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EFFECT OF SOIL POTASSIUM LEVELS AND DIFFERENT POTASSIUM FERTILIZER FORMS ON YIELD AND STORABILITY OF 'GOLDEN DELICIOUS' APPLES

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Abstract. The experiment was founded in the spring of 1999 on the grey brown podzolic soil created from boulder clays. The trees of 'Golden Delicious' were planted on rootstock M 26 at 3.5 × 1.2 m spacing (2381 trees ha^{-1}). The first factor in the experiment consisted the levels of potassium in the arable soil layer: 12, 16 and 20 mg K·100 g^{-1} of soil d.m., on the basis of annual chemical analyses. The second factor of the investigation was three forms of potassium fertilizers: potassium chloride (KCl), potassium sulphate (K_2SO_4) and potassium nitrate (KNO_3). Each year the analyses of macro- and microelements in the soil and leaves were made. The controlled of potassium fertilization made the possible to maintain the planned potassium levels in the soil. Different potassium levels did not cause the significant differences in yielding of the trees. Different potassium levels and fertilizer forms did not cause any significant changes in flesh firmness, soluble solids, in the weight loss of fruit after harvest as well after storage. The using of fertilizer in the form of potassium sulphate caused an increase of the participation of fruit with bitter pit.

Key words: potassium, chlorides, sulphates, nitrates, growth, yield, apple trees

INTRODUCTION

Successful production of fruit requires a fruit grower to make a maximum use of all available agrotechnical resources. Fertilization is one of the most important factor of providing to the trees all the necessary nutrients, so that the trees could grow properly and give a high quality yield. The important factors to be considered in determining a proper fertilization program are the growth and the crop of the trees and the nutrient content in the soil and in the plant [Sadowski et al. 1990].

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The potassium is uptaken by apple trees in high levels, even greater than is actually needed to grow and yield properly. Excessive amount of potassium in soil can cause worse absorption of magnesium and calcium. In the orchard there is no possibility of limiting the amount of potassium uptaken by apple trees. That is why, only the analyses of its content in the soil and leaves, is a basis for a decision to apply potassium fertilization [Komosa and Szewczuk 2002].

Usually the content of potassium and phosphorus for orchard soil is determined by Egner-Riehm's method and the content of magnesium by Schachtschabel's one. In horticulture, for determining all macro and microelements the universal method according to Nowosielski [1978] is used. Komosa and Stafecka [2002] found out that the universal method is a good one for orchard soils, too. Most often, potassium is applied as potassium chloride or potassium sulphate. Too high rates of potassium fertilizers can have the influence on the healthiness of fruit during the storage [Tomala 1995].

The aim of the present study was the estimation of the yield and growth of 'Golden Delicious' apple trees as the effect of the application the different forms and rates of potassium fertilizers. The rates of potassium fertilizers were determined by monitoring the nutrient content in the soil.

MATERIAL AND METHODS

The experiment was founded in the Experimental Station of Environmental and Life Sciences University in Wrocław. The experimental orchard was set on the grey brown podzolic soil created of boulder clays. In the spring of 1999, two-year-old trees of 'Golden delicious' cultivar on rootstock M 26 were planted at the spacing 3.5 × 1.2 m (2381 trees ha^{-1}). The experiment was established in a randomised split-plot design in four replications with 4 trees per plot. The experimental plot had 67.2 m^2 with 16 trees, of which 4 in the middle were studied and the remaining 12 trees made surroundings. Herbicide fallow strips were in the tree rows and between them the grass alleys were maintained. Before planting, the nutrient contents in the soil were determined (tab. 1). The arable soil layer (0–20 cm) had: low contents of nitrogen, sulphur and iron, standard amounts of phosphorus, manganese, copper and boron, high contents of potassium, magnesium, calcium, zinc, chloride and an admissible level of sodium. The subarable soil layer (20–40 cm) showed the low contents of nitrogen, phosphorus, potassium, sulphur, zinc and copper, standard levels of calcium, magnesium, iron, manganese and boron, and high content of chlorides.

The field trail was established as a two-factor experiment. The first factor consisted in increasing levels of potassium in the arable soil layer: 12, 16 and 20 mg K in 100 g^{-1} of soil d.m., based on annual chemical analyses. The second factor was three forms of potassium fertilizers: potassium chloride (KCl), potassium sulphate (K_2SO_4) and potassium nitrate (KNO_3). The control treatment was the native level of potassium in the soil 9.6 mg K (layer of 0–20 cm) and 2.2 mg K·100 g^{-1} soil d.m. (20–40 cm) – table 1. In the control treatment only the_nitrogen fertilization was applied (similar as the rest studied treatments) in the rate of 60 kg N·ha^{-1} in ammonium nitrate (NH_4NO_3).

Table 1. The content of macro and microelements in the soil before planting of apple trees (1998)
Tabela 1. Zasobność gleby w makro- i mikroskładniki przed sadzeniem drzew (1998)

Depth Głebokość cm	mg 100 g^{-1} soil d.w.						
	$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca	Mg	$S\text{-}SO_4$
0-20	0.31	2.34	3.8	9.6	127.8	8.6	*
20-40	tr.*	0.55	1.7	2.2	27.9	4.2	*
	mg kg^{-1} soil d.w.					mg 100 g^{-1} soil d.w.	
	Fe	Zn	Mn	Cu	B	Na	Cl
0-20	66.4	9.3	25.3	2.9	0.77	0.6	5.5
20-40	72.9	2.5	39.2	0.9	0.50	0.4	6.3

* traces – ilości śladowe

Table 2. Rates of potassium for different forms of potassium fertilizers applied in 1999–2003
Tabela 2. Dawki potasu dla zróżnicowanych form nawozów potasowych stosowanych w latach 1999–2003

Treatment Kombinacja	K level – Poziom K mg 100g^{-1} soil d.m.	Fertilizer Nawóz	K, kg ha^{-1} 1999	2000	2001	2002	2003
K-1 (KCl)	12	KCl	54	0	0	125	0
K-2 (KCl)	16	KCl	154	0	0	170	129
K-3 (KCl)	20	KCl	254	0	0	100	0
K-1 (K_2SO_4)	12	K_2SO_4	54	0	0	36	0
K-2 (K_2SO_4)	16	K_2SO_4	154	38	0	40	36
K-3 (K_2SO_4)	20	K_2SO_4	254	60	0	186	0
K-1 (KNO_3)	12	KNO_3	54	0	0	123	94
K-2 (KNO_3)	16	KNO_3	154	0	0	177	0
K-3 (KNO_3)	20	KNO_3	254	0	0	277	0

The assumed level of potassium was kept by using different rates of fertilizers (tab. 2). In 2002–2003 years the higher rates of potassium chloride were used. It was caused the necessity of obtaining the required level of potassium in the arable soil layer -16 mg K, in comparison with level -20 mg K in 100 g^{-1} of soil d.m. It could be connected wiyh higher potassium consumption by trees that yielded more intensive by level 16 mg K 100 g^{-1} of soil d.m. All treatments were fertilized with nitrogen and phosphorus, according to the annual analyses of soil and leaves. The soil samples from the herbicide strips of each plot were collected each year in the second half of July, separately from the layers 0–20 and 20–40 cm, by using a soil drill. Soil analyses were carried out using the universal method according to Nowosielski [1974], modified for orchard soils [Komosa and Stafecka 2002].

Nitrogen was used as ammonium nitrate (34%) and saltpetre (13% N, 39% K-only in combination with KNO_3), phosphorus as triple superphosphate (20% P), potassium as potassium chloride (60%), potassium suphate (41%). The fertilization was applied in the spring, in divided rates at monthly intervals.

Fruit yield was determined individually for each tree in 2000–2003. The quality of fruit was estimated on the basis of the weight of 20 fruit samples. The growth of the trees was determined upon the trunk cross-sectional area (TCSA) measured in

1999–2003. The crop efficiency index was calculated as a ratio of cumulative yield to trunk cross sectional area. In 2001–2003 flesh firmness and total soluble solids were determined after harvest. Apples were stored in a cold storage at 2°C and 90% humidity. After 150 days of cold storage flesh firmness, soluble solids, weight loss and percentage of fruit with the symptoms of bitter pit of apple were recorded.

The obtained results were evaluated statistically using the analysis of variance. The significance of differences between means was evaluated according to t-Duncan's multiple range test at P = 0.05.

RESULTS AND DISCUSSION

The obtained results show that the control and fertilized trees of 'Golden delicious' cultivar yielded on the same level (tab. 3). However, a tendency to higher crops was observed for the trees with the level of 16 mg K 100 g^{-1} soil d.m. in comparison with the trees growing at the level of 12 and 20 mg K 100 g^{-1} soil d.m., but the differences were not significant. Komosa and Szewczuk [2002] in previous work with this cultivar did not find the trees reaction on potassium fertilization during first three years after planting. The present results are similar to those reported previously by Zydlik and Pacholak [1995], where after 15 years of applying different rates of potassium, no significant influence on the yield of the 'Cortland' trees on rootstock M 26 was observed. However, Bojarski et al. [2002] noted the increase of yielding of the 'Katja' apple trees after potassium fertilization. On the other hand, the authors did not notice the influence of different rates of potassium fertilizers on the yield of the trees. Similar results were obtained by Jadczuk et al. [2003]. The highest efficiency index was noted for the trees growing at the level of potassium 12 and 16 mg K 100 g^{-1} soil d.m. and fertilized with the chloride form of potassium fertilizer.

Table 3. Effect of potassium level in the soil and the form of potassium fertilizer on the growth and yield of 'Golden Delicious' apple trees (means for 2000–2003)
Tabela 3. Wpływ zasobności gleby w potas i rodzaju zastosowanego nawozu potasowego na wzrost i plonowanie drzew odmiany 'Golden Delicious' (średnia z lat 2000–2003)

Treatment Kombinacja	K level Poziom K mg 100g^{-1} soil	TCSA 1999–2003 cm^2	Fruit weight Masa owocu 2000–2003 g	Total yield Plon łącznie 2000-2003 kg $drzewo^{-1}$	Productivity index Wskaźnik produktywności kg cm^{-2}
Control Kontrola	10	16.0 ab*	161 ab	58.3 abc	1.15 bc
K-1 (KCl)	12	15.0 a	157 a	61.1 bc	1.30 d
K-2 (KCl)	16	16.2 ab	158 a	62.7 c	1.22 cd
K-3 (KCl)	20	20.2 f	172 c	53.4 a	1.03 ab
K-1 (K_2SO_4)	12	17.1 bcd	165 abc	54.8 ab	1.06 ab
K-2 (K_2SO_4)	16	18.2 cde	157 a	59.2 abc	1.13 bc
K-3 (K_2SO_4)	20	16.8 bc	163 abc	56.4 abc	1.10 abc
K-1 (KNO_3)	12	19.4 ef	169 bc	56.8 abc	0.99 a
K-2 (KNO_3)	16	18.0 cde	163 abc	61.2 bc	1.12 bc
K-3 (KNO_3)	20	15.7 ab	161 ab	57.1 abc	1.14 bc

*Means marked by the same letter are not significantly differed at P = 0.05
*Wartości oznaczone tą samą literą nie różnią się istotnie przy P = 0,05

The weight of fruit was correlated with the apple yield. The highest fruit weight was noted for the trees with smaller crops but revealing the strongest growth. They were the trees fertilized with chloride potassium and at the level of 20 mg K 100 g^{-1} soil d.m. (tab. 3).

Differentiated potassium fertilization meant to maintain the theoretical assumed level of the potassium content in the soil, has a different influence on the growth of the trees, which is expressed by the increment of trunk cross-sectional area. High rates of potassium nitrate caused the reduction of the tree growth. The results confirm Sadowski et al. [1988] and Zydlik and Pacholak [1999] opinions. Keeping a high level of potassium in the soil by using potassium chloride caused a stronger growth of 'Golden Delicious' apple trees. Different rates of potassium sulphate did not change the growth of the trees.

Different forms and rates of potassium fertilization did not result any significant changes in flesh firmness and soluble solids in fruit after harvest and after storage (tab. 4).

Table 4. Effect of potassium level in the soil and the form of potassium fertilizer on some features of 'Golden Delicious' apples after harvest and storage (means for 2001–2003)
Tabela 4. Wpływ zasobności gleby w potas i rodzaju zastosowanego nawozu potasowego na wybrane cechy owoców odmiany 'Golden Delicious', po zbiorze i po przechowywaniu (średnia z lat 2000–2003)

Treatment Kombinacja	K level Poziom K mg $100g^{-1}$ soil	Flesh firmness Jędrność kG		Soluble solids Zawartość ekstraktu %		Weight loss Strata wagi %	Bitter pit of apple Gorzka plamistość podskórna jabłek %
		after harvest po zbiorze	after storage po przechowaniu	after harvest po zbiorze	after storage po przechowaniu		
Control	10	7.4 a	4.3 a	13.0 a	13.3 a	4.8 a	1.2 a
K-1 (KCl)	12	7.5 a	4.6 a	11.8 a	12.3 a	5.4 a	1.4 ab
K-2 (KCl)	16	7.4 a	4.4 a	12.3 a	13.0 a	5.3 a	2.0 abc
K-3 (KCl)	20	7.4 a	4.5 a	14.3 a	13.7 a	4.6 a	2.8 abc
K-1 (K_2SO_4)	12	7.3 a	4.5 a	12.3 a	13.8 a	4.5 a	3.2 c
K-2 (K_2SO_4)	16	7.4 a	4.4 a	13.9 a	13.7 a	4.9 a	3.1 bc
K-3 (K_2SO_4)	20	7.5 a	4.5 a	12.4 a	13.0 a	5.0 a	3.0 bc
K-1 (KNO_3)	12	7.3 a	4.7 a	11.3 a	12.3 a	4.8 a	2.1 abc
K-2 (KNO_3)	16	7.6 a	4.5 a	12.5 a	13.3 a	4.6 a	1.5 abc
K-3 (KNO_3)	20	7.4 a	4.5 a	12.8 a	12.4 a	4.9 a	2.5 abc

*Means marked by the same letter are not significantly differed at P = 0,05
*Wartości oznaczone tą samą literą nie różnią się istotnie przy P = 0,05

No significant differences were noted in the weight loss in fruit after storage. Only in the case of potassium sulphate a greater number of fruit with bitter pit was noted in comparison with control trees. The participation of fruit with bitter pit was not high but was noted in each year.

CONCLUSIONS

1. Different potassium levels and fertilizer forms did not cause significant differences in yielding of the trees.

2. The trees has grown at the level of 16 mg K 100 g^{-1} soil d.m. revealed a tendency to the higher yielding in comparison with the trees growing at the level the of 12 and 20 mg K 100 g^{-1} soil d.m., however the differences were not significant.

3. The highest crop efficiency index was noted for the apple trees in the treatments with 12 and 16 mg K 100 g^{-1} soil d.m. levels and the chloride form of potassium fertilizer.

4. The higher fruit weight was noted for tress with the most intensive growth and the lowest level of yielding. The trees were fertilized with potassium chloride at the level of 20 mg K 100 g^{-1} soil d.m.

5. Different fertilization of potassium did not cause significant changes in flesh firmness, soluble solid or weight loss of fruit after harvest as well as after storage.

6. The use of potassium sulphate resulted in a greater number of fruit with bitter pit in comparison with the control trees.

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WPŁYW POZIOMU POTASU W GLEBIE I RODZAJU STOSOWANYCH NAWOZÓW NA PLONOWANIE I JAKOŚĆ PRZECHOWALNICZĄ OWOCÓW ODMIANY GOLDEN DELICIOUS

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 doświadczenia był założony poziom potasu w glebie: 12, 16, 20 mg K 100 g^{-1} gleby, oznaczonego metodą uniwersalną. Drugim czynnikiem doświadczenia były trzy formy nawozów potasowych: sól potasowa (KCL), siarczan potasu (K_2SO_4) i saletra potasowa (KNO_3). Corocznie wykonywano analizę gleby i liści na zawartość makro- i mikroelementów. Kontrolowane nawożenie potasem umożliwiło utrzymanie w glebie założonych poziomów jego zawartości. Nie stwierdzono istotnego zróżnicowania plonowania drzew pomiędzy drzewami kontrolnymi a stosowanym poziomami potasu. Zróżnicowane nawożenie potasem nie spowodowało zwiększenia ubytków naturalnych oraz istotnych zmian w jędrność i zawartości w owocach ekstraktu po zbiorze i przechowywaniu. U owoców z drzew nawożonych siarczanem potasu, w większym stopniu wystąpiła gorzka plamistość podskórna w porównaniu do owoców z drzew kontrolnych nie nawożonych potasem.

Słowa kluczowe: potas, sól potasowa, siarczan potasu, saletra potasowa, wzrost, plon, jabłoń

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