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EFFECT OF SOIL POTASSIUM LEVEL AND DIFFERENT POTASSIUM FERTILIZER FORMS ON NUTRITIONAL STATUS, GROWTH AND YIELD OF APPLE TREES IN THE FIRST THREE YEARS AFTER PLANTING

ABSTRACT. Studies were carried out in 1999-2001 on typical grey brown podzolic soil created of boulder clays for growing apple trees of 'Golden Delicious' cultivar on M.26 rootstock. Two-year-old trees were planted at 3.5 x 1.2 m spacing (2381 trees$\cdot$ha^{-1}) in the spring of 1999. Herbicide fallow strips were in tree rows but grass was maintained between the rows.

Investigation was to examine the effect of an increasing potassium level: 12, 16 and 20 mg K 100 g^{-1} of soil and three potassium fertilizers: potassium chloride (KCl), potassium sulphate (K_2SO_4) and potassium nitrate (KNO_3) on the growth, yield and nutrient content in the soil and in the leaves of apple trees. Different forms of potassium fertilizers permitted to define the effect of anions accompanying potassium, mainly sulphates (S-SO_4), upon the basic parameters of growth and yield of apple trees in the initial 3-year period of cultivation. The content of available forms of nutrients in the soil was analysed by the universal method, where in the macroelements and boron were determined in the modified Spurway extract, but other micro-elements in the modified Lindsay extract.

It was found that in the 3-year-old apple orchard, there was a tendency towards both a higher apple yield and an increased number of one-year-old shoots with the use of the sulphatic form of potassium fertilizer (K_2SO_4), although it has not been statistically proven. Such a fertilizer was accompanied by an increase of sulphates in the soil. There was also chloride accumulation when the chloride form of potassium fertilizer (KCl) was used.

An increasing level of potassium in the soil raised the content of this nutrient in the leaves, although they did not enhance sulphur as a result of potassium sulphate application. However, a higher chloride content in the foliage was recorded as an effect of apple tree fertilization with potassium chloride.

Key words: potassium, sulphur, sulphates, chlorides, nitrates, universal method, apple trees

INTRODUCTION. Significant effect of potassium on the quality and quantity of apple yield was shown by Sadowski et al. (1983, 1985, 1992) and Czuba et al. (1994), however the efficiency of K application depended on the form of fertilizer. Kämpfer and Zehler (1967) and Czuba et al. (1994) pointed a higher efficiency of potassium sulphate than potassium chloride in nutrition of apple trees. It could be connected with a positive effect of sulphur, since a deficiency of this nutrient in soil becomes more and more common. This is mainly caused by: decreasing emission of SO_x to the atmosphere, use of potassium chloride (KCl) instead of potassium sulphate (K_2SO_4) for plant fertilization, limited use of magnesium sulphate ($MgSO_4$) as a Mg source. A low status of soil sulphur fertility in the Wielkopolska region was presented by Jakubus (2000) and also by the regional analytical stations (WIOŚ, 1997, 1998).

Many papers stress a high importance of sulphur in plant nutrition (Jakubus, 2000, 2000a, 2001, 2001a), however this problem has not been sufficiently recognized for fruit plants. Some studies conducted in Poland indicated a low sulphur level in soils of apple orchards (Stafecka, 2000).

The present research was to determine the effect of an increasing potassium level in the soil by using different K fertilizers: potassium sulphate (K_2SO_4), potash salt (KCl) and saltpetre (KNO_3), on the growth, fruit yield, and nutrient contents in the soil and leaves of apple trees in the first three years after planting.

MATERIAL AND METHODS. The experiment was carried out in 1999-2001 at the Samotwór Experimental Station, University of Agriculture, Wrocław. The trial was set on a typical grey brown podzolic soil created from boulder light clay. The soil profile had the following construction: A_p-A-E_{et}-Bt-C. Horizons A_p, A and E_{et} were build of sandy loam, but B_t and C of light clay. Horizons A_p and A contained 0.66% of C-organic. Two-year-old trees of 'Golden Delicious' cultivar grafted on M.26 rootstock were planted at 3.5 x 1.2 m spacing (2381 trees ha^{-1}) in the spring of 1999. Herbicide fallow strips were in the tree rows, but grassed ones between them.

As shown in Tables 1 and 2, before planting trees, the arable soil layer (0-20 cm) had a low content of nitrogen, sulphur and iron, a standard amount of phosphorus, manganese, copper and boron, a high content of potassium, magnesium, calcium, zinc and chloride, and an admissible level of sodium. The subarable soil layer (20-40 cm) showed a low amount of nitrogen, phosphorus, potassium, sulphur, zinc and copper, a standard level of calcium, magnesium, iron, manganese and boron, and a high content of chlorides. In both layers, no excessive accumulation of sodium was found.

Table 1. Content of macroelements (CH_3COOH extraction), pH and EC in the soil before planting apple trees (1998)

Depth [cm]	[mg 100 g^{-1} soil d.w.]							pH	EC [mS cm^{-1}]
	$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca	Mg	$S\text{-}SO_4$		
0-20	0.31	2.34	3.8	9.6	127.8	8.6	*	7.10	0.22
20-40	*	0.55	1.7	2.2	27.9	4.2	*	5.80	0.18

* Trace

Table 2. Content of microelements (Lindsay solution extraction) Na and Cl (CH_3COOH extraction) in the soil before planting apple trees (1998)

Depth [cm]	[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

The field trial was established as a two-factor experiment. The first factor consisted of increasing levels of potassium in the arable soil layer: 12, 16 and 20 mg K in 100 g of soil, based on annual chemical analyses. The second factor included three forms of potassium fertilizers – KCl, K_2SO_4 and KNO_3 – used for achieving the required levels. The rates of nitrogen, phosphorus and potassium in the particular years, estimated upon the annual soil analyses, are presented in Table 3.

Table 3. Rates of fertilizers in 1999-2001

Treatment	K level [mg 100 g^{-1} soil]	Ferti-lizer	1999			2000			2001		
			N	P	K	N	P	K	N	P	K
			[kg ha^{-1}]								
Control	10		0	150	0	80	80	0	0	0	0
K-1 (KCl)	12	KCl	84	150	54	80	80	0	0	20	0
K-2 (KCl)	16	KCl	84	150	154	80	80	0	0	20	0
K-3 (KCl)	20	KCl	84	150	254	80	80	0	0	20	0
K-1 (K_2SO_4)	12	K_2SO_4	84	150	54	80	80	0	0	20	0
K-2 (K_2SO_4)	16	K_2SO_4	84	150	154	80	80	38	0	20	0
K-3 (K_2SO_4)	20	K_2SO_4	84	150	254	80	80	60	0	20	0
K-1 (KNO_3)	12	KNO_3	84	150	54	80	80	0	0	20	0
K-2 (KNO_3)	16	KNO_3	84	150	154	80	80	0	0	20	0
K-3 (KNO_3)	20	KNO_3	84	150	254	80	80	0	0	20	0

Nitrogen was used as ammonium nitrate (34% N) and saltpetre (13% N, 39% K – only in combination with KNO_3), phosphorus as triple superphosphate (20% P), potassium as potassium chloride (50% K), potassium sulphate (41% K) and saltpetre. Single rates of nitrogen, phosphorus and potassium amounted to: 60, 30 and 100 kg ha^{-1}, respectively. The fertilization was applied three times each year: mid-March, mid-April and mid-May. Fertilizer rates were divided to improve nutrient utilization by plants and to decrease environmental pollution. In 1999 nitrogen was not applied in the control considering an intensive growth of young trees after planting and also to achieve a better plant response to higher potassium levels and potassium form fertilizers. In 2001 nitrogen was not applied because of its sufficient level in the soil as an effect of fertilization in 1999 and 2000.

The experiment was established in 4 replications, each consisted of one plot (67.2 m^2) with 16 trees, of which four in the middle were studied. The remaining 12 trees made a surrounding.

Fruit yield was determined individually for each tree in 2000-2001. A mean fruit weight was calculated upon a 20 fruit sample. The growth of trees was determined in 2000-2001 upon the number of annual shoots and trunk cross-sectional area (TCSA).

Ten soil samples from the herbicide strips of each plot were collected, separately from the layers 0-20 and 20-40 cm, using a soil drill, each year in the 2nd half of July. Soil analyses were carried out by the universal method according to Nowosielski (1974), modified for orchard soils (Komosa and Stafecka, 2002). Soil samples were dried at room temperature, ground in a mortar and put through a sieve of l mm mesh diameter. Extractions of $N\text{-}NH_4$, $N\text{-}NO_3$, P, K, Ca, Mg, $S\text{-}SO_4$, Na, Cl, and B were carried out in 0.03 M CH_3COOH in a proportion of soil: extraction solution = 1:10 (20 g of soil dry weight and 200 cm^3 of 0.03 M CH_3COOH) during 30 minutes. After extraction, determinations were conducted according to IUNG (1983): $N\text{-}NH_4$ by microdistillation upon Bremner`s method modified by Starck, $N\text{-}NO_3$ by ORION ionoselective electrode, P – colorimetrically with ammonium vanado-molybdate, K, Ca, Mg, Na, – by atomic absorption spectrometry (AAS), $S\text{-}SO_4$ – nephelometrically with $BaCl_2$, Cl – nephelometrically with $AgNO_3$, B – colorimetrically with curcumin.

Microelements – Fe, Mn, Zn and Cu – were extracted with Lindsay solution, which contained in 1 dm^3 : 5 g $EDTAH_4$, 9.0 ml 25% ammonia, 4 g citric acid, 2 g $(CH_3COO)_2Ca{\cdot}2H_2O$. Extractions were conducted in a proportion of soil to extraction solution = 1 : 4 (50 g of soil dry weight and 200 cm^3 of Lindsay solution) during 30 minutes. After extraction, Fe, Mn, Zn and Cu were determined by AAS method (IUNG, 1983).

In the 2nd half of July, 4 mixed samples of leaves were taken from 4 experimental plots. Each sample consisted of about 100 leaves collected from the middle part of long-shoots, taking 3-4 leaves per shoot. Samples were dried and ground in a mill. In leaves, total forms of macroelements (N, P, K, Ca, Mg, S) and microelements (Fe, Mn, Zn, Cu, B) were determined. Total N was established after digesting leaves in concentrated sulphuric acid with an addition of sulpho-salicylic acid and after reducing of $N\text{-}NO_3$ to $N\text{-}NH_4$ with sodium thiosulphate in the presence of selenium mixture, P, K, Ca and Mg were determined after leaf digestion only in concentrated sulphuric acid. Sulphur was analysed by dry digestion of leaves in a muffle furnace with HNO_3 and $Mg(NO_3)_2$. For microelements: Fe, Mn, Zn and Cu, leaves were burnt in a mixture of acids: HNO_3, $HClO_4$ and H_2SO_4 in a 10:1:1 proportion, while boron was determined after dry digestion with calcium hydroxide (IUNG, 1972).

After mineralization, total N was determined in leaves by the Kjeldahl method, P – colorimetrically with ammoniummolybdate; K, Ca, Mg, Fe, Mn, Zn, Cu – by AAS method, S – by Butters-Chenery method and B – colorimetrically with curcumin (IUNG, 1972).

The results of biometric measurements and chemical analyses were statistically elaborated by an analysis of variance and Duncan`s t - test at P=0.05. To generalize the results, statistical analyses were based on two-year measurements – for biometrics, or three-year data – for plant and soil chemical analyses. Statistical elaboration for soil nutrient content was combined for both layers (0-20 and 20-40 cm).

RESULTS AND DISCUSSION. In the first two years of fruiting, there was no significant difference in apple yield, although a tendency towards a higher crop was visible for trees of K-2 (K_2SO_4) combination in which the level of 16 mg K 100 g^{-1} of soil was maintained by potassium sulphate (Tab. 4). In the same treatment, there was also the greatest number of annual shoots, but no significant difference was found for TCSA and the mean fruit weight.

Table 4. Effect of K soil level and three K fertilizers on growth and yield of 'Golden Delicious' apple trees (means for 2000-2001)

Treatment	K level [mg 100 g^{-1} soil]	Number of annual shoot	TCSA [cm^2]	Fruit weight [g]	Total yield 2000-2001 [kg $tree^{-1}$]
Control	10	36.9 a*	8.7 a	169 a	21.2 a
K-1 (KCl)	12	29.7 a	7.4 a	170 a	21.5 a
K-2 (KCl)l	16	32.5 a	8.1 a	167 a	21.4 a
K-3 (KCl)	20	35.4 a	8.6 a	177 a	20.7 a
K-1 (K_2SO_4)	12	32.3 a	8.1 a	176 a	18.3 a
K-2 (K_2SO_4)	16	39.8 a	8.7 a	168 a	22.2 a
K-3 (K_2SO_4)	20	38.1 a	7.9 a	173 a	20.2 a
K-1 (KNO_3)	12	34.9 a	8.7 a	175 a	18.5 a
K-2 (KNO_3)	16	36.2 a	8.4 a	169 a	20.8 a
K-3 (KNO_3)	20	33.9 a	7.9 a	167 a	19.6 a

* Means marked by the same letter are not significantly differed at P= 0.05

Potassium fertilization significantly increased the content of this nutrient in the upper soil layer at the level of 16 and 20 mg K 100 g^{-1} of soil (Tab. 5). In the subarable layer, it was observed only for the level of 20 mg K 100 g^{-1} of soil after application of potassium chloride but not for potassium sulphate and saltpetre. It may indicate a better utilization of potassium or/and its more efficient translocation in the soil treated with both latter fertilizers.

The use of potassium sulphate caused an increase of sulphate sulphur (S-SO_4) in the soil in both arable and subarable layer at 16 mg K 100 g^{-1} of soil and also in the deeper layer at 20 mg K 100 g^{-1} of soil (Tab. 5). Such an increase should be regarded as a very positive effect. The recommended guide value of sulphur content giving a satisfactory growth and yield of apple trees is 1-3 mg S-SO_4.100 g^{-1} of soil (Komosa and Stafecka, 2002).

The use of KCl to maintain the highest potassium level (20 mg K 100 g^{-1} soil) increased the accumulation of chlorides in the arable and subarable layer to 4.9 and 4.5 mg Cl 100 g^{-1} of soil, respectively. Komosa and Stafecka (2002) suggest chloride admissible content up to 5.0 mg Cl 100 g^{-1} of soil. Permanent use of KCl in orchards evokes

T a b l e 5. Soil content of N-NH_4, N-NO_3, K, S-SO_4, Cl, P and pH in relation to K level, fertilizer form and depth of soil sampling (means for 1999-2001)

Treatment	K level [mg 100 g^{-1} soil]	Depth [cm]	N-NH_4	N-NO_3	N-NH_4+ N-NO_3	K	S-SO_4	Cl	P	pH
			[mg 100 g^{-1} soil]							
Control	10	0-20 20-40	0.30ab* 0.27ab	0.60a 0.57b	0.90a 1.11a	10.1a-e 9.0abc	0.8ab 0.6a	3.8abc 2.3ab	4.8f 1.8ab	7.22 7.07
K-1 (KCl)	12	0-20 20-40	0.53bc 0.20a	2.97a-d 0.67a	3.50cd 0.87a	13.3d-g 7.1a	2.3abc 0.6a	3.3abc 2.8abc	4.8f 2.2ab	7.07 7.10
K-2(KCl)	16	0-20 20-40	0.27ab 0.37abc	2.97cd 2.30a-d	3.23bcd 2.67a-d	15.5fgh 8.5ab	1.4abc 1.7abc	4.2abc 3.2abc	3.8def 1.6ab	7.18 7.07
K-3 (KCl)	20	0-20 20-40	0.20a 0.17a	2.07a-d 1.50abc	2.27a-d 2.70a-d	22.7i 13.8efg	0.8ab 0.4a	4.9c 4.5bc	4.8f 2.5abc	7.15 7.12
K-1 (K_2SO_4)	12	0-20 20-40	0.40abc 0.27ab	2.47bcd 1.97cd	2.87a-d 2.57a-d	12.0b-f 9.2abc	1.4abc 1.6abc	2.3ab 2.0a	4.9f 2.7bcd	6.99 7.23
K-2 (K_2SO_4)	16	0-20 20-40	0.60c 0.27ab	3.43d 1.43abc	4.03d 1.70abc	17.3gh 9.7a-d	5.0d 3.4cd	2.4ab 2.4ab	4.1ef 2.0ab	7.46 7.21
K-3 (K_2SO_4)	20	0-20 20-40	0.30ab 0.17a	2.07a-d 1.83a-d	2.37a-d 2.00abc	18.8hi 12.6c-f	3.1bcd 3.1bcd	2.4ab 2.2ab	3.8def 2.1ab	7.39 7.19
K-1 (KNO_3)	12	0-20 20-40	0.30ab 0.23a	1.10ab 0.77ab	1.40ab 1.00a	11.0a-e 8.1ab	1.4abc 0.7ab	2.4ab 3.0abc	4.2ef 2.1ab	7.25 7.84
K-2 (KNO_3)	16	0-20 20-40	0.43abc 0.20a	3.07cd 1.00ab	3.50cd 1.20a	16.7gh 8.8abc	1.7abc 0.4a	2.4ab 2.0a	3.5cde 1.4a	7.22 6.67
K-3 (KNO_3)	20	0-20 20-40	0.40abc 0.27ab	2.30a-d 1.47abc	2.70a-d 1.73abc	18.1h 8.6abc	1.8abc 0.4a	2.2ab 2.2ab	3.9ef 1.5a	7.39 7.29

* Explanation – see Table 4

an unfavourable accumulation of chlorides in soil and a decline of sulphates (Stafecka, 2000; Komosa and Stafecka, 2002). With the use of chloride and saltpetre forms of potassium fertilizers, the content of sulphate sulphur ($S\text{-}SO_4$) in the soil was maintained at a lower level of the recommended range and did not significantly differ.

Neither an increasing level of soil potassium nor the application of different forms of K fertilizers during the three-year study affected the soil pH. It was maintained within the range of neutral and basic reactions because of a high content of calcium and magnesium (Tab. 5).

No significant effect was found in reference to the application of different potassium fertilizers on the content of nitrogen, phosphorus, calcium, magnesium, sodium, iron, manganese and copper in the soil (Tab. 5 and 6).

Soil potassium level had a significant influence on some macro- and microelements. Tables 5 and 6 show that an increased K content in the soil caused a decrease of magnesium – in relation to the control – in the arable layer at the levels of 16 and 20 mg K 100 g^{-1} of soil after the application of potassium chloride. Also, a significant decline of soil magnesium followed the supply of potassium sulphate to the level of 12 mg K 100 g^{-1} of soil and potassium nitrate to reach 20 mg K 100 g^{-1} of soil.

In the upper soil layer, an application of potassium saltpetre significantly reduced the content of sodium as compared to the control. Reduction of this element was also marked after potassium sulphate and potassium chloride were supplied to achieve the levels of 12 and 20 mg K 100 g^{-1} of soil (Tab. 6).

Contrary to magnesium and sodium, there was no clear influence of potassium fertilization on changes in calcium content. Only a significant enriching effect in the subarable soil layer in comparison to the control, was observed after fertilizing with saltpetre to reach 12 mg K 100 g^{-1} of soil (Tab. 6).

The low potassium level – 12 mg K 100 g^{-1} of soil – maintained by using saltpetre, reduced the content of iron. It was also visible in the subarable layer at the same K level after application of potassium sulphate (Tab. 6).

Table 6. Soil content of Ca, Mg, Na, Fe, Mn, Zn, Cu and B in relation to K level, fertilizer form and depth of soil sampling (means for 1999-2001)

Treatment	K levels [mg 100 g^{-1} soil]	Depth [cm]	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
			[mg 100 g^{-1} soil]				[mg kg^{-1} soil]			
Control	10	0-20 20-40	82.4d-g* 33.0a	11.1g 8.0a-e	1.47d 1.13abc	64.9bcd 77.3e	21.4ab 19.4ab	19.4b-e 13.4b	4.2f 2.3abc	0.58a-d 0.59a-d
K-1 (KCl)	12	0-20 20-40	104.3g 48.6a-d	6.8ab 6.0a	1.13abc 1.23a-d	66.3b-e 65.8b-e	20.7ab 20.9ab	5.4a 3.0a	3.3de 1.7a	0.74bcd 0.35ab
K-2 (KCl)	16	0-20 20-40	64.4a-f 42.8abc	8.0a-e 8.4b-f	1.37cd 1.27bcd	64.7bcd 67.4b-e	19.7ab 25.0b	5.3a 3.6a	2.9cde 2.0ab	0.94d 0.37ab
K-3 (KCl)	20	0-20 20-40	71.2b-g 42.7abc	10.1efg 9.1c-g	1.07ab 1.17abc	68.5b-e 66.0b-e	18.3a 20.3ab	27.2f 25.2ef	3.3de 2.3abc	0.82cd 0.39abc
K-1 (K_2SO_4)	12	0-20 20-40	74.0b-g 54.4a-d	8.5b-f 7.8a-d	0.97a 1.30bcd	59.3ab 59.9abc	17.2a 17.8a	20.5cde 15.6bcd	3.6ef 2.7bcd	0.59a-d 0.71a-d
K-2 (K_2SO_4)	16	0-20 20-40	72.3b-g 50.3a-d	9.1c-g 8.1a-e	1.30bcd 1.23a-d	60.9a-d 65.9b-e	16.5a 19.4ab	16.7bcd 14.4bc	3.4de 2.2abc	0.73bcd 0.43abc
K-3 (K_2SO_4)	20	0-20 20-40	78.5c-g 39.6ab	10.0efg 9.4c-g	1.13abc 1.10ab	64.2a-d 67.4b-e	16.9a 18.4a	21.7def 23.2ef	2.8cd 2.0ab	0.43abc 0.27a
K-1 (KNO_3)	12	0-20 20-40	100.3fg 77.4c-g	10.5fg 11.0g	1.20abc 1.10ab	52.3a 64.6bcd	15.3a 20.9ab	4.6a 3.6a	2.7bcd 2.5bc	0.70a-d 0.71a-d
K-2 (KNO_3)	16	0-20 20-40	59.0a-e 32.9a	9.5d-g 7.6a-d	1.13abc 0.97a	67.6b-e 71.6cde	20.5ab 21.3ab	4.0a 3.3a	3.2de 2.3abc	0.72bcd 0.27a
K-3 (KNO_3)	20	0-20 20-40	93.5efg 46.1abc	8.0a-e 7.2abc	1.20abc 0.97a	69.9bcd 72.1de	16.3a 20.3ab	4.7a 3.3a	2.7bcd 2.3abc	0.82cd 0.39abc

* Explanation – see Table 4

Potassium fertilization developed marked differences in copper soil content in the upper layer wherein all the used fertilizers caused a decline of this element in relation to the control (Tab. 6). This influence was not observed in the deeper layer.

No significant changes were found in the amounts of boron and manganese, but zinc content varied. It was probably an effect of natural soil fertility variation (Tab. 6).

The content of nutrients in leaves of apple trees is shown in Table 7. Generally, they showed an optimum or high level of nitrogen, optimum amounts of phosphorus and manganese, and a high content of potassium, magnesium and boron (Sadowski et al., 1990). Calcium, iron, and copper were maintained within the standard range (Kenworthy after Sadowski,1967), and sulphur was below 0.41-0.50% in dry weight of leaves, defined by Kenworthy and Martin (1966) as “the range without any symptoms of deficit or toxicity”. The content of zinc was maintained within the same range.

Increasing levels of potassium in the soil significantly raised the content of this nutrient in leaves – as compared to the control – only after application of potassium sulphate to the level of 20 mg K 100 g^{-1} of soil, and there were also such trends in other treatments (Tab. 7). The effectiveness of K fertilization was the highest with the use of potassium sulphate. No differences in the growth and yield of apple tress were found between treatments with potassium chloride and saltpetre. Application of potassium sulphate did not increase sulphur content in leaves. Neither the fertilization with potassium chloride had a significant effect on chloride content in leaves; the smallest level of this nutrient occurred in apple trees fertilized with potassium sulphate and saltpetre at 16 and 20 mg K 100 g^{-1} of soil.

Potassium fertilization significantly lowered iron leaf content in comparison to the control. With some exceptions, similar results were obtained for zinc and copper. There was no significant effect of potassium fertilization on the boron content in leaves (Tab. 7).

Neither was such effect found in reference to the increasing levels of potassium in soil and different K fertilizers on the content of nitrogen, phosphorus, calcium, magnesium, sulphur, chlorine, manga-nese, copper and boron (Tab. 7). However, a significant decrease of iron

Table 7. Content of macro- and microelements in Golden Delicious' leaves in relation to K level and fertilizer forms (means for 1999-2001)

Treatment	K level [mg 100 g^{-1} soil]	N	P	K	Ca	Mg	S	Cl	Fe	Mn	Zn	Cu	B
		[% in leaf]						[mg kg^{-1} leaf d.w.]					
Control	10	2.29a*	0.24bc	2.01bc	1.44a	0.36a	0.19a	87a	109.8e	91.7c	25.7b	6.7c	56.6ab
K-1 (KCl)	12	2.41ab	0.23abc	1.89ab	1.58a	0.36a	0.18a	90a	105.0cde	91.3bc	20.8a	6.2ab	54.6a
K-2 (KCl)	16	2.45b	0.24bc	1.90ab	1.58a	0.35a	0.18a	93a	106.3de	84.9abc	19.2a	6.5bc	55.2ab
K-3 (KCl)	20	2.41ab	0.23abc	2.16cd.	1.40a	0.35a	0.17a	93a	74.2a	84.7abc	22.0ab	5.9a	54.5ab
K-1 (K_2SO_4)	12	2.41ab	0.24bc	1.87a	1.40a	0.36a	0.16a	80a	96.1b-e	79.9a	19.9a	6.0a	54.5ab
K-2 (K_2SO_4)	16	2.35ab	0.21a	2.02bc	1.58a	0.34a	0.18a	83a	84.6a-d	81.2ab	21.2a	6.2ab	54.5ab
K-3 (K_2SO_4)	20	2.37ab	0.25c	2.17d	1.44a	0.36a	o.16a	73a	78.2ab	84.0abc	22.0ab	5.9a	55.4ab
K-1 (KNO_3)	10	2.34ab	0.24bc	1.92ab	1.37a	0.38a	0.17a	93a	78.2ab	81.8abc	21.0a	6.2ab	57.2b
K-2 (KNO_3)	16	2.38ab	0.22ab	1.98abc	1.43a	0.34a	0.17a	73a	78.1ab	86.6abc	18.9a	6.1a	53.7ab
K-3 (KNO_3)	20	2.36ab	0.22ab	2.05c	1.49a	0.35a	0.17a	73a	83.5bc	90.6bc	18.9a	6.0a	55.4ab

* Explanation – see Table 4

content was observed as a result of saltpetre application. Under the influence of this fertilizer, there was also a tendency towards a decline of nitrogen and calcium content in leaves.

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