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SOME ASPECTS OF INTEGRATED PLANT NUTRITION IN ORCHARDS

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Abstract. Results of our experiments are interpreted according to fertilizing system developed by long-term experiments and investigations. The potassium fertilization and favourable N/K ratio can increase the frost tolerance of generative organs of fruit trees to some extent. The effect of suitable growing site can surpass the effect of fertilizers. Frequently, the increase of phosphorus and potassium levels in the soil and leaves are relatively small comparing to amount of fertilizers, because of the strong fixation in the fertilized soil layer and – in other cases – leaching from root zone. Main soil characters should be taken into consideration to determine the favourable phosphorus, potassium levels in the soil. The excess of lime can be compensated by potassium fertilization to some extent, but on acid soils the NPK fertilization may be more effective – or effective at all – following lime or dolomite application.

Key words: nutrient background, environmental conditions, fertilizing system

INTRODUCTION

Nowadays two main tendency is combining in fruit growing, namely the intensity and the environment protection. These tendencies are in contradiction to each other to some extent. The **integrated fruit production** (IFP) makes possible the joint realization of these aspects. The main directives of IFP are the followings in connection of nutrient management of orchard:

1. Selection of favourable growing site.
2. The fertilization, and first of all the mineral fertilization should be applied on soil- and leaf analysis, fertilizers can be used in accordance with nutrient demand of fruit trees.
3. Organic fertilizers and green manure have to be prefered to artificial fertilizers.
4. Soil fertility should be reserved or improved.
5. Quantity of nitrogen fertilizer shouldn't exceed the nitrogen demand of plant, and the releasing nitrogen of soil has to be taken into consideration for determining the doses.

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6. The soil-pH should be optimised at establishing of orchard.

7. Foliar fertilization may be applied in the case of nutrient deficiency and for improving fruit quality.

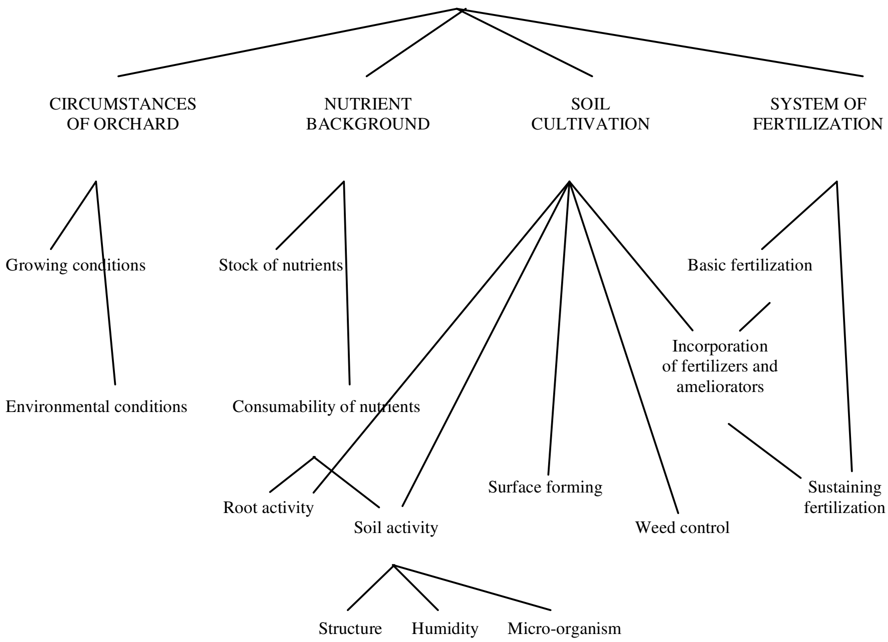

Fig. 1. Nutritional management of orchards
Rys. 1. Gospodarka składnikami mineralnymi w sadach

Besides fertilization there are a lot of **factors having influence on nutritional status** of fruit trees. They are both environmental circumstances and farming solutions. Results of this polyfactorial relationship are reflected in nutritional supply and yield of fruit trees. Relation of some important factors is shown by scheme (fig. 1).

METHODS

The nutritional management or nutritional status of orchards depends first of all on the **nutrient background** and on **fertilization system** (mentioned later).

At the same time the **soil cultivation** also may have direct effect on nutrient supply because most part of fertilizers and ameliorator materials are incorporated into root zone by soil cultivation. In order to efficient fertilization, it should be taken in consideration immediately the nutrient element, soil type, proper depth of cultivation and the time of application too.

The main role of soil cultivation is the weed control and the forming of soil surface. But besides this main purpose it has also indirect effect on nutrient supply, because the favourable soil surface can increase the soil activity by reserving higher soil humidity, and consequently it can result better and longer availability soil nutrients. The deeper soil cultivation – in itself or combining with organic matters, as well as with lime application – has also indirect effect on nutrient supply by developing of soil structure and root activity. In this way the active root system can better utilize the soil nutrients.

At first view, it hasn't evidence that the circumstances of orchard – which consist of groups of environmental- and growing conditions – may have effect on the nutritional status of orchards. In our fruit growing – in spite of selection positive growing site – plantations suffer frequently from different **stress effects**. For example:

1. Soil problems:
   – high lime content or strong acidity,
   – light sand or heavy clay soil,
   – low intensity of releasing nutrient caused by high fixation.
2. Extremities of continental climate:
   – fluctuation of low and high temperature can interrupt the dormant season and increase the risk of frost damage,
   – shortage of rainfall and draught summer can result the failure of flower bud differentiation, and it initiates alternation in yield,
   – the heavy rain, the high ground water table can result excess of water and consequently strong vegetative growth – especially if it is combined with frost damage or strong pruning or bad rootstock-scion combination.

All of these effects can cause great problems in the nutritional management of orchard.

RESULTS

During our **long term fertilizing experiments** we had opportunity to investigate effect of winter or spring frost and soil lime content what represent the relation between the stress tolerance and nutrient supply of trees.

Frost damage of peach flower buds was investigated at the end of January – after a continuous, cold winter – when the minimum temperature was 22°C below zero (fig. 2).

Potassium fertilization had favourable influence on tolerance of winter frost damage and on yield of **peach trees**. It is considered that the potassium in leaves of should be above 2.5% and the N/K ratio is required to be less then 1.5 in order to keep the health condition of trees and to have good yield [Szűcs 1986].

Fortunately so severe cold winter used to occur rarely in our peach growing area, but the fluctuation of warm and cold winter periods may cause similar damage at lower (12–16°C below zero) temperature too.

Effect of fertilization on frost tolerance of **apricot** flowers [Szűcs 1985] were investigate in climate chamber at minus 4.2°C (fig. 3).

Correlation was better when we compared the results in relation to N/K ratio, what should be near 1.0 because above 1.5 N/K ratio the frost damage may be only high.

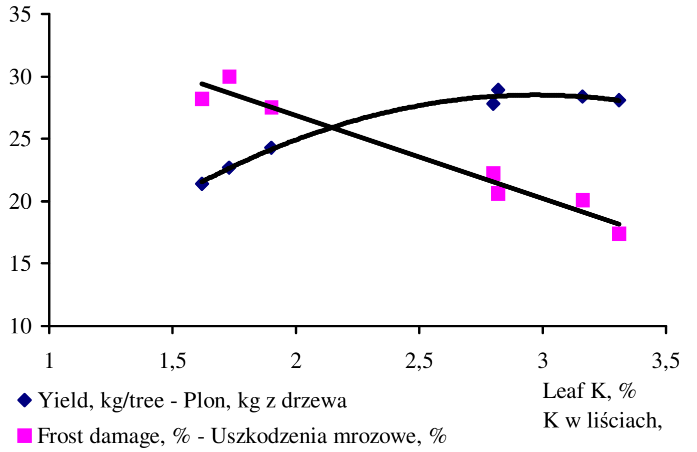

Fig. 2. Potassium supply and frost damage of flower buds and correlation with yield of peach trees
Rys. 2. Odżywienie potasem, uszkodzenia mrozowe pąków kwiatowych i korelacja z plonem brzoskwiń

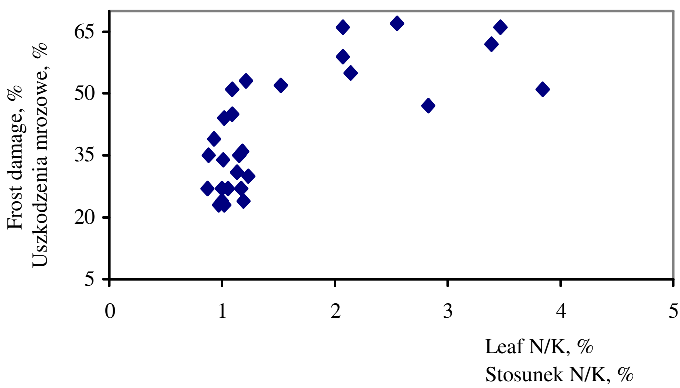

Fig. 3. Effect of potassium supply on frost damage of apricot flowers
Rys. 3. Wpływ odżywienia potasem na uszkodzenia mrozowe kwiatów moreli

Table 1. Nutrient supply and yield of apricot trees
Tabela 1. Odżywienie składnikami mineralnymi a plon moreli

Fertilizer treatment Kombinacja nawożenia	Leaf K, % K w liściach, %	N/K ratio stosunek N/K	Yield, kg tree^{-1} Plon, kg drzewo^{-1}
Control – Kontrola (0)	0.94	2.73	15.5
NPK	1.79	1.50	43.5
NPK_2	2.20	1.17	49.0

The yield of apricot trees showed close relation with fertilization (tab. 1).

In the case of **sour cherry** fertilizing experiment we had opportunity to compare not only the effect of fertilizing treatments but also the different height of growing site on survival rate of flower after a spring frost [Szűcs 1996]. About the half of repetitions of the trial were settled about 2 meters higher uphill position than the others. The minimum night temperature was 4.5°C below zero and the damage was very serious, consequently only very few of the flowers could survive it (fig. 4).

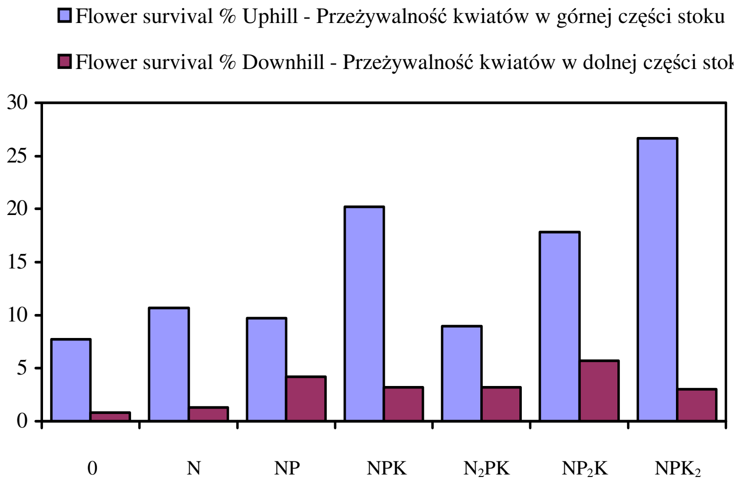

Fig. 4. Effect of fertilization and growing site on frost survival rate of sour cherry flowers
Rys. 4. Wpływ nawożenia i stanowiska na przeżywalność kwiatów wiśni w czasie przymrozku

Our results suggest that the nutrient supply may moderate the frost damage. The higher dose of nitrogen – opposite to potassium – is disadvantageous in preventing frost damage. But on the base of the figures it is evident that small difference in growing position has much greater importance than nutrient supply.

In Hungary we have a lot of **lime soils**. The lime can consider as stress factor, which may have great influence on efficiency of fertilizers and on nutrient supply as well as on yield. In the case of peach fertilizing experiment we had more than 100 experimental plots - and following factor and cluster analysis – we formed different groups (clusters) by computer system [Szűcs 1995]. The regression analysis was carried out by data of cluster means.

The potassium supply has positive effect on yield, but we can get better explanation and useful practical information if the yield is related to lime content of the soil (fig. 5).

According to this linear correlation (r = - 0.7) the lime content of soil has negative effect on yield of peach trees. The interpretation of data – being far from trend line – can be found in their potassium background. Namely, clusters 2, 3, and 7 represent the low potassium supply (1.68–2.19% K). In this case the negative effect of lime is much stronger than in the case of clusters 6 and 4 (2.65–2.94% K) or in clusters 1, 5, 8 and 9 where potassium level is high enough (3.04–3.29% K).

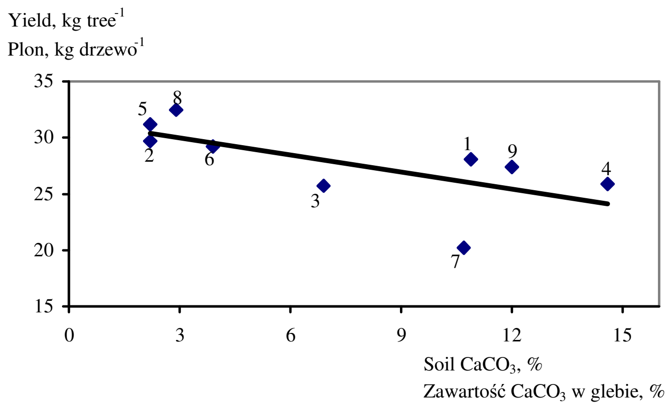

Fig. 5. Relation between soil lime content and yield of peach trees
Rys. 5. Zależność pomiędzy zawartością wapnia w glebie a plonem brzoskwiń

Table 2. Favourable phosphorus content in the soil of orchards, average of 0–60 cm layer
Tabela 2. Pożądana zawartość fosforu w glebie w sadzie – średnio w warstwie 0—60 cm

Clay content Zawartość części spławialnych %	$CaCO_3$ %	pH (H_2O)	Soil P_2O_5 Zawartość P_2O_5 w glebie mg kg^{-1}
< 20	0	< 6.4	60
	> 1	> 7.6	100
	< 1	6.5-7.5	80
> 20	0	< 6.4	80
	> 1	> 7.6	120
	< 1	6.5-7.5	100

Table 3. Favourable potassium and magnesium content in the soil of orchards, average of 0–60 cm layer
Tabela 3. Pożądana zawartość potasu i magnezu w glebie w sadzie – średnio w warstwie 0–60 cm

Clay content Zawartość części spławialnych %	Soil K_2O Zawarość K_2O w glebie mg kg^{-1}	Soil Mg Zawarość Mg w glebie mg kg^{-1}
< 15	100	60
16-20	120	80
21-35	160	100
36-60	200	140
61-70	230	180
> 71	250	200

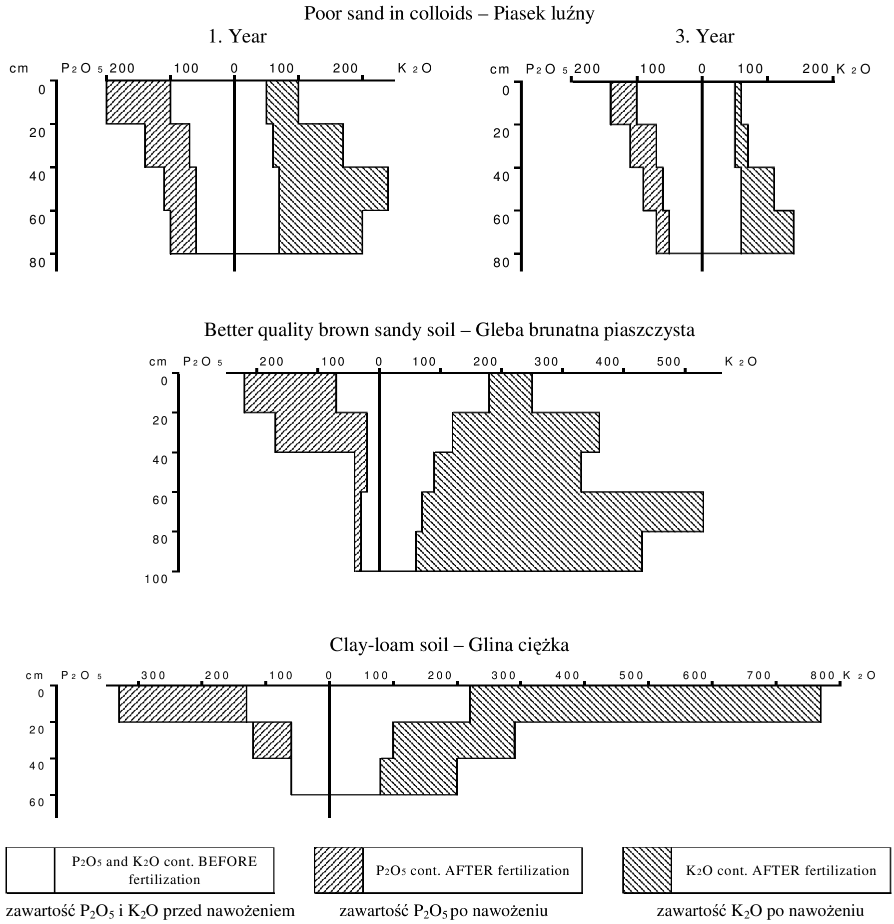

Fig. 6. Effect of fertilization on phosphorus and potassium content of soils (pure sand, brown sand, clay-loam)

Rys. 6. Wpływ nawożenia na zawartość fosforu i potasu w glebach (piasek luźny, gleba brunatna piaszczysta, glina ciężka)

Consequently, the yield decreasing effect of lime depends on the nutrient supply, or rather the effect of lime can be compensated by potassium fertilisation to some extent.

It can be found frequently that the increase of phosphorus and potassium levels in the soil and leaves are relatively small comparing to amount of fertilizers. One of the explanations of this phenomenon may be the strong **fixation** in the fertilized soil layer and – in other cases – **leaching** from root zone, what we measured in our trials. The tendency is demonstrated on soil profile diagrams (fig. 6).

For investigation this question we analysed 3 different soil types (*poor sand*: H < 1%, clay content < 10%, *better sand*: H > 1%, clay content 10–15%, *loamy soil* with 40–50% clay fraction) after the fertilization. The superphosphate and potassium salt were mixed into the upper soil layer [Szűcs and Faragó 1979].

We took consideration the main soil characters when we determined the favourable phosphorus, potassium and magnesium **boundary values** in soils (tab. 2, 3).

We consider that these recommended soil nutrient levels have to be realised in 60 cm deep soil layer (but mainly in root zone). It doesn't mean over-fertilization, and doesn't mean that it would be enough during the life of orchard, but these P, K, Mg levels will not appear as limiting nutrient factor, and these levels can be corrected easily on the base of leaf analysis.

The evaluation of apple fertilizing experiment serves as a good example for **agreement with potassium boundary value** in soil, K-level of leaves, maximum yield and fruit quality (fig. 7, 8).

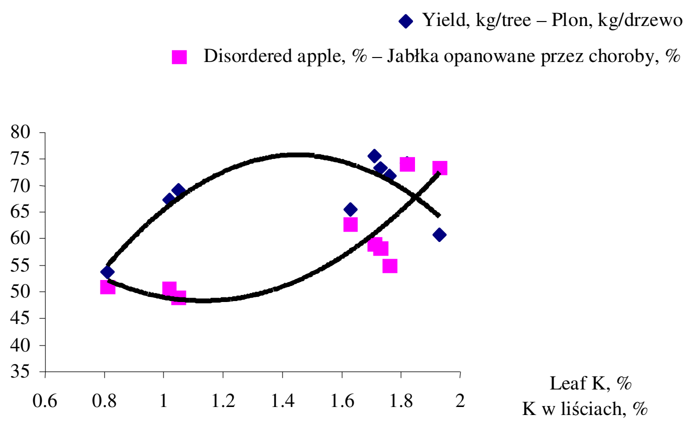

Fig. 7. Relation of leaf-K to yield and fruit quality
Rys. 7. Zależność pomiędzy zawartością K w liściach jabłoni a jakością owoców

By the figure 7, potassium content of 1.2–1.4 % seems to be the optimum level in the foliage, if you take into consideration the maximum yield and smallest storage disorders at the same time. If this potassium level is fitted to the trend line of figure 8, you can find the value of 200–230 mg K_2O/kg soil, what agree with data of table 3, because our experimental soil contains 55–60% of clay. By the figure 8, luxury potassium consumption also can be seen, but it may be disadvantageous for fruit quantity and mainly for the quality.

The **fertilizing system of orchards** consists of two parts, so called "basic" and "maintenance fertilization. During the **basic fertilization** the soil phosphorus, potassium and magnesium capacity can be fulfilled according to data of tables 2 and 3. It is required to have done it before plantation, mainly on loam and clay soils.

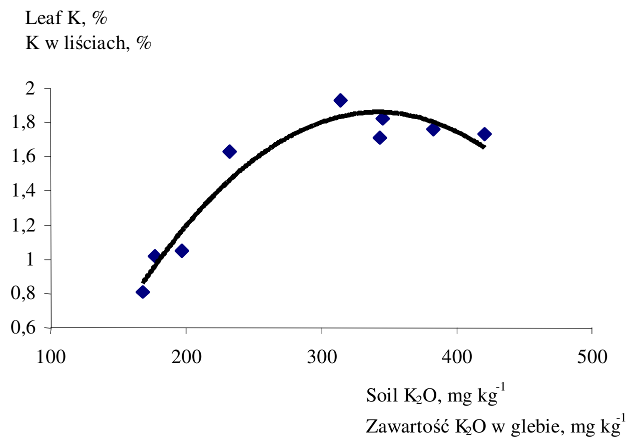

Fig. 8. Correlation of soil and leaf potassium content
Rys. 8. Korelacja pomiędzy zawartością potasu w glebie i w liściach

For calculating the **fertilization of bearing orchards** we have completed a mathematical formula about 20 years ago. In spite of long time, it may consider correct and environment protective. This system avoid from over fertilization by using fertilizers in accordance with nutrient requirement of trees and soil characters.

The **calculation** of maintaining fertilizer-needs is based on following relation. (It is the same equation for each nutrient element but with different parameters.)

$$\text{Nutrient element}\,(\text{kg} \cdot \text{ha}^{-1}) = Q \cdot A \cdot VS^2 \, \frac{1 + 0{,}01\sum C}{X^2}$$

where: Q – yield, t·ha^{-1}; A – basic data of nutrient removal by 1 t fruit and proportional wood, kg·t^{-1}; VS – standard value of leaf nutrient, % dm; X – nutrient content in leaf sample, % dm; C – correction factors

The **basic data** and standard value of **leaf nutrient** can be found in tables 4 and 5.

Table 4. Favourable nutrient content (Standard value) in leaves, % d.m.
Tabela 4. Pożądane zawartości (wartości standardowe) składników mineralnych w liściach, % s.m.

Species – Gatunek	N	P	K	Ca	Mg
Apple – Jabłoń	2.0-2.7	0.12-0.20	1.0-1.6	1.2-1.8	0.27-0.40
Pear – Grusza	1.8-2.6	0.17-0.20	1.0-1.6	1.2-1.6	0.33-0.47
Plum – Śliwa	2.2-3.2	0.17-0.23	2.0-3.0	2.0-2.8	0.5-0.7
Apricot – Morela	2.0-27	0.17-0.33	2.2-3.1	1.5-2.1	0.4-0.6
Cherries – Wiśnie i czereśnie	2.2-3.2	0.17-0.23	1.4-2.0	1.9-2.7	0.5-0.8
Peach – Brzoskwinie	2.6-3.6	0.18-0.26	2.3-3.2	1.7-2.4	0.4-0.6
Raspberry – Malina	2.6-2.3	0.20-0.30	1.0-1.6	0.8-1.5	0.3-0.4
Red currant – Porzeczka czerwona	2.4-2.7	0.20-0.30	2.0-2.6	1.8-2.2	0.3-0.4
Black currant – Porzeczka czarna	2.6-3.0	0.25-0.30	1.5-2.0	1.5-2.5	0.25-0.4

Table 5. Nutrient removal by 1 ton fruit and joined yearly wood increasing, kg t^{-1} (basic data)
Tabela 5. Ilość składników wynoszona rocznie z 1 toną owoców i odpowiadającym im drewnem, kg t^{-1} (dane bazowe)

Species – Gatunek	N	P_2O_5	K_2O	CaO
Apple – Jabłoń	1.2	0.4	2.0	1.5
Pear – Grusza	1.2	0.4	2.0	2.5
Plum – Śliwa	2.0	1.0	4.8	3.0
Apricot – Morela	2.2	0.9	4.4	2.3
Cherries – Wiśnie i czereśnie	2.6	0.9	4.4	3.0
Peach – Brzoskwinie	1.5	1.1	5.6	2.3
Raspberry (currants) – Malina (porzeczka)	6.0	1.6	7.0	4.0

In this mathematical formula the leaf analysis is the most important correcting factor because it works similarly to the function of $1/X^2$.

If the nutrient quantity (found in the leaf sample) is 1.2 times higher than the standard value, then the application of a given element may be interrupted for a time.

As **correction factors** the pH, P_2O_5, K_2O, Humus, lime and clay content of the soil are taken into consideration. For calculating the size of corrections we applied different correction equations [Szűcs 1997]. These rather simple mathematical formulas can be completed in quantity and quality if more information are available, but even this simple form is sufficient to avoid over-fertilization and to assure the nutrient demand of fruit trees.

CONCLUSIONS

It belongs to the duty of advisors and specialists to take into consideration or to integrate so many influencing factors as possible in order to keep the nutrient balance of orchards.

The yield decreasing effect of lime depends on the nutrient supply, or rather the effect of lime can be compensated by potassium fertilisation to some extent.

The potassium supply can moderate frost damage. The higher dose of nitrogen is disadvantageous in tolerating frost.

At slope the growing sites may have much more importance than nutrient supply.

Potassium fertilization and lime interaction shows the positive effect of good potassium supply on the greater tolerance of fruit trees.

Besides the importance of potassium in plant physiology, the stress effects of continental climate fruit-growing also may give motivation, why the potassium has been found as the most effective nutrient element in our long term experiments.

In order to ensure good nutrient supply of fruit trees, the recommended soil and leaf nutrient levels should be realized in the orchards.

REFERENCES

Szűcs E., Faragó M., 1979. A feltöltő jellegű foszfor és kálium trágyázás hatása a talaj tápanyagtartalmára és a fák tápláltságára. Újabb Kut. Eredm. a Gyüm. term, 15–26.

Szűcs E., 1985. Effect of fertilization on nutrient supply, yield, growth and frost hardiness of apricot trees. Acta Hort. 192, 137–141.

Szűcs E., 1986. A tápanyagellátottság hatása az őszibarack termőrügyek fagytűrő képességére. Kertgazd. vol. XVIII, 6, 39–42.

Szűcs E., 1995. Effect of lime content on phosphorus and potassium dynamics and yield of peach trees. Acta Hort. 383, 491–498.

Szűcs E., 1996. Effect of nutrient supply on frost hardiness, setting of sour cherry flowers and on yield. Acta Hort. 410, 551–555.

Szűcs E., 1997. Possibilities to meet nutritional requirement of fruit trees and environmental protection. Acta Hort. 448, 433–437.

NIEKTÓRE ASPEKTY INTEGROWANEGO ODŻYWIANIA W SADACH

Streszczenie. Na podstawie wieloletnich badań opracowano system integrowanego odżywiania roślin sadowniczych prowadzony w sadach z IPO. Nawożenie potasem i właściwy stosunek N/K mogą do pewnego stopnia zwiększyć odporność generatywnych organów drzew owocowych na mróz. Jednakże dobór właściwego stanowiska może mieć większe znaczenie niż nawożenie. Wzrost zawartości fosforu i potasu w glebie i w liściach jest często niewielki, w porównaniu z ilością tych składników dostarczonych w nawozach; jest to związane z ich wiązaniem w nawożonej warstwie gleby, a – w innych przypadkach – z wymywaniem ze strefy zalegania korzeni. Podstawowe właściwości gleby powinny być brane pod uwagę przy określaniu optymalnego poziomu fosforu lub potasu w glebie. Nadmiar minerałów wapiennych w glebie może być w pewnym stopniu, równoważony przez nawożenie potasem. Na glebach kwaśnych bardziej efektywne może być nawożenie NPK po zastosowaniu wapna, zwłaszcza dolomitowego.

Słowa kluczowe: podstawy odżywiania, warunki środowiska, system nawożenia

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