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CHANGES IN CHEMICAL COMPOSITION OF LEAVES AND SHOOTS DURING VEGETATION OF APPLE-TREE ROOTSTOCKS IN MOTHER PLANTATION

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ABSTRACT

On the basis of analysis of leaves one can acquire information on the nutrition status of trees. In the course of the vegetation period changes take place in the level of various minerals in the leaves and shoots. Those changes are the result of processes taking place in the plant, and depend also on the weather conditions in a given year and on the level of yielding. Mother plantations, due to their specific nature (no yielding, strong vegetative growth), differ in the dynamics of uptake of macro-elements. The study was conducted during the period of 1998-2002, on production mother plantations of two apple-tree rootstocks with the greatest economic importance – M.9 and M.26. The chemical composition of leaves and shoots was analysed on three dates (in spring, summer and autumn). The highest content of nitrogen in leaves was noted at the start of vegetation, and the lowest after the termination of growth (end of September). Significant differences in the level of potassium in leaves were noted between June and August. The content of phosphorus in leaves decreased, as did that of magnesium, while the level of calcium increased during the vegetation season. Changes in the content of macro-elements in the shoots of rootstocks were smaller than in the leaves.

Key words: propagation of apple rootstocks, M.9, M.26, macroelements, period of vegetation.

INTRODUCTION

The condition for the achievement of high productivity of mother plantations of rootstocks is to provide the mother plants with optimum supply of nutrients. To meet this condition it is necessary to understand the nutrient requirements of the mother plants.

Estimation of the status of supply with minerals is currently conducted on the basis of analysis of leaves and soil, and of visual evaluation of the condition of plants [Sadowski et al., 1990, Nurzyński, 2003]. On the basis of analysis of leaves one can acquire information on the nutrition status of trees. Correct interpretation of the results obtained requires knowledge of the limit values of the content of minerals in leaves and in soil [Borys, 1979, Sadowski et al., 1990]. Until now no such limit values have been established for mother plantations of apple-tree rootstocks which differ in many respects from other stages of nursery production. Mother plants remain at the same site for over a dozen years and every year thousands of rooted layers are taken off, whereas the plants never bloom and never bear fruit. Determining the limit values for the content of minerals in leaves for apple-tree nurseries, Kłossowski and Czynczyk [1974] applied only one time of leaf sampling, i.e. the middle of August.

Therefore it appears worthwhile to undertake an attempt at determining the limit values and also to extend to time of leaf sampling for analyses with relation to mother plantations of apple-tree rootstocks. It is also worthwhile to analyse the chemical composition of layers obtained on a mother plantation, that constitute the starting material at further stages of nursery production.

The content of minerals in leaves is determined primarily by the kind of soil, fertilisation, rootstock, cultivar, and also by the time of taking samples for chemical analyses [Nurzyński et al. 1987].

Numerous authors studied the changes in the content of various minerals in leaves of fruit trees during the vegetation season. Bowersox and Ward [1977a, 1977b] as well as Vitanova and Prodanov [1979, 1980] decided that August was the period of the most stable level of minerals in leaves of cherry tree. Also Żelazo and Jadczuk [1994], studying the changes in the concentration of macro-elements in leaves of apple-tree, arrived at the conclusion that August was the best time for taking samples for analyses. According to Nurzyński [2003], leaves of apple, pear and plum trees should be taken for analyses in the period from mid-July to mid-August.

In the opinion of Treder and Olszewski [2004], the level of nitrogen in apple tree leaves is affected by the level of yielding which, at the same time, affects also the intensity of growth. No such effect can take place in mother plantations. Świerczyński et al. [2005], in turn, did not demonstrate any clear effect of foliar feeding on the content of macro-elements in leaves of apple-tree grafts growing in a nursery. As reported by Filipczak and Olszewski [2005], seasonal variations have a stronger effect on nitrogen content in leaves than foliar feeding with that element. Pacholak et al. [2004] point out that the content of available elements in soil was not correlated with the content of elements in leaves. Also Wrona [2004] did not demonstrate any significant effect of varied fertilisation on the level of nitrogen in leaves of apple trees cv. 'Jonagored' growing on various rootstocks. Whereas, Zydlik et al. [2011] demonstrated, in the case of cv. 'Topaz', that the site and the content of minerals in the soil have an effect on the mineral composition of leaves.

The objective of the study presented here was to investigate the changes taking place during the vegetation season in the chemical composition of leaves and shoots of apple-tree rootstocks M.9 and M.26 in a mother plantation.

MATERIAL AND METHOD

The study was conducted in the years 1998-2002, at private production nursery farms situated in the province of Lublin. The experiment comprised model mother plantations of two apple-tree rootstocks with the greatest economic importance - M.9 T337 and M.26. In the mother plantations the rootstocks were propagated through horizontal layering. The content of macro-elements in the soil was at an optimum level and high in terms of the limit values of apple-tree orchards [Sadowski et al. 1990]. The experiment was performed in the period of full use of the mother plantations, i.e. in the 4th-9th year from planting.

The analyses were made for leaves and shoots on three dates: date I (20th June), when the shoots were ca. 30 cm long, date II (20th August), i.e. in a period accepted as the optimum for analyses of the chemical composition of leaves of orchard plants, and date III (30th September), when the shots stopped growing but before the application of chemical defoliation which might have an effect on the chemical composition of the plant material being analysed. The material taken for analyses on each of the dates comprised 100 leaves from the central part of the shoots, and 30 shoots.

In the plant material the content of total nitrogen was assayed with the Kiejdahl method, content of potassium, magnesium and calcium with the ASA method using an atomic absorption spectrometer, and the content of phosphorus with the vanadium-molybdenum method, colorimetrically.

The climate conditions during the periods of the study are presented in Tables 1 and 2.

Table 1. Average monthly air temperatures (°C) during vegetative season in 19982002, according to Felin Meteorological Station University of Life Sciences in Lublin

Month	Many year averages of mean air temperature (1951 - 2000)	Year									
		1998		1999		2000		2001		2002	
		Temperature °C.	Variation	Temperature °C	Variation	Temperature °C	Variation	Temperature °C	Variation	Temperature °C	Variation
April	7.5	9.5	2.0	8.8	1.3	11.1	3.6	8.5	1.0	8.6	1.1
May	13.0	13.8	0.8	11.1	1.9	14.4	1.4	13.9	0.9	12.4	0.6
June	16.5	17.5	1.0	18.5	2.0	17.0	0.5	15.3	1.2	17.8	0.7
July	17.9	17.5	0.4	20.0	2.1	17.0	0.9	21.6	3.5	21.6	3.7
August	17.3	15.9	1.4	17.3	0.0	18.2	0.9	19.7	2.4	25.0	3.2
September	12.9	12.3	0.6	14.7	2.2	11.1	1.8	11.9	1.0	12.9	0.0
October	7.9	6.4	1.5	7.2	0.7	10.6	2.7	10.2	2.1	8.3	0.4
Mean IV-X	13.3	13.3	0.0	13.9	0.6	14.2	0.9	14.4	1.1	15.2	1.9

Table 2. Monthly sums (mm) of precipitation during vegetative season in 1998 2002, according to Felin Meteorological Station University of Life Sciences in Lublin

Month	Many year sums of precipitation (1951 -2000)	Year									
		1998		1999		2000		2001		2002	
		Precipitation mm	% of norm	Precipitation mm	% of norm	Precipitation mm	% of norm	Precipitation mm	% of norm	Precipitation mm	% of norm
April	40.6	63.9	157.4	81.6	201.0	68.0	167.5	64.9	160.0	18.3	45.1
May	58.3	49.6	85.1	45.9	78.7	50.7	87.0	19.9	34.1	28.6	49.1
June	65.8	61.5	93.5	160.9	244.5	36.4	55.3	47.6	72.3	116.8	177.
July	78.0	84.0	107.7	102.1	130.9	138.1	177.1	260.9	334.5	126.2	161.

August	69.7	100.8	144.6	33.5	48.1	28.3	40.6	67.5	96.8	18.7	26.8
September	52.1	59.7	114.6	37.6	72.2	66.7	128.0	125.8	241.5	42.5	81.6
October	40.3	62.6	155.3	34.9	86.6	2.2	5.5	19.3	47.9	92.9	230.
Mean IV-X	57.8	68.9	119.2	70.9	122.7	55.8	96.5	86.6	149.8	63.4	109.

The results were processed with the method of multiple-factor variance. The significance of the results was estimated with the Tukey test at confidence level of a= 0.05%.

RESULTS

The highest nitrogen content in the leaves and shoots was noted on the June date of analysis for rootstock M.9, and the lowest also for M.9, on the September date of analysis. Statistical analysis revealed significant differences in nitrogen content in leaves among the dates of analyses. A significant difference (0.16% in favour of rootstock M.26) in nitrogen content between the rootstocks was noted in September, also in August more nitrogen was assayed in leaves of rootstock M.26, whereas on the first sampling date leaves of M.9 were richer in nitrogen (by 0.13%) than those of M.26. The later the leaves were sampled the lower their content of nitrogen. A greater dynamics of the decrease was observed in leaves of rootstock M.9 (3.01 2.15%) compared to M.26 (2.88 2.31%) (Tab. 3).

Table 3. Content of nitrogen (N % d.m.) in the leaves and shoots in dependence on kind of date of measurement and rootstocks (1998-2002)

Date of measurement	Rootstock	Laeves	Mean for date of measurement	Shoots	Mean for date of measurement
20th June	M.9 M.26	3.01 d* 2.88 d	2.94 c	1.17 c 0.93 b	1.05 b
20th August	M.9 M.26	2.52 c 2.58 c	2.55 b	0.74 ab 0.66 a	0.71 a
30th September	M.9 M.26	2.15 a 2.31 b	2.23 a	0.65 a 0.70 a	0.67 a

***Means in the column in the row followed by the same letter are not significantly different at α = 0.05**

Like in the leaves, also in the shoots the highest content of nitrogen was shown in the June analyses (1.05%), and the lowest in September (0.67%). On the first two dates of analyses the shoots of rootstock M.9 had a higher nitrogen content, the advantage going to rootstock M.26 on the final date of analysis. Statistical analysis of mean values for both rootstocks confirmed a distinct decrease of nitrogen content in the shoots between June and August and September (Tab. 3).

Differences in phosphorus content in the leaves between the rootstocks were insignificant on each of the dates of analyses. The analyses of leaves revealed that the content of that element decreased in the course of the vegetation season. In spring its content, average for both rootstocks, was higher by 23.5% than in autumn and the differences were statistically significant (Tab. 4).

Table 4. Content of phosphorus (P % d.m.) in the leaves and shoots in dependence on kind of date of measurement and rootstocks (1998-2002)

Date of measurement	Rootstock	Laeves	Mean for date of measurement	Shoots	Mean for date of measurement
20th June	M.9 M.26	0.21 b* 0.21 b	0.21 c	0.14 b 0.12 ab	0.13 b
20th August	M.9 M.26	0.18 ab 0.19 ab	0.18 b	0.12 ab 0.09 a	0.10 a
30th September	M.9 M.26	0.18 ab 0.16 a	0.17 a	0.11 ab 0.09 a	0.10 a

*** For explantions, see Table 3.**

Analyses of the chemical composition of shoots revealed higher levels of phosphorus in the case of rootstock M.9 compared to M.26, on each of the dates. The shoots of the rootstocks had a lower content of phosphorus than the leaves, but the dynamics of changes was the same. Statistical analysis showed that in June the content of phosphorus in the shoots was significantly higher than on the other two dates of analyses. Dates two and three (average for both rootstocks) revealed the same level of phosphorus (0.10%).

The content of potassium in the leaves of the rootstocks (taken individually), sampled on the various dates, did not differ significantly, but as a mean for both rootstocks it displayed variation between June and August. The highest level of potassium in the leaves was noted in June (1,61%), in August its content was 1.48%, and at the end of September 1.54% (Tab. 5).

Table 5. Content of potassium (K % d.m.) in the leaves and shoots in dependence on kind of date of measurement and rootstocks (1998-2002)

Date of measurement	Rootstock	Laeves	Mean for date of measurement	Shoots	Mean for date of measurement
20th June	M.9 M.26	1.49 a* 1.74 a	1.61 b	0.92 c 0.87 c	0.88 c
20th August	M.9 M.26	1.51 a 1.44 a	1.48 a	0.63 ab 0.69 b	0.65 b
30th September	M.9 M.26	1.45 a 1.62 a	1.45 ab	0.51 a 0.55 ab	0.53 a

*** For explantions, see Table 3.**

Potassium content in the shoots of both rootstocks decreased over the vegetation season. This is observable in the mean values for the rootstocks, as well as the mean values for the dates within each of the rootstocks individually. Nearly all differences were significant. In September the content of potassium in the shoots was lower by 40% than in June.

The content of magnesium in leaves of rootstocks M.9 and M.26 decreased from 0.25% in June and 0.22% in August to 0.20% in September. The differences were statistically proven. On each of the dates of analysis, leaves of rootstock M.26 had a higher magnesium content than leaves of M.9 (Tab. 6).

Table 6. Content of magnesium (Mg % d.m.) in the leaves and shoots in dependence on kind of date of measurement and rootstocks (1998-2002)

Date of measurement	Rootstock	Laeves	Mean for date of measurement	Shoots	Mean for date of measurement
20th June	M.9 M.26	0.23 abc* 0.27 c	0.25 c	0.09 a 0.09 a	0.09 b
20th August	M.9 M.26	0.20 ab 0.25 bc	0.22 b	0.07 a 0.08 a	0.07 a
30th September	M.9 M.26	0.18 a 0.22 abc	0.20 a	0.07 a 0.07 a	0.07 a

*** For explantions, see Table 3.**

Magnesium content in the shoots (Tab. 6) of the rootstocks studied, as in the case of leaves, decreased in the course of the vegetation season. The difference in the level of magnesium between June and August and September was statistically proven, but when the two rootstocks were considered individually no differences were found between June and the other dates of analyses.

On each date of analysis the leaves of rootstock M.9 had a higher calcium content than those of M.26. The highest difference was noted in June (0.48%) and that difference was significant. In the leaves of rootstock M.26 an increase of calcium level was noted in August and September. The highest concentration of that element in the leaves of M.9 was found in August, and the other dates showed results similar to each other (Tab. 7).

Table 7. Content of calcium (Ca % d.m.) in the leaves and shoots in dependence on kind of date of measurement and rootstocks (1998-2002)

Date of measurement	Rootstock	Laeves	Mean for date of measurement	Shoots	Mean for date of measurement
20th June	M.9 M.26	1.02 b* 0.54 a	0.78 a	0.63 a 0.43 a	0.59 a
20th August	M.9 M.26	1.13 b 0.88 b	1.01 b	0.55 a 0.38 a	0.53 a
30th September	M.9 M.26	1.07 b 0.94 b	1.00 b	0.63 a 0.38 a	0.50 a

*** For explantions, see Table 3.**

A decreasing trend was noted in calcium concentration in the shots of both rootstocks (from 0.59 to 0.50%) over the vegetation season. In this case statistical analysis did not reveal any significant differences.

DISCUSSION

The content of nutrients in leaves is subject to variation during the vegetation season [Nurzyński et al., 1987, 1990, 2003, Żelazo and Jadczuk, 1994, Ugolik, 1995]. As reported by Nurzyński et al. [1990] and Żelazo and Jadczuk [1994] the contents of nitrogen, phosphorus, potassium and magnesium decrease at the end of the vegetation season, while that of calcium increases. The same regularity was observed in this study, and it was especially pronounced in the case of nitrogen, phosphorus and magnesium. Tagliavini et al. [1992] report that during vegetation the level of calcium and magnesium in leaves of apple trees increases, while that of nitrogen, potassium and phosphorus drops. In a study by Kumicki [1994] on changes in nitrogen content in leaves of one-year old grafts of apple trees a gradual decrease in the concentration of that element was observed during the vegetation season, and Lipecki [1995] noted a drop in nitrogen content in leaves of cv. 'Jonathan' during the period from the beginning of May till October. A decrease in nitrogen levels in leaves of several apple tree cultivars was noted also by Szwedo and Murawska [1999], the highest level being observed in June and the lowest in October. Wrona [2004] reports that the level of nitrogen in leaves of cv. 'Jonagored' decreased over the vegetation season irrespective of the rootstock.

In the experiment described here, the higher nitrogen level in the leaves and shoots of rootstock M.9 relative to M.26 can be attributed to the earlier start of vegetation by the former. Rootstock M.26 ends its vegetation late [Rejman et al., 2002], due to which it could have taken nitrogen up longer and hence the higher content of nitrogen in the leaves of that rootstock than in leaves of M.9 on the August and September dates of analyses, when nitrogen may have been already transported from the leaves of rootstock M.9 to the permanent plant parts. This is supported in research by Aguirre et al. [2001], in which leaves and shoots of rootstock M.9 T337 had lower levels of nitrogen than those of rootstock M.26, and the dynamics of decrease of nitrogen uptake in autumn was greater in the case of rootstock M.9.

During the period of the experiment, for both rootstocks studied, on the August date of analyses the contents of nitrogen, potassium, phosphorus and magnesium in the leaves were at levels defined by the limit values for apple trees [Sadowski et al. 1990] as optimum and high. Rootstock M.9 grows less rapidly than M.26, due to which the content of macro-elements in its leaves can be higher than in the case of rootstock M.26. This is indicated by the results obtained in this experiment, as well as by research of Tagliavini et al. [1992] who attribute the decrease in the levels of nitrogen, magnesium and calcium in leaves of faster-growing apple trees to the phenomenon of dilution.

As reported by Treder and Olszewski [2004], Domagała-Świętkiewicz [2006] and Wrona [2004], the weather conditions in a given year have a strong effect on the content of nitrogen in leaves of fruit trees. Also Pacholak et al. [2004] indicate that the climate conditions, and especially rainfall deficit and increased temperatures, cause a decrease in the levels of nitrogen, phosphorus and potassium in leaves, and an increase of the concentration of magnesium. During the five years of the experiment the distribution of temperatures and rainfalls during the vegetation seasons did not vary significantly (Tab. 1 and 2), therefore the effect of atmospheric conditions on changes in the levels of macro-elements can be excluded.

Comparison of the results obtained in numerous experiments concerned with plants in fruit tree nurseries is difficult, as rootstocks growing in a nursery are one-year old plants with a shallow root system precluding the uptake of nutrients from deeper layers of soil. The perennial mother plants of the rootstocks have that possibility.

The depth and architecture of plant root systems can also have an effect on the possibility of nutrients uptake, especially in periods of drought. As reported by Lipa [2010], the architecture and depth of the root systems of mother plants of rootstocks M.26 and M.9 do not differ significantly. The early spring nutrition of fruit trees is related with reserves of macro-elements accumulated in lignified parts of the plants during the preceding vegetation season [Aguirre et al., 2001, Tagliavini and Miliard, 2005]. Such reserves are not stored by mother plants, as the whole aboveground part is taken off with the layers. Therefore the high requirements for nutrients in spring (at the start) may justify the application of high doses of fertilisers.

CONCLUSIONS

1. The results obtained demonstrated the occurrence of changes in the chemical composition of leaves over the vegetation season. That regularity was noted in both clones of the rootstocks under study.
2. During vegetation a decrease was observed in the levels of nitrogen, phosphorus, potassium and magnesium, and an increase in the concentration of calcium in leaves and a constant level of that element in shoots.
3. The changes in the contents of macro-elements in the shoots of the rootstocks were smaller than those in the leaves.
4. Towards the end of the vegetation season, on the second and third dates of analyses, the changes in the levels of macro-elements in the shoots were not statistically significant, with the exception of potassium.

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Responses to this article, comments are invited and should be submitted within three months of the publication of the article. If accepted for publication, they will be published in the chapter headed 'Discussions' and hyperlinked to the article.
