Nutrient demand of stone fruits

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Summary: Effects of nitrogen, phosphorus and potassium fertilization were investigated on the change of nutrient content, vegetative and generative production of apricot, peach and sour cherry trees, as well as on frost hardiness in long term experiments. Nitrogen and phosphorus fertilization increased only the concentration of these elements in cherry leaves without effect on growth and yield. Consequent potassium effect was proved on these stone fruit species. Effect on yield appeared following the first higher crop load.
Potassium supply has positive effect on frost hardiness of apricot and sour cherry flowers and peach flower buds.
In peach, the lime content of soil decreased the yield but it could be compensated by potassium dressing to some extent.
Favourable nutrient boundary values were determined for soil and foliage.

Key words: *potassium supply, frost, lime, N/K ratio*

Introduction

There is great importance of long term fertilizing experiments to obtain exact data of nutrient demand of fruit trees (*Terts,* 1970). The soil adsorption capacity has great influence in effectiveness of phosphorus and potassium (*Szűcs & Faragó,* 1979). In case of sour cherry the effect of nitrogen, phosphorus and potassium dressing was proved (*Petersen,* 1977). *Mercik* et al. (1990) and *Ystaas* et al. (1995) have emphasised positive effect of potassium for growth and yield of cherry trees, but only moderate reaction to N and P fertilization. Their experiments were carried out on acid soil where lime and dolomite application improved the Ca and Mg supply and increased the yield too.

Calcium has important role in fruit quality, namely to prevent cracking of sweet cherry (*Lang* et al. 1998) and pitburn of apricot (*Bussi & Amiot,* 1998), where the higher N and decreasing Ca content of the fruit marked these disorders.

Our stone fruit experiments were carried out on calcareous soil. It offered possibility to investigate potassium and lime interaction too.

Frost damage belongs to the greatest risk factors in our fruit growing of continental climate. Many factors are involved in developing frost hardiness. Even the nitrogen may have positive effect on cold hardiness of peach buds (*Proebsting,* 1961). During the long experimental period we had opportunity to investigate the effect of nutrient supply on frost injury.

Material and method

Our experiments were started at the same time in planting orchards. Potassium and phosphorus fertilizers were given and incorporated into 50 cm deep soil layer only once before plantation of peach trees, but divided doses (pre- and post-plantation) were used in the cases of apricot and cherry trials. Nitrogen was applied annually at springtime.

The type of soil was pseudomiceliar, calcareous, chernozem loam.

Detailed design of experiments has been published previously (*Terts,* 1972, *Szűcs,* 1983, 1984, 1987) but the main characters are summarised in *Table 1*.

Table 1 Characters of stone fruit experiments

Fruit species	Apricot	Sour cherry	Peach
Variety	Hungarian best	Meteor	Dixired
Rootstock	Wild apricot seedling	Mahaleb seedling	Peach seedling
Experimental years	15	13	9
Treatments	10 NPK combinations	7 NPK combinations	13 NK combinations
Repetitions	12	9	8
Design	split-plot	block	split-plot
Nutrient dose: Nitrogen N kg/ha annually	0, 100, 200	0, 100, 200	0, 75, 150, 300
Phosphorus P_2O_5 kg/ha accumulated	0, 1600, 2400	0, 740, 1480	uniformly
Potassium K_2O kg/ha accumulated	0, 2400, 3600	0, 1100, 2200	0, 1200, 3600

Phosphorus and potassium of the soil were determined from Ammon-lactate solution by the Eghner- Riehm method. Leaf nutrients were analysed after liquid digestion for N, P, K (Kjeldahl method) and from ash for K, Ca, and Mg elements. Effect of frost injury was determined visually by discoloration of flower organs.

Table 2 The effect of fertilization on nutrient content of sour cherry leaves (d.m. %)

	Control	NPK	N_2PK	NP_2K	NPK_2	SD 0.05
N	2.49	2.76	2.83	2.86	2.87	0.17
P	0.174	0.186	0.193	0.201	0.193	0.012
K	0.46	1.04	0.98	1.13	1.40	0.20
Ca	2.12	2.22	2.11	2.27	2.05	NS.
Mg	0.91	0.82	0.79	0.80	0.66	0.06

Table 3 Effect of NPK fertilization on the yield of Meteor sour cherry trees (kg/tree)

Ages	0	N	NP	NPK	N_2PK	NP_2K	NPK_2	SD 0.05
9	32	30	30	34	33	30	30	NS.
10	27	28	29	29	33	31	33	NS.
11	4	3	4	5	4	6	8	NS.
12	39	41	39	51	49	50	45	9.9
13	23	24	17	31	33	31	33	3.0

Table 4 Trunk circumference of apricot trees in final year of experiment (cm)

0	N	K	NP	NK	PK	NPK	N_2PK	NP_2K	NPK_2	SD 0.05
62.2	58.4	66.7	58.3	62.1	65.2	63.3	60.9	62.9	63.2	4.2

Data were evaluated by analysis of variance (Fischer method), regression analysis, as well as in the case of peach, experiment factor- and cluster analysis were made by the help of computer program belonging to Computer and Automation Institute of Hungarian Academy of Sciences.

Results

Sour cherry

Different nutrient levels could be developed in the soil according to treatments, but the leaf analysis reflected the soil nutrient content more or less depending on the particular element. The fact and also the intensity of potassium fertilization could be detected consequently by leaf analysis. The nitrogen and phosphorus fertilization did not change the N and P content of foliage significantly, except in the cherry trial and only in some years.

The magnesium content of leaves remained within the optimum range. It can be interpreted as nutrient antagonism that the magnesium level decreased following potassium fertilization. Similar reaction was found in the case of peach too.

After a shorter or longer time, the effect of potassium fertilization or rather the shortage of potassium supply manifested also in the form of decreasing yield.

In the case of cherry only the potassium fertilization showed significant differences in yield. The negative tendency of nitrogen is not evident, but next to the absolute potassium shortage the N/K ratio may be also important because differences in yield began to appear after the N/K ratio had risen above 3 and had reached the value of 4–5.

In the case of sour cherry we had opportunity to compare not only the effect of fertilizing treatments but also the different heights of growing sites on survival rate of flowers after a spring frost. About the half of repetitions of the trial were settled about 2 meters higher uphill positions 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.

Our results suggest that the nutrient supply may moderate frost damage. The higher dose of nitrogen – oppositely to potassium – is disadvantageous in preventing frost damage. But on the base of the figures it is evident that even small difference in growing position has much greater importance than nutrient supply. It is not possible to correct the bad decision at selecting places for establishing orchard by fertilization.

Apricot

Effect of fertilization appeared on the vegetative productivity of fruit trees only after a longer (9–11 years) period, in spite of the nutrient analysis had shown the differences in potassium status within 1–3 years. Strong potassium deficiency was discovered on those plots, which did not receive potassium. Most serious symptoms developed in the case of N or NP combinations. Deficiency symptoms were visible on the foliage and the condition of trees. Similar tendency was found in the cases of two other stone fruit species.

In spite of the symptoms the growth of trees (expressed in trunk circumference) showed significant difference only in the case of the apricot trees and only after 14 years of fertilization.

The size of trees calls the attention for the importance of nutrient ratio because the smallest trees were found in those combinations, which were fertilized with nitrogen but without potassium.

The potassium level of foliage and the yield are shown *(Table 5)* in the case of the three most important treatments of apricot fertilizing experiment. Data represent the average of 11–14 years.

This four-year-period of experiment presented the most useful information about potassium demand of apricot trees.

Table 5 Nutrient supply and yield of apricot trees

	K %	N/K ratio	Yield kg/tree
Control	0.94	2.73	15.5
NPK	1.79	1.50	43.5
NPK_2	2.20	1.17	49.0

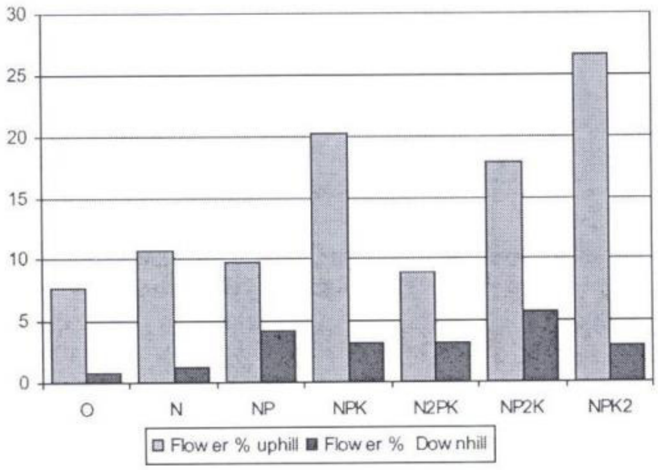

Figure 1 Effect of fertilization and grow ing site on frost survival of sour cherry flowers

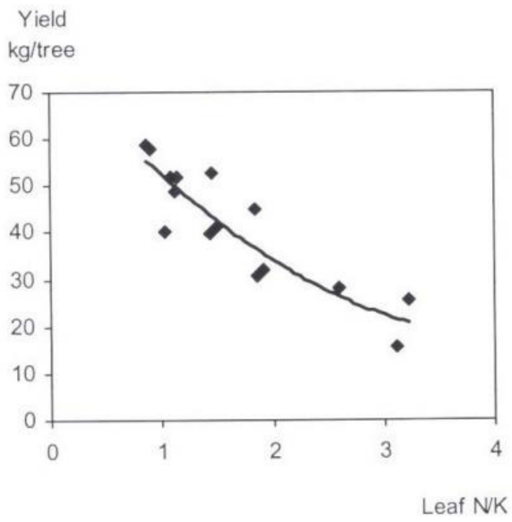

Figure 2 Nutrient supply and yield of apricot trees

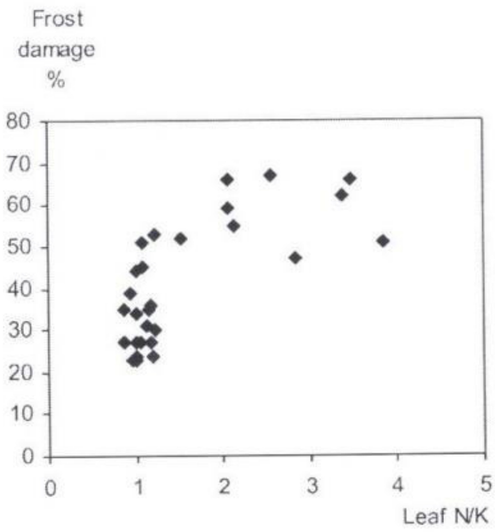

Figure 3 Effect of potassium supply on frost damage of apricot flow ers

We had the greatest differences in yield in the 11th year, when the spring frost caused serious damage in flowers. In this year the yield was 5–7 kg/tree in combinations without potassium and 25–44 kg/tree with potassium.

According to the results of the experiment the following range of potassium supply has been determined for apricot trees.

By making groups from yield and leaf analytical data according to these categories we have got exponential relationship. The correlation was stronger in the case of N/K ratio ($r = -0.97$) than by potassium content ($r = 0.87$). The regression by N/K ratio is shown in *Figure 2*. On the base of fruiting level and condition of trees as well as frost tolerance we consider it very important that in apricot orchards the leaf potassium content should be above 2.3% and the nitrogen-potassium ratio between 0.8–1.2.

Effect of fertilization on frost tolerance of apricot flowers were investigated in climate chamber at the end of gradual cooling until 4.2 °C below zero and keeping this temperature for one hour. Flowers were in full bloom. Potassium had a favourable effect on frost hardiness of apricot flowers. Correlation was better when we compared the results in relation to N/K ratio.

Peach

At first case the 7 years old trees showed significant differences in yield. The double dose of potassium did not give more yield statistically than the simple one. But after some fruiting years, only those trees had sufficient nutrient supply, which had higher dose of potassium (3600 kg K_2O/ha) before plantation. We have got the strongest relation between the potassium level and yield of peach trees in one of the spring frost affected years *(Figure 4)*.

The many plots of the peach experiment offered possibility to evaluate the dominant factors by factor analysis. Six factors were formed. In this 6-dimension factor space the plots were collected into 9 groups by cluster analysis.

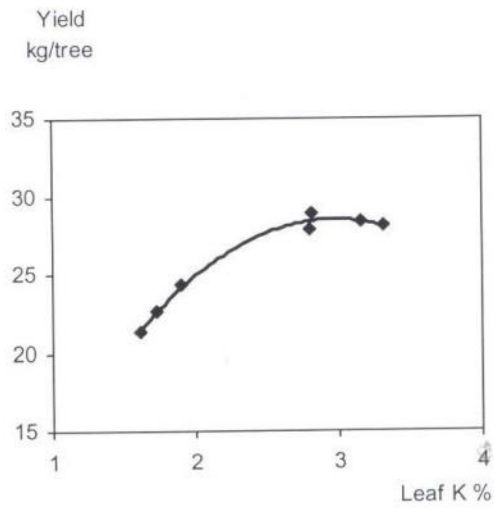

Figure 4 Correlation betw een potassium supply and yield of peach trees

By means of factor analysis it was stated that in this fertilizing experiment two strong factors had outstanding effects. The first factor had the following parameters: potassium content of soil and leaves as well as the Mg and Ca content of leaves in the opposite sense. In the second factor the lime content of the soil was dominant and other parameters had influences with negative sense, namely the humus-, potassium-, phosphorus content in the soil and the phosphorus content in leaves.

These factors have great reality because they reflect well the relationship of soil and nutrient dynamic. The average data of those experimental plots, which belong to the same cluster, are the so-called "cluster means". The regression analysis – carried out by cluster means – gives possibilities for wide-ranging interpretation.

This correlation *(Figure 5)* is only medium (r = –0.8) but characters and tendency is very similar to the former one *(Figure 4)* when the comparison was carried out on fertilization treatment only. We can get better explanation and useful practical information if the yield is related to lime content of the soil *(Figure 6)*.

According to this linear correlation (r = –0.7) the lime content of soil has negative effect on the 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).

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.

Frost damage of peach flower buds was investigated at the end of January after a continuous, long, cold winter period when the minimum temperature was 22 °C below zero *(Figure 7)*. Fortunately, severe winter temperature occurs rarely in the peach growing area, but fluctuation of warm and moderate cold (12–16 °C below zero) winter periods may cause similar damage. It happened two years later in our experiment too.

It is considered that the potassium content in the leaves of peach trees should be above 2.5% and the N/K ratio is required to be less than 1.5 in order to keep the orchard in good health condition and to have good fruiting capacity.

Conclusions

Potassium was the most effective nutrient in our stone fruit experiments.

The explanation can be the following for the rare and low effectiveness of N and P fertilization. The releasing nitrogen from humus of this soil type (above 2%) met the nitrogen demand of trees. The phosphorus supply of trees was favourable without further fertilizer in spite of the relatively moderate phosphorus content (60–100 mg P_2O_5/kg) of the soil. The enhanced root system of large spaced trees can play a great part in this phenomenon.

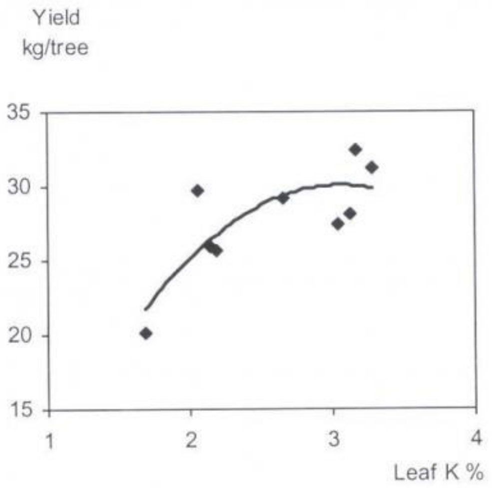

Figure 5 Leaf potassium and yield of peach trees (with cluster means)

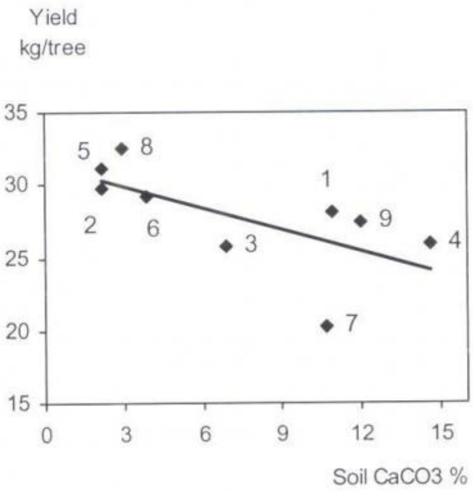

Figure 6 Relation betw een soil lime content and yield of peach trees (1–9 cluster means)

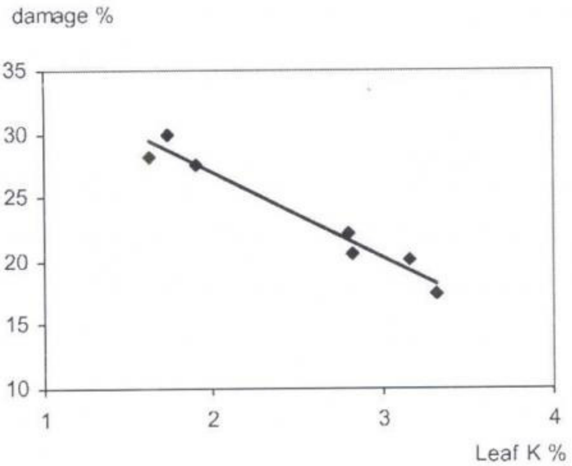

Figure 7 Potassium supply and frost damage of peach flower buds

We did not have positive effect of nitrogen fertilization in contradiction to the cited results mentioned in the chapter of introduction. Negative tendency of nitrogen application appeared in these trials because potassium deficiency symptoms were stronger in treatment with nitrogen but without potassium and correlation was closer to N/K ratio than considering K content only.

Potassium-magnesium antagonism may have greater importance and can cause magnesium deficiency in those soils, which have low magnesium content. In this situation magnesium application in the soil or/and to the foliage is necessary.

The nutrients supply moderates frost damage. The higher dose of nitrogen – contradictory to potassium – is disadvantageous in tolerating frost.

At sloppy growing sites, even a small difference in growing position may have much more importance than nutrient supply.

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

There is a lot of stress effect in our continental climate in relation to fruit growing (water shortage, fluctuation and extremity in temperature, high lime content or low pH at other places, low intensity of releasing nutrient caused by high fixation or low nutrient capacity of the soil).

Besides the importance of potassium in plant physiology, these reasons also may give motivation why potassium has been found as the most effective nutrient element in our long term experiments.

Favourable phosphorus content in the soil of orchards, average of 0–60 cm layer

Clay content %	$CaCO_3$ %	pH (H_2O)	Soil P_2O_5 mg/kg
< 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

In order to ensure good nutrient supply of stone fruit trees the following nutrient levels are recommended in soil and leaf of orchards.

Favourable potassium and magnesium content in the soil of orchards, average of 0–60 cm layer

Clay content %	Soil K_2O mg/kg	Soil Mg mg/kg
< 15	100	60
16–20	120	80
21–35	160	100
36–60	200	140
61–70	230	180
> 71	250	200

Favourable nutrient content in leaves (d.m. %)

Species	N	P	K	Ca	Mg
Apricot	2.0–27	0.17–0.33	2.2–3.1	1.5–2.1	0.4–0.6
Cherries	2.2–3.2	0.17–0.23	1.4–2.0	1.9–2.7	0.5–0.8
Peach	2.6–3.6	0.18–0.26	2.3–3.2	1.7–2.4	0.4–0.6

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