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Interaction of nutrient supply and crop load of apple trees (*Malus domestica* Borkh.)

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Summary: Long term fertilisation trials were combined with storage experiments with 'Jonathan' apple trees and fruits to study influence of tree nutrition on quantity and quality of crop. The site of experiments is a typical Carpathian-basin environment with loamy silt soil, high lime content and arid summers. Conclusions has been drown from six years' set of data. Augmented levels of soil fertilisation increased cropping capacity of apple trees, however, the fruit load has not met with cropping capacity in every year. More the def cit came into view in crop load, less the fruit quality resulted in. The deficit in cropping capacity, however, could not have been determined with simple rates as fruit weight per trunk circumference or similar. Better determination was obtained where foliar nutrient contents were correlated to crop per tree figures. In general terms, the N and Ca content in leaves increased with yields when K and P content formulated reciprocally. When storage quality of 'Jonathan' apple fruits were related to crop load (kg/tree), influence of crop deficit became visible. As the crop load and foliar nutrient levels interacted, the fruit quality (number of disordered apples after 6 month of storage) subjected of both physiological phenomena. Higher determination degree were obtained when crop load was assessed together with single or multiple foliar analysis data.

Key words: nutritional status, fruit load, storage, disorders, lime

Introduction

Plant nutrition plays an important role in fruiting capacity of fruit trees. Nutritional status of trees in a given year is mainly influenced by the nutrient supply and the actual fruit load and also by a number of other growing and climatic factors (*Wilkinson*,1968; *Quinlan*,1971; *Sadowski*,1995). The aim of our study is the better understanding of this complex. Attempts were made to determine fruiting capacity by the use of DRIS indices (*Sumner*,1977) of foliar analysis and yields (*Szűcs and Kállay*, 1990).

The storage ability of fruit is improved if fruit load tends to meet the cropping capacity of trees (*Sharples*,1980; *Szűcs and Kállay*, 1997). However, it seems to be difficult to determine the magnitude of yields being able to utilize nutritional offer, in other words, to have an indication for over- or under fertilization.

Material and methods

A long term, split-plot designed fertiliser trial at Ernyei-tanya Hungary, provided the data for statistical analysis (*Terts*, 1970). The experimental plantation was established on pseudomyceliar calcareous chermozem loam soil, orchard non-irrigated. Lime content of soil was relatively high and variable. Cultivar tested was Jonathan on M4 rootstock. Basic treatments experimented (fertilizers per hectare): 0 – no fertilization, N – 130 kg N/year, NPK – 130 kg N/year +780 kg P_2O_5 +2800 kg K_2O during 13 years; 2 NPK – 260 kg N/year + 1560 kg P_2O_5 + 5600 kg K_2O during 13 years, N3PK – 130 kg N + 1560 P_2O_5 + 5600 kg K_2O in 9 years. Trunk circumference, yield per tree and rate of disordered apples during storage of 2 °C in air were assessed, mineral nutritional content of soil, leaves and fruits was determined regularly.

Data collected during 6 consecutive years were computed in random. Relative importance of factors experimented was compared by the determination coefficient in (DC) of single and multiple linear regression analysis. In our work, we used the determination coefficient in per cent form. It symbolises the rate of variation of dependent variable, accounted for the given parameter.

In cases of correlations characterised by higher degree of determination, attempts were done to decode the shape and magnitude of physiological relations. For that purpose 10 clusters were formulated by the use of 15 parameters. In a cluster data of statistically uniform plots were randomised, and correlations were estimated by the use of clusters' means.

Results

Fertilization treatments applied during 13 years resulted in marked differences of soil nutrient content, yields and also storage losses (*Table 1*). Yields and storage quality of apples varied from year to year (*Table 2*).

Table 1 Effect of fertilization on nutrient content, yield and storage losses (Means of six years)

Treatments	$CaCO_3$%	P_2O_5 mg/kg	K_2O mg/kg	Yield kg/tree	Disordered apples%
0	22	67	161	72	29
N	20	73	169	67	34
NPK	20	124	299	81	39
2NPK	19	172	427	78	41
N3PK	19	180	344	82	31

Table 2 Effect of years on yields and storage losses (Means of treatments)

Years	Yield kg/tree	Disordered apples%
Year 1	61	60
Year 2	75	16
Year 3	66	32
Year 4	63	57
Year 5	94	33
Year 6	92	15

The trunk circumference of apple trees was 47cm with little variations. No fertilization effect was proved after 13 year.

In the first step influence of lime and soil nutrient content was evaluated in nutritional status of apple trees. For comparison, influence of fruit load was also presented *Table 3* consists data of determination (DC%) of single factors in variation of foliar analysis readings and also of yields.

Table 3 Soil lime and nutrient content, yield and their effect on nutritional status of apple trees (Means, Coefficient of Variation and Determination Coefficient of foliar analysis data and of yield)

Parameter	Mean	CV%	N DC%	P DC%	K DC%	Ca DC%	Mg DC%	Yield DC%
$CaCO_3$%	19.9	18.1	0.1	2.4	6.7	6.1	3.2	8.4
P_2O_5mg/kg	121.3	52.9	1.9	1.8	25.8	0.5	17.3	2.0
K_2Omg/kg	277.9	45.1	1.4	1.4	45.2	3.9	23.2	2.5
Yield kg/tree	75.8	24.0	2.3	8.5	1.0	1.6	3.2	

Lime has slightly more influence on yields than on leaf analysis readings, however this difference is little. Rise in soil phosphorus content was ineffective in foliar P, its effect on K and Mg may be accounted for the potassium fertilizer, given together with phosphorus. Uptake of potassium into leaves was enhanced by the K fertilization, its averse influence on foliar Mg is also clear. In the experiment, however, yield did not answered on massive fertilization, involvement of lime was more pronounced than soil nutritives. Among foliar analysis data, only P appears to be influenced somewhat by the fruit load.

Results presented on *Table 3* produced good arguments for the complexity of fertilization and nutritional status. In this complex effect of single factors is widely influenced by other averse factors and this competition leads to poor determination. In multiple regression analysis opposed factors may be separately evaluated on nutritional status, and therefore, one may understand more in the complex.

On *Table 4* soil lime content and soil fertilizers were computed in single and multiple regressions with foliar analysis data and yield. Influence of fruit load on nutrient contents of leaves was evaluated similarly.

The lime content of soil determined more in the variability of yields than that of the soil nutrients. Influence of fertilizers, drawn into multiple correlations with lime on yield remained smaller than our expectations. In estimations, where soil lime content together with yield were examined, determinations in variations of foliar nutrient contents increased. That was the case if yield were taken into multiple correlations with other soil nutrient factors, as well.

As far as influence of yield on nutritional status of trees was examined, its influence on leaf P content became obvious as a rule. As yields increased, P decreased in leaves, and this process was not balanced by high soil phosphorus contents.

The K content of soil was clearly represented in the foliage, however, relation of soil K to yields was not explained in linear regressions. In order to eliminate the estimations errors, due to use of linear regression on non-linear relations, we successfully applied polynomial regression analysis (data not shown).

Cluster analysis of data available resulted in 10 clusters of experimental plots. By the use of means indirect relations of potassium fertilization with foliar K content to yield and also to fruit storage ability are presented on *Figure 1, Figure 2 and Figure 3.*

Vide variation of K content of leaves was correlated to massive K fertilization of soil on a second degree polinom, that is, in fact, a sure sign of saturation. The due point for soil K might be somewhere at 250 mg/kg level, above which no significant increase in K content of leaves could have been achieved.

This saturation leads to much less determination in variability of yields *(Figure 2),* accounted for foliar K content. For acceptable yields a substantial rise in

foliar K content seems to be necessary, however, K contents above 1.5% dry weight had not correlated with further fruit load. The sharp rise in storage losses of fruits *(Figure 3),* harvested from trees of above 1.5% leaf K levels, focuses on the harmful effects of over fertilization.

Table 4 Effect of lime and soil nutritive content on nutritional status with and without involvement of yield (Multiple Determination Coefficients in per cent of variation of foliar analysis data and of yield)

Factor 1	Factor 2	Factor 3	N	P	K	Ca	Mg	Yield
$CaCO_3$%			0.1	2.4	6.7	6.1	3.2	8.4
$CaCO_3$%	P_2O_5 mg/kg		2.3	3.7	29.4	7.3	18.8	9.5
$CaCO_3$%	K_2O mg/kg		1.7	3.3	47.9	11.6	24.4	9.8
$CaCO_3$%	Yield kg/tree		3.0	9.0	6.8	6.4	9.0	
$CaCO_3$%	P_2O_5 mg/kg	K_2O mg/kg	2.4	3.7	48.2	12.1	25.6	9.9
$CaCO_3$%	P_2O_5 mg/kg	Yield kg/tree	4.6	9.8	29.5	7.8	27.0	
$CaCO_3$%	K_2O mg/kg	Yield kg/tree	4.1	9.5	48.2	12.4	33.3	
P_2O_5 mg/kg	K_2O mg/kg		2.0	1.9	45.5	4.6	24.5	2.7
P_2O_5 mg/kg	K_2O mg/kg	Yield kg/tree	3.8	9.4	45.5	7.1	31.4	

senescent disorders. As feeble storage quality of apples were well correlated with enhanced sink power of fruits (*Kállay* et al.,1987), it is very likely that harmful effect of over fertilization might be more possible if the actual fruit load is less than that the estimated cropping capacity of trees (*Szűcs & Kállay*, 1990). In other words, the fruit quality might be an acceptable index to determine levels of over fertilization in an indirect way.

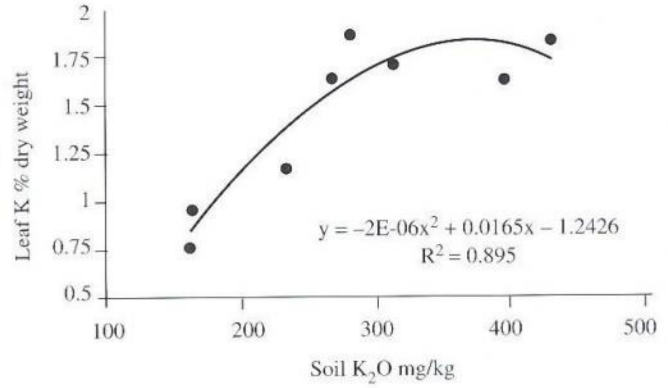

Figure 1 Relation of soil K – leaf K content of apple trees

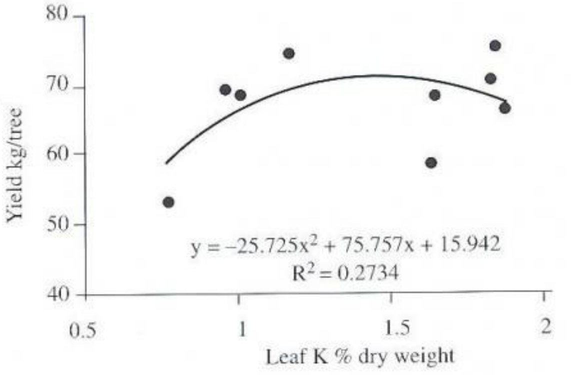

Figure 2 Relation of soil K content and yield of apple trees

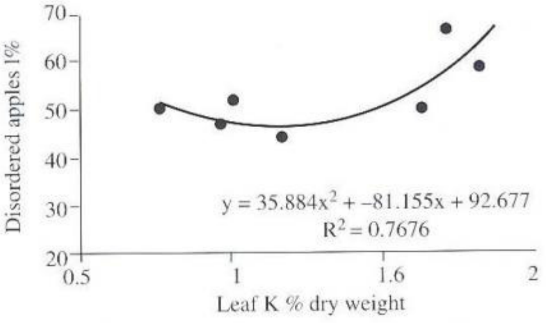

Figure 3 Leaf K content and strorage losses of apples

Discussion and conclusions

In fruit growing practice determination of adequate soil mineral content is of basic importance. Good utilization of fertilizers is often limited by other factors, like lime content, weather conditions, and growing methods. In our experiments the massive fertilization caused less increase in yields than that interest that factors limited the yields were not in storage losses. It may have some physiological likely to limit sensitivity of fruits for

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