EFFECT OF 25 YEARS OF DIFFERENTIATED FERTILIZATION WITH NPK AND MAGNESIUM ON GROWTH AND FRUIT YIELD OF APPLE 'CORTLAND' AND ON THE CONTENT OF MINERALS IN SOIL AND LEAVES

Eugeniusz Pacholak

Department of Pomology, Horticultural Faculty
University of Life Sciences in Poznań
Dąbrowskiego 159; 60-594 Poznań, POLAND

(Received August 4, 2008/Accepted October 6, 2008)

A B S T R A C T

The studies were carried out during 1982-2007 in the experimental orchard of Pomology Department, University of Life Sciences in Poznań on the area of the Orchard and Experimental Farm in Przybroda. Trees of 'Cortland' apple on M.26 rootstock were planted in autumn of 1979 on proper grey-brown podsolic soil at 5 x 3m spacing (667 trees per l ha). The experiment consisted of 15 combinations grouped in 8 blocks. The first differentiated fertilization was applied in 1982, i.e. in the third year after planting and it was continued without any changes until 2007. Fertilization was done with nitrogen (in the form of 34% ammonium nitrate), potassium (60% of potash salt), phosphorus (46% triple superphosphate) and magnesium (24% magnesium sulphate) in the spring, 4-5 weeks before tree blooming. The differentiated fertilization had a significant effect on the content of available nutrients in soil, both in the arable and in the subarable layers. Fertilization with phosphorus, potassium and magnesium increased the content of these elements in both soil layers. No interdependence was found between the content of mineral elements in soil and in leaves. Independently of fertilization, leaf nutrient content was at the optimal level. 25 years of differentiated fertilization did not exert any effect on growth and yield of 'Cortland' apple, which depended more on the tree age and the course of weather conditions.

Key words: apple, cultivar, fertilization, growth, yield, soil, leaves

INTRODUCTION

Intensification of horticultural production in connection with Poland's accession to the European Union has become an absolute necessity. There are many ways of reaching this goal and one of them is the reduction of chemization, but at the same time, maintenance of a high yield and good fruit quality. The factor exerting a negative influence on the environment and quality of the produced fruit is excessive use of mineral fertilizers (Cain, 1953; Sadowski and Kępka, 1974). Studies carried out for many years indicate that fruit trees belong to species with low demand for fertilization (Greenham, 1979, 1980; Terts, 1968; Vang-Petersen, 1984; Pacholak and Łysiak, 1993). Furthermore, the specific character of perennial plants causes that direct effects of supplying mineral components to fruit trees can be observed after many years.

Elaboration of the proper fertilization recommendations, regarded as the main yield-creating factor, is very difficult and the effectiveness of mineral fertilization frequently seems to be problematic (Piątkowski, et al., 1982; Pacholak, 1986). Results of experiments performed by Bould et al. (1972) indicate, that mineral fertilization in conditions of natural rainfalls and with a good soil preparation before orchard establishment are less necessary than other agronomic treatments. This follows also from the new technology of orchard management, which can be compared to a closed system because the cut down shoots, fallen leaves, flowers and buds remain in the orchard and only a small amount of mineral components is carried away with harvested fruit.

In spite of a lack of distinct reaction to mineral fertilization, it is necessary to define the fertilization needs because it has always been and will be one of the basic agronomic treatments having big influence on the conditions and development of trees. However, in the determination of fertilization needs and the optimization of tree nutrition one must consider the effect of various factors on the content of mineral elements in soil, leaves and fruits and the actual tree growth and fruit yield of must be taken into account as well (Sadowski,1985).

The objective of this work was to define the effect of fertilization with phosphorus, potassium and magnesium during 25 years on production efficiency of 'Cortland' apple trees grown on M.26 rootstock and on the content of these minerals in the soil and leaves, as well as to determine the interdependence between fruit yield, mean air temperature and rainfall.

MATERIAL AND METHODS

Experiment was established in the orchard of Pomology Department, University of Life Sciences in Poznań at the area of the Agricultural and Pomology Experimental Farm in Przybroda. Apple trees of 'Cortland' cultivar on M.26 rootstock were planted in the autumn 1979 at the spacing of 5 x 3 m (667 trees/ha) on proper grey-brown podsolic soil overlaying light boulder clay. The arable layer with mechanical composition of medium sand and the subarable layer composed of light medium sand were lying at the depth of 60-150 cm on sandy loam with a significant amount of sand. Groundwater level in May 1982 was at a depth of 180 cm. pH in the arable soil layer before establishing the experiment varied from acidic to slightly acidic. Content of available phosphorus, potassium and magnesium in the arable and subarable layers was on a medium level. The proportion of K : Mg in the both layers was on a correct level. Content of organic matter in the arable layer was 0.89% and in the subarable layer 0.87%, and the content of silt and clay fractions ranged from 15.5% in the arable layer to 17% in the subarable layer.

Before tree plantating, in the first decade of September 1979, a deep ploughing was carried out, 40 $t.ha^{-1}$ of manure and 200 kg ha^{-1} of K_2O (in the form of 60% of potash salt) and 185 kg ha^{-1} of P_2O_5 (as triple superphosphate) were applied. In the first year (1980) and in the second year (1981) after planting, nitrogen fertilization in the amount of 15 g per 1 m^2 was applied under all trees. Since 1982 (i.e. from the third year after tree plantation) differentiated tree fertilization was applied in 15 combinations grouped in 8 blocks (Tab. 1). The surface of a fertilized plot was 90 m^2, on which 12 trees were planted. Observations were carried out on 2 trees; the remaining trees constituted isolation belts.

Throughout all the years of studies, i.e. from 1982 to 2007, phosphorus fertilizers (triple superphosphate), potassium fertilizers (60% potash salt), magnesium (magnesium sulphate) and nitrogen fertilizers (ammonium nitrate) were applied in the first decade of April, 4-5 weeks before tree blooming. Tree training, protection against diseases and pests were carried out according to the recommendations for commercial orchards. Starting with the year 1982, soil cultivation system included herbicide bare fallow in tree rows (2.3 m) and moved grass 2.7 m-wide in the interrows.

During entire period of the experiment (1982-2007), every 4 years soil samples from the layers: 0-20 cm and 21-40 cm and leaf samples were taken in the third decade of July for chemical analyses. Analyses of P, K and Mg content in soil, soil pH and N, P, K and Mg content in leaves were carried out in the Chemical and Agricultural Station in Poznań and in the laboratory of Pomology Department in Poznań.

Yielding was estimated on the basis of yields from single trees and was recalculated per unit area. Results referring to yielding were elaborated statistically by analysis of variance for each year and for 4-year periods, and the sum of yields was calculated for the whole period of the studies. Significance of differences between the mean values were estimated using Duncan's multiple range test at $p = 0.05$.

Effect of environmental factors on yield was evaluated by calculating linear correlations between mean temperature, the sum of rainfalls during vegetation and tree yielding.

Characteristics of climatic conditions in the years 1982-2007

Data presented in Table 2 indicate that weather conditions in the experimental years varied considerably. Mean annual temperatures and temperatures during vegetation season were higher than the multi-year average in as many as 22 years. It had a significant effect on the experiment because mean annual temperatures as well as mean temperatures during vegetation periods were higher by about 1.5°C than multi-year average calculated for 1955-1984. Hence, also the sum of temperatures during the vegetation period was also higher and it exerted a positive effect on growth and yielding of 'Cortland' apple trees.

On the other hand, one can notice high variation of rainfall sums, particularly during vegetation periods, from 167.1 mm in 1982 to 540.8 mm in 1987. Precipitation sums in comparison with multi-year average decreased from 527.7 mm to 505.7 mm, and during the vegetation season, from 332.8 mm to 309.3 mm.

Summing up, one can state that during the whole period of the studies, there were 12 dry years (1982, 1989, 1992, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005 and 2006), 8 years were moderately moist (1983, 1984, 1985, 1986, 1990, 1991, 1994, 1997) and 6 years were moist (1987, 1988, 1993, 1996, 1998, 2007).

A comparison of the precipitation sums with the mean temperatures in the particular years shows a high regularity indicating that with an increased amount of rainfalls, the temperature decreases and *vice versa*.

Table 1. Fertilizer treatments

Fertilizer treatments	Nutrients and doses [kg ha^{-1}]			
	N	P_2O_5	K_2O	MgO
Control	0	0	0	0
$N_1P_1K_1Mg_1$	60	40	80	60
$N_2P_2K_2Mg_2$	120	80	160	120
$N_1K_1Mg_1$	60	0	80	60
$N_2K_2Mg_2$	120	0	160	120
N_1K_1	60	0	80	0
N_2K_2	120	0	160	0
N_1	60	0	0	0
N_2	120	0	0	0
K_1	0	0	80	0
K_2	0	0	160	0
P_1	0	40	0	0
P_2	0	80	0	0
Mg_1	0	0	0	60
Mg_2	0	0	0	120

Table 2. Mean temperatures and precipitation sums in 1982-2007 (Meteorological station, Experimental Station Przybroda)

Years	Mean annual temperature [°C]	Mean temperature during growing period (April-September) [°C]	Sum of temperatures during growing period (April-September) [°C]	Annual precipitation [mm]	Sum of rainfalls during growing period (April-September) [mm]
1955-1982	7.9	14.2	2598	528	333
1982	8.7	14.9	2726	320	167
1983	9.2	15.6	2854	486	249
1984	7.9	13.6	2488	542	371
1985	7.1	14.1	2580	522	374
1986	7.6	14.1	2580	529	309
1987	7.3	14.0	2565	682	423
1988	9.0	14.8	2708	820	541
1989	9.7	15.3	2799	350	206
1990	9.8	14.6	2671	484	330
1991	9.0	15.2	2781	443	291
1992	10.1	17.2	3147	393	170
1993	8.8	15.3	2799	681	423
1994	9.9	16.4	3001	541	314
1995	9.3	16.1	2946	478	298
1996	7.6	15.0	2745	566	464
1997	9.2	15.7	2873	484	329
1998	10.0	16.9	3092	580	338
1999	10.2	17.0	3111	487	262
2000	9.5	16.6	3037	527	295
2001	9.1	15.6	2854	487	318
2002	9.9	17.1	3129	516	230
2003	9.9	19.2	3513	328	184
2004	9.3	15.7	2873	439	242
2005	9.4	16.6	3037	490	296
2006	9.2	16.4	3001	425	299
2007	9.3	15.4	2818	546	320
Mean for 1982-2007	9.1	15.7	2878	506	309

RESULTS AND DISCUSSION

Fertilization with phosphorus, potassium and magnesium repeated every year increased the content of these elements in soil and this increase was significantly higher in the layer of 0-20 cm than in the layer of 21-40 cm (Tab. 3). Also, content of the available minerals in both layers analysed depended on a dose of a given element in the fertilization programme.

Analysing the content of available phosphorus, potassium and magnesium on the experimental plots where these elements were not applied, no decrease in their content in the soil was found either in the arable (0-20 cm) or in the subarable (21-40 cm) layer.

Similar effect of fertilization on mineral components' availability was found by Kępka and Sadowski (1978), Pacholak (1984) and Lipecki and Szwedo (1995). Thus, it must be pointed out that content of phosphorus, potassium and magnesium in combinations where they were not applied, was relatively stable. Similar results in multi-year experiments on fertilization were obtained by Mercik (1971).

The fertilization affected also K/Mg proportion and soil pH (Tab. 3). Potassium fertilization with no magnesium fertilization worsened the proportion of potassium to magnesium. On the other hand, fertilization with magnesium improved this proportion very much.

Soil acidification was observed on the fertilized plots, particularly in combinations where nitrogen fertilizer was applied (Tab. 3). Kępka and Sadowski (1978), Delver (1980), Lipecki (1991) and Kozanecka (1999) have also found that mineral fertilization, particularly with nitrogen, cause physico-chemical changes in soil, which is evidenced by decrease of pH, and has an effect on the content of other mineral components as well.

Changes in the content of available mineral elements in both soil layers was not consistent with the content of these components in leaves, where it was relatively stable during 25 years of the experiment. The only exception was nitrogen, whose content in leaves showed greater differentiation and varied from optimal to high values. The greatest content of this element was found in trees under which nitrogen fertilization was applied. The content of phosphorus, potassium and magnesium in the leaves was at the optimal level, independently of fertilization and of the content of these components in soil (Tab. 4).

Many researchers stress that fertilization affects the level of minerals' content in the leaves (Fallahi and Kriszna Mohan, 2000). Such dependence did not occur in our studies, where age and the course of weather conditions had a greater influence than fertilization on leaf mineral content. This agrees with results of the studies of Tromp (1980) and Jadczuk (1994).

Analysis of tree growth and yielding indicated that fertilization did not exert any significant effect on these features. Twenty five years of differentiated fertilization did not

T a b l e 3. Effect of 25 years of fertilization with N, P, K and Mg on concentration of P, K and Mg, K/Mg ratio and pH in 0-20 and 21-40 cm soil layers

Treatment	P [mg 100g^{-1}]		K [mg 100g^{-1}]		Mg [mg 100g^{-1}]		K/Mg ratio		PH	
	0-20	21-40	0-20	21-40	0-20	21-40	0-20	21-40	0-20	21-40
Initial analysis in 1982	3.9	3.1	6.4	5.3	3.4	3.2	1.9	1.6	5.5	5.7
Control	-1.0	-0.6	-1.4	-1.3	-1.0	-1.1	2.1	1.9	5.2	5.3
$N_1P_1K_1Mg_1$	+4.9	+2.9	+8.5	+5.4	+2.9	+3.9	2.4	1.5	3.8	4.5
$N_2P_2K_2Mg_2$	+10.2	+8.4	+13.5	+10.0	+5.5	+7.4	2.2	1.4	3.5	4.5
$N_1K_1Mg_1$	-0.6	0.0	+8.9	+7.3	+6.0	+4.5	1.6	1.6	4.2	4.3
$N_2K_2Mg_2$	0.0	0.0	+12.7	+9.1	+5.4	+3.6	2.2	2.1	3.6	4.0
N_1K_1	-0.4	-0.1	+10.4	+7.7	-0.5	-0.7	5.8	5.2	3.8	4.6
N_2K_2	-0.1	-0.6	+8.8	+7.5	-0.9	-1.1	6.1	6.1	3.5	4.2
N_1	0.0	-0.7	-1.2	-2.0	-0.9	-0.3	2.1	1.1	4.1	4.4
N_2	-0.4	0.0	-2.2	-0.1	-2.1	-1.5	2.8	3.0	3.6	4.0
K_1	-0.9	-0.7	-18.3	+12.6	+0.8	+0.4	5.9	5.0	5.3	5.5
K_2	-0.1	-0.9	+22.4	+18.2	-0.2	-0.2	9.0	7.8	5.1	5.0
P_1	+6.4	+4.2	-1.1	-0.5	+0.4	+0.4	1.4	1.3	5.3	5.4
P_2	+10.4	+5.9	-0.6	-1.2	-0.3	-0.4	1.9	1.5	5.1	4.7
Mg_1	0.0	0.0	-0.4	+0.8	+10.3	+9.5	0.4	0.5	5.2	5.3
Mg_2	-0.5	0.0	-0.2	0.0	+14.0	+9.4	0.4	0.4	4.6	5.1

+/- increase or decrease of nutrient in relation to control, year 1982

T a b l e 4. Effect of differentiated N, P, K and Mg fertilization on leaf nutrient concentration (mean values for 1985-2000)

Treatment	Leaf nutrient content [% of d.m.]				
	N	P	K	Mg	Ca
Control	2.26 a*	0.15 a	1.26 a	0.28 a	1.73 a
$N_1P_1K_1Mg_1$	2.83 b	0.15 a	1.34 a	0.33 a	1.70 a
$N_2P_2K_2Mg_2$	2.82 b	0.16 a	1.39 a	0.31 a	1.52 a
$N_1K_1Mg_1$	2.77 b	0.15 a	1.22 a	0.32 a	1.60 a
$N_2K_2Mg_2$	2.78 b	0.16 a	1.32 a	0.30 a	1.48 a
N_1K_1	2.72 b	0.16 a	1.34 a	0.27 a	1.57 a
N_2K_2	2.63 b	0.15 a	1.39 a	0.26 a	1.60 a
N_1	2.59 b	0.15 a	1.27 a	0.29 a	1.57 a
N_2	2.65 b	0.15 a	1.16 a	0.27 a	1.53 a
K_1	2.30 a	0.14 a	1.28 a	0.30 a	1.57 a
K_2	2.23 a	0.13 a	1.37 a	0.26 a	1.63 a
P_1	2.33 a	0.15 a	1.37 a	0.27 a	1.68 a
P_2	2.27 a	0.15 a	1.38 a	0.28 a	1.68 a
Mg_1	2.21 a	0.15 a	1.23 a	0.28 a	1.69 a
Mg_2	2.27 a	0.15 a	1,37 a	0.33 a	1.56 a

*Mean values marked with the same letters do not differ significantly at the level of p = 0.05

T a b l e 5 . The influence of fertilization on the yield of 'Cortland' apple trees in 1982-2007

Fertilizers treatment	Mean yields [kg per tree] in the years							Total yield in 1982-2007	
	1982-1985	1986-1989	1990-1993	1994-1997	1998-2001	2002-2005	2006-2007	kg	%
Control	11.1 a*	31.0 a	55.0 a	49.8 a	19.6 a	23.8 ab	24.5 a	806 a	100
$N_1P_1K_1Mg_1$	11.4 a	31.9 a	60.8 a	55.8 bc	19.8 a	27.3 bc	27.3 ab	864 a	107
$N_2P_2K_2Mg_2$	11.6 a	32.4 a	59.3 a	61.2 c	23.1 b	28.0 bc	21.9 a	884 a	110
$N_1K_1Mg_1$	11.4 a	32.6 a	54.6 a	55.7 b	21.2 ab	23.6 ab	25.7 ab	827 a	102
$N_2K_2Mg_2$	11.7 a	31.6 a	49.7 a	46.9 a	20.4 a	27.7 bc	30.4 b	794 a	98
N_1K_1	9.1 a	33.1 a	50.0 a	50.8 ab	20.9 a	16.8 a	20.0 a	779 a	97
N_2K_2	11.2 a	29.9 a	54.9 a	54.9 ab	23.5 b	26.6 b	27.3 ab	836 a	104
N_1	11.8 a	30.7 a	51.2 a	49.8 a	20.5 a	17.3 a	21.6 a	757 a	94
N_2	13.2 a	32.7 a	54.5 a	45.9 a	18.0 a	20.2 a	20.1 a	754 a	93
K_1	12.1 a	33.0 a	56.8 a	49.2 a	22.3 ab	25.1 b	24.2 a	812 a	101
K_2	10.7 a	32.5 a	56.5 a	47.4 a	21.5 ab	26.1 b	21.4 a	797 a	99
P_1	11.4 a	34.6 a	59.1 a	58,3 bc	25.5 b	31.5 c	27.1 ab	912 a	113
P_2	11.6 a	33.1 a	59.1 a	53.0 ab	22.0 ab	26.8 b	24.0 a	841 a	104
Mg_1	11.3 a	33.7 a	64.0 a	53.4 ab	25.1 b	31.1 c	28.5 b	902 a	112
Mg_2	12.9 a	35.8 a	63.1 a	52.0 ab	19.3 a	24.4 b	23.7 a	837 a	104

*Means marked with the same letters did not differ significantly at the probability level of $p = 0.05$

Table 6. Influence of differentiated N, P, K and Mg fertilization on vegetative growth of 'Cortland' apple-tree

Fertilization treatment	TCSA in 2007	Cropping efficiency coefficient
Control	250.6 bc*	3.2 b
$N_1P_1K_1Mg_1$	272.5 cd	3.2 b
$N_2P_2K_2Mg_2$	236.5 ab	3.7 bc
$N_1K_1Mg_1$	238.2 ab	3.5 b
$N_2K_2Mg_2$	253.3 bc	3.1 b
N_1K_1	292.4 c	2.7 a
N_2K_2	256.0 bc	3.3 b
N_1	337.4 d	2.2 a
N_2	252.4 bc	3.0 b
K_1	229.6 ab	3.5 bd
K_2	229.7 ab	3.5 bd
P_1	223.6 ab	4.1 c
P_2	199.0 a	4.2 c
Mg_1	254.8 bc	3.5 b
Mg_2	215.3 a	3.9 c

*Mean values marked with the same letter do not differ significantly at p = 0.05

exert any significant effect on growth of the trees, expressed as trunk cross-sectional area, as compared with not fertilized control (Tab. 6). The only exception were trees fertilized with nitrogen at the dose of 60 kg ha^{-1}, which were characterized by significantly higher trunk cross-sectional area than the trees from other combinations. On the other hand, application of 80 kg P ha^{-1} and 120 kg Mg ha^{-1} significantly decreased the tree growth vigour.

'Cortland' apple trees on M.26 rootstock started fruiting in the third year after plantating (Fig. 1). Yields, independently of fertilization, kept increasing until 15^{th} year from 0.4 kg in 1982 to 88.9 kg per a tree in 1996. During the following 11 years, the yields from not fertilized trees were stable at the level of about 23 kg and the yields from fertilized trees at the level of 25 kg per a tree (Fig. 1). The yield analysed for 4-year periods (Tab. 5) systematically increased, but no significant differences were found between the yield from fertilized trees and the control, not fertilized ones.

As shown by our studies, the yield depended in a high degree on tree age and on the course of weather conditions in a given year. Lack of reaction to fertilization confirms the results obtained by Słowik and Morozowski (1973), Pacholak (1986) and Hołubowicz and Pacholak (1978). The above-mentioned authors explain the absence of such reaction by a good preparation of soil before tree plantating, while Terts (1968) explains it by low requirement of apple trees for nutrients. In the successive periods, statistical differences were found between combinations, but in

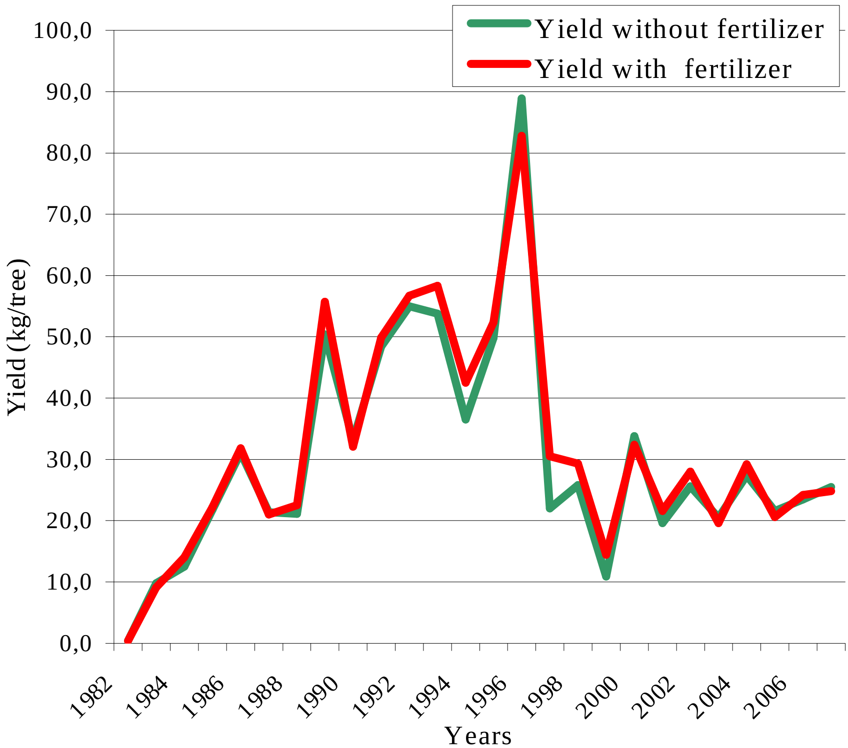

Figure 1. The influence of fertilization on the yield of 'Cortland' apple trees during 1982-2007

the calculation of the sum of yields for 25 years, no significant effect of fertilization on the tree yielding was found (Tab. 5). It is worthy of noting that the lowest total yield for the entire period of the experiment was obtained in from trees fertilized with nitrogen, while the highest yield was produced by trees fertilized with low doses of phosphorus (40 kg ha^{-1}) and magnesium (60 kg ha^{-1}). Since there are no significant differences between the combinations, it must be stressed that the course of weather conditions exerted an influence on the yield calculated per hectare (Fig. 2), which in that period varied between 2.7 and 57.3 t ha^{-1}, and the mean yield for 25 years was 20.8 t ha^{-1}.

Analysis of relationship between yield, mean temperature during vegetation season, the sum of rainfall during vegetation season and content of mineral elements in soil and leaves showed a significant positive correlation between temperature during vegetation season and Mg content in leaves and a negative correlation between the rainfall sum during vegetation season and phos-phorus content in the leaves (Tab. 7).

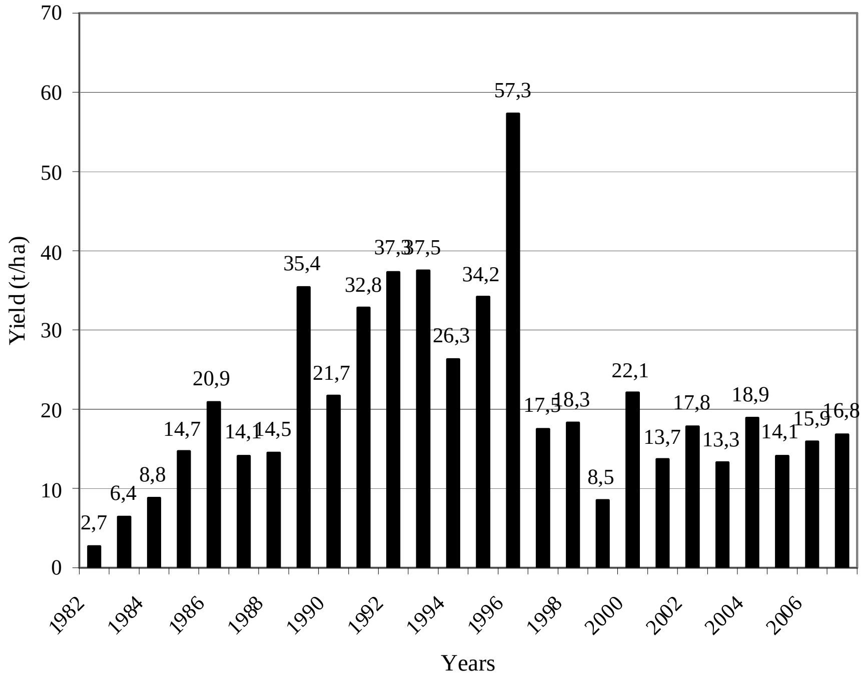

Figure 2. Yielding of 'Cortland' apple tree on M.26 rootstock during 1982-2007

T a b l e 7 . Linear correlation coefficients between environmental factors and yielding

Factors	Yield
1. Mean temperature in growing period	+0.41**
2. Sum of rainfalls in growing period	-0.29*
3. Content of nutrient in leaves	
N	+0.02
P	-0.19*
K	-0.03
Mg	+0.24*
Ca	+0.19*
4. Content of nutrients in soil	
P	+0.11
K	+0.12
Mg	+0.08

*Correlations is significant at p = 0.05
**Correlations is significant at p = 0.01

CONCLUSIONS

1. Fertilization of apple orchard for 25 years with differentiated doses of NPK and Mg resulted in an increase of the content of available elements in the arable (0-20 cm) and in the subarable (21-40 cm) soil layers. Absence of fertilization caused a decrease in soil mineral nutrient content during that period.
2. Differentiated contents of mineral nutrients in soil did not exert any effect on total content of minerals in leaves. Independently of the kind and dose of fertilizer applied, nutrients content in leaves was at the optimal level.
3. Fertilization applied for 25 years did not exert any significant effect on the sum of yields of 'Cortland' apples. Yield expressed per tree and per hectare depended on the course of weather conditions in the particular years and on tree age.

REFERENCES

Bould C., Hughes H.M., Gunn E. 1972. Effect of soil management and NPK fertilizers on tree growth, yield and leaf nutrient composition of dessert apples. EXPL. HORT. 24: 25-36.

Cain I.C. 1953. The effect of nitrogen and potassium fertilizers on the 3 performance on mineral composition on apple trees. PROC. AM. SOC. HORT. SCI. 62: 46-53.

Delver P. 1980. Der Einfluss des Wasserhaushaltes auf die Nährstoffversorgung und Nährstoffbedarf in Obstanlagen. ERWERBSOBSTBAU 3: 68-75.

Fallahi E., Krishna Mohan S. 2000. Influence of nitrogen and rootstock on tree growth, fruit quality, leaf mineral nutrients and fire blight in 'Scarlet Gala' apple. HORT. TECH. 10 (3): 589-592.

Greenham D.W.P., 1979. Nutrient cycling: the estimation of orchard nutrient uptake. Proc. Inter. Conf. Canterbury.

Greenham D.W.P. 1980. Nutrient cycling: estimation of orchard nutrient uptake. In: Mineral Nutrient of Fruit Trees, London, pp. 345-352.

Hołubowicz T., Pacholak E. 1978. Wpływ nawożenia i uprawy gleby na wzrost i plonowanie wiśni. SAD NOW. 3: 8-10.

Jadczuk E. 1994. Wpływ podkładki, odmiany i nawożenia na poziom odżywiania, wzrost i owocowanie wiśni. Rozprawy naukowe i monografie. SGGW.

Kępka M., Sadowski A. 1978. Wpływ nawożenia azotem na niektóre właściwości chemiczne gleby oraz na wzrost i owocowanie jabłoni. Cz. I. ROCZ. NAUK. ROL. A. 103: 49-64.

Kozanecka T. 1999. Zmiany w zasobności gleby w sadzie w zależności od wieloletniego zróżnicowanego nawożenia azotem i potasem i od sposobu jej utrzymania. ZESZ. PROB. POST. NAUK ROL. 465: 460-470.

Lipecki J. 1991. Utrzymywanie gleby w sadzie a odżywianie roślin sadowniczych. Intensywny Sad w Polsce, Olsztyn, pp. 22-30.

Lipecki J., Szwedo J. 1995. The effect of long –term use of herbicides and sword and various NPK fertilization on some chemical properties of the soil In the orchard. FOLIA HORT. 7(2): 3-9.

Mercik S. 1971. Studia nad zależnością pomiędzy zasobnością gleb w potas a efektywnością nawożenia tym składnikiem. Rozp. Nauk. SGGW, 13 p.

Pacholak E. 1984. Wpływ nawożenia i nawadniania na zawartość składników pokarmowych w liściach drzew i w glebie sadu jabłoniowego. PR. KOM. NAUK ROL. I LEŚ. PTPN 57: 233-243.

Pacholak E. 1986. Wpływ nawożenia i nawadniania na wzrost i plonowanie jabłoni odmiany James Grieve. ROCZ. AR W POZNANIU 180: 1-79.

Pacholak E., Łysiak G. 1993. Wpływ nawożenia i nawadniania na zmiany zawartości składników w glebie oraz na wzrost i plonowanie po replantacji. PR. KOM. NAUK ROL. I LEŚ. PTPN 75: 139-147.

Piątkowski M., Kłosowski W., Mochecki J., Potocka M. 1982. Zróżnicowane nawożenie azotem i potasem oraz skomasowane nawożenie fosforem i potasem jabłoni w pełni owocowania. PR. INST. SAD. I KWIAC. T. A 23: 13-22.

Sadowski A., Kępka M. 1974. Results of nine year N and K fertilizer trial and Yellow Transparent apple trees. Proc. 19th Intern. Hort. Congr. Warszawa 1A, 392 p.

Sadowski A. 1985. Rola analizy chemicznej w nowoczesnej produkcji ogrodniczej. Mat. Konf. Nauk Tech. IUNG Puławy, pp. 119-129.

Słowik K., Morozowski M. 1973. Wpływ zróżnicowanego nawożenia i nawadniania na plonowanie jabłoni Spartan i McIntosh. PR. INST. SAD. KWIAC. E: 84-90.

Tromp J. 1980. Mineral absorption and distribution in young apple trees under various environmental conditions. Konf. Mineral Nut. of Fruit Trees. London, pp. 173-181.

Terts I. 1968. Teliama – fragyazasi tartankiserlet eremenyei homoktalajom. SZŐLŐ GYÜLNÖLCSEERM 4: 54-72.

Vang-Petersen O. 1984. Godskning med kvaelstaf oo kalium til surkirsebaer. TIDSSKR. PLANTEBIOL 88: 81-90.

WPŁYW 25-LETNIEGO ZRÓŻNICOWANEGO NAWOŻENIA NPK i Mg NA WZROST I PLON JABŁONI ODMIANY 'CORTLAND' ORAZ ZAWARTOŚĆ SKŁADNIKÓW W GLEBIE I LIŚCIACH

Eugeniusz Pacholak

S T R E S Z C Z E N I E

Badania przeprowadzono w latach 1982-2007 w sadzie doświadczalnym Katedry Sadownictwa Uniwersytetu Przyrodniczego w Poznaniu na terenie Rolniczo-Sadowniczego Gospodarstwa Doświadczalnego w Przybrodzie. Drzewa odmiany 'Cortland' na podkładce M.26 posadzono jesienią 1979 roku na glebie płowej właściwej, w rozstawie 5 x 3 m (667 drzew na hektar). W doświadczeniu było 15 kombinacji w 8 blokach. Pierwsze zróżnicowane nawożenie zastosowano w 1982 roku, to jest od trzeciego roku po posadzeniu stosowano bez zmian aż do 2007 roku. Przez wszystkie lata nawożono wiosną na 4-5 tygodni przed kwitnieniem: azotem (w formie saletry amonowej 34%), potasem (sól potasowa 60%), fosforem (superfosfat potrójny 46%) oraz siarczanem magnezu 24%. Zróżnicowane nawożenie miało istotny wpływ na zawartość składników przyswajalnych w glebie zarówno w warstwie ornej, jak i podornej. Nawożenie fosforem, potasem i magnezem zwiększało zawartość tych pierwiastków w obu warstwach gleby. Nie stwierdzono współzależności między zawartością składników w glebie i w liściach. Niezależnie od nawożenia zawartość składników w liściach była na poziomie optymalnym, a 25-letnie zróżnicowane nawożenie nie miało istotnego wpływu na wzrost i plon odmiany ‘Cortland’, który bardziej zależał od wieku drzew i przebiegu warunków pogodowych.

Słowa kluczowe: jabłoń, odmiana, nawożenie, wzrost, plon, gleba, liście