 cm in the herbicide strips in relation to potassium fertilizer and potassium level in soil (means from 2002–2004)

Tabala 1. Zawartość $N-NH_4$, $N-NO_3$, K, $S-SO_4$, Cl, P, Ca i Mg w warstwie 0–20 cm gleby w pasie herbicydowym w zależności od nawożenia potasowego i poziomu potasu w glebie (średnio z lat 2002–2004)

	K level – Poziom K mg·100 g^{-1} of soil – gleby	Potassium fertilizer – Nawożenie potasowe			Mean Średnio
		KCl	K_2SO_4	KNO_3	
mg $N-NH_4$ 100 g^{-1} of soil – gleby	12	1.4 a	1.9 a	1.2 a	1.5 a
	16	1.2 a	1.4 a	0.8 a	1.1 a
	20	0.8 a	1.1 a	1.6 a	1.2 a
Mean – Średnio		1,2 a	1.4 a	1.2 a	
mg $N-NO_3$ 100 g^{-1} of soil – gleby	12	1.9 a	1.6 a	1.9 a	1.8a
	16	2.3 a	1.5 a	2.1 a	2.0a
	20	2.8 a	1.9 a	4.2 a	3.0a
Mean – Średnio		2,4 a	1.7 a	2.7 a	
mg K·100 g^{-1} of soil – gleby	12	15.7a	12.3a	17.7 a	15.2 a
	16	14.4a	19.8a	21.0 a	18.4 ab
	20	21.2a	22.5a	28.6 a	24.1 b
Mean – Średnio		17,1a	18.2a	22.4 a	
mg $S-SO_4$·100 g^{-1} of soil – gleby	12	0.8 a	1.8 bc	0.7 a	1.1a
	16	0.8 a	2.0 cd	0.8 a	1.2a
	20	1.1abc	2.9 d	1.0 ab	1.7a
Mean – Średnio		0,9 a	2.2 b	0.8 a	
mg Cl 100 g^{-1} of soil – gleby	12	1.8 a	1.9 a	1.8 a	1.9 a
	16	2.0 a	1.7 a	1.7 a	1.8 a
	20	2.1 a	2.0 a	2.1 a	2.1 a
Mean – Średnio		2,0 a	1.9 a	1.9 a	
mg P 100 g^{-1} of soil – gleby	12	6.9 a	6.4 a	6.5 a	6.6 a
	16	5.4 a	7.3 a	6.2 a	6.3 a
	20	6.9 a	7.5 a	6.8 a	7.1 a
Mean – Średnio		6,4 a	7.1 a	6.5 a	
mg Ca 100 g^{-1} of soil – gleby	12	55.8 a	53.2 a	63.3 a	57.4 a
	16	53.2 a	62.4 a	59.3 a	58.3 a
	20	67.6 a	75.9 a	92.1 a	78.5 a
Mean – Średnio		58,9 a	63.8 a	71.6 a	
mg·Mg 100 g^{-1} of soil – gleby	12	4.0 a	3.9 a	6.4 a	4.0 a
	16	2.9 a	2.9 a	4.5 a	4.5 a
	20	5.0 a	6.6 a	4.3 a	5.1 a
Mean – Średnio		4,8 a	3.4 a	5.3 a	
pH_{H_2O}	12	6.7 a	6.9 a	7.0 a	6.9 a
	16	7.0 a	7.0 a	7.1 a	7.0 ab
	20	7.1 a	7.2 a	7.3 a	7.2 b
Mean – Średnio		7,0 a	7.0 a	7.1 a	
EC (mS·cm^{-1})	12	0.26 a	0.18 a	0.22 a	0.27 a
	16	0.29 a	0.26 a	0.26 a	0.23 a
	20	0.28 a	0.26 a	0.36 a	0.28 a
Mean – Średnio		0.27 a	0.23 a	0.28 a	

Means marked by the same letter are not significantly differed at $\alpha = 0.05$
Średnie oznaczone tą samą literą nie różnią się istotnie przy $\alpha = 0,05$

the lowest for K_2SO_4. Relatively insignificant increase in soil salinity resulting from K_2SO_4 was probably caused by the fact that worse soluble $CaSO_4$ (gypsum) was formed due to high calcium content in the soil.

High potassium levels maintained in 0–20 cm soli layer did significantly increase its content in the soil layer of 20–40 cm (tab. 2). These data evidently prove the effect of increasing potassium levels on the content of chlorides and magnesium, as well as on soil pH and EC. Increased values of chlorides content resulted mainly from application of high rates of KCl and KNO_3 aimed at maintaining the level of 20 mg K·100 g^{-1} d.m. of soil.

The influence of potassium fertilization on magnesium content in the soil was of a diverse nature. When increasing KCl rates were applied, magnesium content in 20–40 cm soil layer did increase (tab. 2). It decreased, however, when affected by KNO_3 fertilization. No effects, regarding magnesium content, were recorded in the case of K_2SO_4 application.

Similarly to the 0–20 cm soil layer, increasing potassium fertilization significantly increased pH values in 20–40 cm subsoil (tab. 2). This effect occurred under the influence of all the examined potassium fertilizers. There was also observed increased soil salinity (EC) as a result of high KNO_3 rates.

Comparing obtained results with those connected with a young orchard [Komosa and Szewczuk 2002], it is possible to state that potassium fertilization introduced in an older orchard also led to the increase of available potassium content in the soil and a sulfate form of fertilizer provided for increased sulfur content in arable soil layer.

There was not recorded the effect of increasing potassium levels in the soil and different kinds of potassium fertilizers on the content of the nitrogen, phosphorus, potassium, calcium, magnesium, chlorine and sulfur contents in apple trees leaves (tab. 3). There was noticeable, however, a tendency to raised potassium levels in leaves resulting from high rates of KCl and KNO_3. This phenomenon was also reported in earlier research works by Komosa and Szewczuk [2002] conducted in a young orchard. The increase of potassium content in leaves, as well as magnesium decreased, and no considerable effect of potassium fertilization on the content of the remaining components, was also reported by Jadczuk et al. [1996]. Advantageous influence of potassium fertilization on nutrition status of young apple trees was proved by Leszczyński and Sadowski [1990]. Young trees response to potassium fertilization depended in that investigation on a rootstock.

Fertilization with potassium sulfate did not increase sulfur content, similarly to fertilization with potassium chloride which did not increase chlorine content in leaves. In spite of the fact that there was applied intensive potassium fertilization, antagonism K : Mg and K : Ca in leaves did not occur.

Assessing nutrition state of apple trees on the basis of optimum components ranges assumed after Sadowski [2000], it is possible to state that apple trees featured optimum nutrition regarding nitrogen (at fertilization with KCl, and K_2SO_4), high content values (at KNO_3 fertilization), optimum nutrition considering phosphorus and potassium, as well as high magnesium nutrition levels. Basing the assessment on the data by Leece [1976], optimum nutrition of trees, as far as calcium was taken into account, could be reported (optimum range 1.00–2.00% Ca in d.m. of leaves), in the case of sulfur (optimum 0.20–0.40% S) and for chorine (optimum below 0.30% Cl of d.m.).

Table 2. Content of N-NH_4, N-NO_3, K, S-SO_4, Cl, P, Ca and Mg in the soil layer of 20–40 cm in the herbicide strips in relation to potassium fertilizer and potassium level in soil (means from 2002–2004)

Tabela 2. Zawartość N-NH_4, N-NO_3, K, S-SO_4, Cl, P, Ca i Mg w warstwie 20–40 cm gleby w pasie herbicydowym w zależności od nawożenia potasowego i poziomu potasu w glebie (średnio z lat 2002–2004)

	K level – Poziom K	Potassium fertilizer – Nawożenie potasowe			Mean
	mg·100 g^{-1} of soil –gleby	KCl	K_2SO_4	KNO_3	Średnio
mg N-NH_4 100 g^{-1} of soil – gleby	12	1.1 a	1.2 a	0.8 a	1.0 a
	16	1.0 a	1.3 a	1.0 a	1.1 a
	20	0.8 a	1.1 a	1.2 a	1.0 a
Mean – Średnio		1,0 a	1.2 a	1.0 a	
mg N-NO_3 100 g^{-1} of soil – gleby	12	1.6 a	1.5 a	1.3 a	1.5 a
	16	1.0 a	1.4 a	1.5 a	1.3 a
	20	1.1 a	1.3 a	1.2 a	1.2 a
Mean – Średnio		1,2 a	1.4 a	1.3 a	
mg·K·100 g^{-1} of soil – gleby	12	9.8 a	9.7 a	10.7 a	10.0 a
	16	10.5 a	13.3 a	12.8 a	12.2 ab
	20	15.8 a	14.6 a	12.7 a	14.4 b
Mean – Średnio		12,0 a	12.5 a	12.1 a	
mg·S-SO_4·100 g^{-1} of soil – gleby	12	1.4 a	1.1 a	0.5 a	1.0 a
	16	1.1 a	2.0 a	0.9 a	1.3 a
	20	0.9 a	1.3 a	1.7 a	1.3 a
Mean – Średnio		1,1 a	1.5 a	1.0 a	
mg Cl 100 g^{-1} of soil – gleby	12	1.5 a	1.6 a	1.4 a	1.5 a
	16	1.6 a	1.7 a	1.6 a	1.6 ab
	20	1.9 a	1.6 a	2.0 a	1.8 b
Mean – Średnio		1,7 a	1.6 a	1.6 a	
mg P 100 g^{-1} of soil – gleby	12	4.8 a	5.4 a	4.6 a	4.9 a
	16	4.0 a	4.7 a	4.1 a	4.2 a
	20	5.2 a	4.6 a	4.4 a	4.7 a
Mean – Średnio		4,6 a	4.9 a	4.4 a	
mg Ca 100 g^{-1} of soil – gleby	12	62.9 a	53.8 a	49.1 a	55.3 a
	16	68.7 a	85.0 a	60.5 a	71.4 a
	20	80.6 a	78.8 a	110.0 a	89.8 a
Mean – Średnio		70,8 a	72.5 a	73.2 a	
mg·Mg 100 g^{-1} of soil – gleby	12	4.4 abc	4.5 abc	7.2 d	5.3 a
	16	3.5 ab	3.2 a	5.7 bcd	4.1 a
	20	6.3 cd	4.7 abc	4.0 ab	5.0 a
Mean – Średnio		4,7 a	4.1 a	5.6 a	
pH_{H_2O}	12	7.1 a	7.0 a	7.0 a	7.0 a
	16	7.4 a	7.2 a	7.2 a	7.3 ab
	20	7.4 a	7.5 a	7.6 a	7.5 b
Mean – Średnio		7,3 a	7.2 a	7.3 a	
EC (mS·cm^{-1})	12	0.24 a	0.18 a	0.19 a	0.20 a
	16	0.24 a	0.21 a	0.19 a	0.21 a
	20	0.22 a	0.20 a	0.23 a	0.22 a
Mean – Średnio		0.23 a	0.20 a	0.20 a	

Means marked by the same letter are not significantly differed at $\alpha = 0.05$
Objaśnienia jak w tabeli 1

Table 3. Content of macroelements and chloride in the leaves of 'GD' apple trees in relation to potassium fertilizer and potassium level in soil (means from 2002–2004)
Tabela 3. Zawartość makroskładników oraz chloru w liściu jabłoni 'Golden Delicious' w zależ–ności od nawożenia potasowego i poziomu potasu w glebie (średnio z lat 2002–2004)

	K level – Poziom K mg·100 g^{-1} of soil – gleby	Potassium fertilizer – Nawożenie potasowe			Mean Średnio
		KCl	K_2SO_4	KNO_3	
N % d.m. N % s.m.	12	2.13 a	2.14 a	1.97 a	2.08 a
	16	2.23 a	2.18 a	2.20 a	2.20 a
	20	2.12 a	2.14 a	2.15 a	2.13 a
Mean – Średnio		2,16 a	2.15 a	2.11 a	
P % d.m. P % s.m.	12	0.24 a	0.25 a	0.24 a	0.24 a
	16	0.24 a	0.24 a	0.23 a	0.24 a
	20	0.25 a	0.26 a	0.25 a	0.25 a
Mean – Średnio		0,24 a	0.25 a	0.24 a	
K % d.m. K % s.m.	12	1.34 a	1.48 a	1.53 a	1.45 a
	16	1.42 a	1.50 a	1.53 a	1.48 a
	20	1.51 a	1.42 a	1.57 a	1.50 a
Mean – Średnio		1,42 a	1.47 a	1.54 a	
Ca % d.m. Ca % s.m.	12	1.34 a	1.35 a	1.31 a	1.33 a
	16	1.44 a	1.40 a	1.33 a	1.39 a
	20	1.36 a	1.29 a	1.32 a	1.32 a
Mean – Średnio		1,38 a	1.35 a	1.32 a	
Mg % d.m. Mg % s.m.	12	0.44 a	0.45 a	0.44 a	0.44 a
	16	0.44 a	0.47 a	0.45 a	0.45 a
	20	0.44 a	0.45 a	0.42 a	0.43 a
Mean – Średnio		0,44 a	0.45 a	0.43 a	
Cl % d.m. Cl % s.m.	12	0.014 a	0.009 a	0.011 a	0.013 a
	16	0.017 a	0.013 a	0.011 a	0.013 a
	20	0.009 a	0.010 a	0.010 a	0.010 a
Mean – Średnio		0.013 a	0.012 a	0.011 a	
S % d.m. S % s.m.	12	0.26 a	0.28 a	0.25 a	0.26 a
	16	0.27 a	0.30 a	0.26 a	0.28 a
	20	0.27 a	0.27 a	0.28 a	0.27 a
Mean – Średnio		0.27 a	0.28 a	0.26 a	

Means marked by the same letter are not significantly differed at $\alpha = 0.05$
Objaśnienia jak w tabeli 1

Diversified potassium level in the soil and the kind of potassium fertilizers did not markedly affect the yield of Golden Delicious apple trees in the fourth to sixth year after their planting (tab. 4). Average of apples yield from one tree with the fertilization of potassium chloride amounted 19.7 kg (46.9 t·ha^{-1}) when for the potassium sulfate 19.3 kg (45.9 t·ha^{-1}) and 19.2 kg (45.7 t·ha^{-1}) for potassium nitrate. Earlier research by Komosa and Szewczuk [2002] and by Szewczuka et al. [2008] also did not prove the effect of potassium on the yield of young trees in their second and third year after planting. However, Jadczuk et al. [1996], obtained the increase in apple trees yield in the second year of fruition (fourth year after planting), under the influence of increasing rates of potassium fertilization. Similar reaction was observed by the authors in subsequent years of trees growth in the orchard, when increase of apples yield was 11 to 17%, resulted from the rate and a method of potassium fertilization [Jadczuk et al. 2003]. The

Table 4. Yield of Golden Delicious apple trees in relation to potassium fertilizer and potassium level in soil (means from 2002–2004)
Tabela 4. Plon jabłoni 'Golden Delicious' w zależności od nawożenia potasowego oraz poziomu potasu w glebie (średnio z lat 2002–2004)

K level – Poziom K mg·100 g^{-1} of soil – gleby	Potassium fertilizer, kg·tree^{-1} – Nawożenie potasowe, kg·drzewo^{-1}			Mean Średnio
	KCl	K_2SO_4	KNO_3	
12	19.5 a	18.7 a	19.6 a	19.3 a
16	20.6 a	20.0 a	19.9 a	20.2 a
20	19.1 a	19.1 a	18.0 a	18.7 a
Mean – Średnio	19.7 a	19.3 a	19.2 a	

Means marked by the same letter are not significantly differed at α = 0.05
Objaśnienia jak w tabeli 1

increase of trees yield as the effect of potassium fertilization was also reported by Bojarski et al. [2002]. According to Jadczuk et al. [2003] diversified results of research on the effect of potassium on apple trees are a consequence of their relatively high tolerance regarding deficit of this nutrient, while diversification in trees growth and yielding can be evident only at significant difference in nutrition level of trees in the course of a long time.

CONCLUSIONS

1. Potassium fertilization with the use of potassium chloride, potassium sulfate and potassium nitrate increased the content of available potassium in arable (0–20 cm) and subarable (20–40 cm) soil layers of apple trees orchard.

2. The increase of available potassium content from 12 to 20 mg K·100 g^{-1} d. m. of soil, resulting from fertilization with potassium chloride, potassium sulfate and potassium nitrate increased pH values (in H_2O) in arable and subarable soil layers as a consequence of increased content of available calcium. Alkalifying effect of potassium sulfate and potassium chloride, classified as physiologically acidifying fertilizers, occurred on neutral and alkaline soils (pH (in H_2O) over 6.90).

3. Increasing rates of potassium fertilization with the use of potassium chloride, potassium sulfate and potassium nitrate did increase sulfates content in arable and subarable soil layers, while chlorides content in a subarable one.

4. The effect of potassium fertilization on available magnesium content was recorded only in a subarable layer when potassium nitrate was applied. Increased fertilization with potassium nitrate decreased the content of available magnesium.

5. There was not observed any effect of potassium fertilization on available nitrogen and phosphorus contents in the soil.

6. Due to application of high rates of potassium nitrate, to maintain the level of 20 mg K·100 g^{-1} d.m. of soil, there was recorded increased soil salinity (EC) both in

arable and subarable soil layers. This phenomenon did not take place in the case of potassium chloride and potassium sulfate application.

7. There were not found any effects of increasing rates of potassium fertilization and the kinds of fertilizers on the contents of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and chlorine in Golden Delicious apple tree leaves. Nitrogen nutrition status of trees was optimum (with KCl and K_2SO_4 fertilization) or high (with KNO_3). As a result of application of the examined fertilizers there was optimum status of plant nutrition for phosphorus, potassium, calcium, sulfur and chlorine, as well as high for magnesium.

8. Increased contents of potassium in the soil and potassium fertilizers applied did not affect the yield of Golden Delicious apple trees after they coming into full fruition period.

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WPŁYW POZIOMÓW POTASU I RODZAJU NAWOZÓW POTASOWYCH NA PLONOWANIE ORAZ STAN ODŻYWIENIA JABŁONI MAKROELEMENTAMI I CHLOREM PO WEJŚCIU DRZEW W OKRES OWOCOWANIA

Streszczenie. Doświadczenie założono wiosną 1999 r. na glebie płowej wytworzonej z glin lekkich zwałowych. Drzewa odmiany Golden Delicious na podkładce M.26 posadzono w rozstawie 3,5 × 1,2 m (2381 drzew·ha^{-1}). Pierwszym czynnikiem badań było zróżnicowane nawożenie potasem w celu uzyskania poziomów: 12, 16 i 20 mg K 100 g^{-1} s.m. gleby, oznaczonego metodą uniwersalną. Drugim był rodzaj nawozów potasowych: chlorek potasu (sól potasowa 60%), siarczan potasu i saletra potasowa. Corocznie wykonywano analizy gleby i liści na zawartość makroelementów i chloru. Nawożenie potasem z zastosowaniem chlorku potasu, siarczanu potasu i saletry potasowej zwiększało zawartość przyswajalnego potasu w warstwie ornej (0–20 cm) i podornej (20–20 cm) gleby sadu jabłoniowego. Wzrost zawartości przyswajalnego potasu od 12 do 20 mg K·100 g^{-1} s.m. gleby na skutek nawożenia chlorkiem potasu, siarczanem potasu i saletrą potasową zwiększał pH (w H_2O) gleby w warstwie ornej i podornej, w wyniku wzrostu zawartości przyswajalnego wapnia. Alkalizujący wpływ, uznawanych za fizjologicznie zakwaszające nawozy, siarczanu potasu i chlorku potasu, wystąpił na glebach obojętnych i zasadowych [pH (w H_2O) powyżej 6,90]. Wzrastające nawożenie potasem z zastosowaniem chlorku potasu, siarczanu potasu i saletry potasowej zwiększało zawartość siarczanów w warstwie ornej i podornej gleby oraz chlorków w warstwie podornej. Obniżający wpływ nawożenia potasem na zawartość przyswajalnego magnezu zaznaczył się tylko w warstwie podornej w wyniku stosowania saletry potasowej. Nie stwierdzono natomiast wpływu nawożenia potasem na zawartość przyswajalnego azotu i fosforu w glebie. Na skutek stosowania wysokich dawek saletry potasowej dla uzyskania poziomu 20 mg K·100 g^{-1} s.m. gleby, zwiększało się zasolenie gleby (EC), zarówno w warstwie ornej, jak i podornej. Efekt ten nie wystąpił przy stosowaniu chlorku potasu i siarczanu potasu. Nie stwierdzono wpływu wzrastającego nawożenia potasem i stosowanych nawozów potasowych na zawartość azotu, fosforu, potasu, wapnia, magnezu, siarki i chloru w liściach jabłoni odmiany Golden Delicious. Stan odżywienia jabłoni azotem był optymalny (przy nawożeniu KCl i K_2SO_4) lub wysoki (przy KNO_3). W wyniku stosowaniu badanych nawozów potasowych stwierdzono optymalny stan odżywienia fosforem, potasem, wapniem i chlorem oraz wysoki magnezem. Wzrost zawartość potasu w glebie oraz stosowane nawozy potasowe nie miały wpływu na plonowanie jabłoni odmiany Golden Delicious po wejściu drzew w okres pełnego owocowania.

Słowa kluczowe: chlorki, siarczany, azotany, sady, analiza gleby, analiza rośliny

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