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APPLE TREES FERTILIZATION AND ITS INFLUENCE ON THE POTASSIUM CONTENT IN SOIL AND PLANTS IN CORRELATION WITH CALCIUM AND MAGNESIUM ABSORTION

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Abstract

The paper presents how the soil fertilization with NPK in different doses and combined with two types of foliar fertilizers, applied to an apple tree orchard, changes the potassium content in soil and leaves. For a better understanding of the results, chemical analysis of the leaves and of the soil at two depths: 0-20cm and 20-40cm were chemically performed. The study was carried out in an apple orchard, located in the Didactic Farm "V. Adamachi" that belongs to the University of Life Sciences from Iasi (IULS), Romania. Results shows that fertilizers applied in the soil had a positive influence, increasing the soil content of potassium closer to the optimal range: 200-300 ppm. However, the content of potassium in the apple tree leaves stays low and below the optimum condition. The control (no fertilizers applied) had the lowest content for Kt (0.99%) in the leaves. Studying the content of calcium (mean – 1.65%) and magnesium (mean - 0.74%) in the dry matter of the leaves we see that there are not significant differences between the fertilization variants. Their values exceed the optimal limits.

Key words: *apple orchard, dry matter, foliar fertilizers, optimal content of potassium, NPK.*

INTRODUCTION

Potassium is a nutrient with major importance in the biochemical processes that take place in the plant: protein synthesis, lignin formation, transport and storage of carbohydrates imprinting resistance to drought, diseases and pests (Cheng, 2013; Malvi, 2011).

Potassium is the most abundant cation in the plant cell.

The harvests are directly dependent on the presence in the soil in optimal quantities but also in the plants, where it directly influences both the quantity and especially the quality of the production (Papp et al., 2004). The use of different potassium fertilizers and different doses in a Golden Delicious' orchard did not determine the increase of the yield, but its quality (Szewczuk et al., 2008).

Its action in the soil and plant cannot be understood as a stand-alone one, but its evolution in both environments is directly related to nitrogen and phosphorus, with which it achieves high and stable productions.

Increasing the concentration of some ions can lead to the blocking of others or reduce their absorption by plants, thus the application of potassium fertilizers caused a decrease of foliar nitrogen (Holb et al., 2009).

In the soil, potassium is important especially through its accessible fraction to plants, which represents approximate 1% of the total soil potassium. Specific to this form is the fact that it can undergo, in specific soil conditions, by decreasing the content accessible to plant nutrition. Suboptimal concentrations of potassium in the soil will force the plants to absorb it against the electrochemical ingredient (Ragel et al., 2019). The harvests are at high levels, when potassium represents more than 5% of the amount of exchangeable bases (Davidescu & Davidescu, 1999).

The texture, the pH, the buffering capacity of the soil, as well as the alternation of dry and wet periods, determine the change of potassium into fixed forms and therefore inaccessible to plants. Soil acidification leads to a decrease in potassium in the leaves with negative effects on fruit quality (color, sugar content) (Raese, 1995) while Fazio et al. (2012) noted that the accessibility of calcium, phosphorus and molybdenum increases with increasing pH, while the absorption of zinc, magnesium and potassium is not influenced by pH. In the same register, Malvi (2011) said that high pH soils negatively affected potassium absorption, which will aggravate the K/Mg antagonism.

This study was undertaken to improve apple nutrition with potassium on calcareous soil through minimal soil fertilization completed with foliar fertilizers with macro and microelements. The second aim was to increase the concentration of available potassium in the soil. During the three years of experiencing, observations were made on the evolution of the potassium content in the soil, the accumulation of potassium, calcium and magnesium in the plant.

MATERIALS AND METHODS

Location and experimetal design

The study was conducted for three years (2019-2021) in the Didactic Farm V. Adamachi of IULS, Iaşi County, in an apple tree orchard, Idared variety, grafted on MM-106 rootstock, spacing between trees is 4 x 4 m. Orchard soil type is aric cambic chernozem, rich in calcium. Prior setting the experiment, the activity of hydrogen ions from a soil sample is measured potentiometric, in aqueous suspension (1:2.5): the pH value is 8 for 0-20 cm and 8.3 for the 21-66 cm depth. For the same depths, through Scheibler method, was determined $CaCO_3$ (%) in soil: 4.8% (0-20 cm) - 7.8% (21-66 cm), and Ca^{2+} (13.3%-16%), Mg^{2+} (0.45%-0.62%) analyzed with atomic absorption spectrophotometry method

Fertilizing treatments were randomized within one block; groups of three trees; in three replications. In the experience were studied 9 variants of fertilization with mineral and foliar fertilizers, including the control: V1 - Control variant - no fertilizers; V2 - NPK 15.15.15 - 180kg ha^{-1} active ingredient, V3 - NPK 15:15:15 - 270kg ha^{-1} active ingredient, V4 - Pentakeep, V5 - Cropmax, V6 - V2+Pentakeep, V7 - V3+Pentakeep, V8 - V2+Cropmax, V9 - V3+Cropmax.

An NPK complex fertilizer, with 15:15:15 NPK ratio was used for soil fertilization, at a dosage of 180 kg ha^{-1} and 270 kg ha^{-1} active ingredient. Cropmax fertilizer was included in the experiment being a bio-stimulant compatible with organic farming, rich in nutritive elements, amino acids and vitamins, recommended for the efficiency of mineral fertilization. Cropmax has 0.2% N, 0.17% P, 0.017% K, 0.001% Ca, 0.033% Mg and microelements. Pentakeep Super fertilizer contain: 16% N, 2.18% P, 2.49% K, 0% Ca, 1.8% Mg, microelements and 5-aminolevulinic acid, with a much more concentrated composition in nutritious elements applied on trees foliage, recommended as well to complete mineral fertilization.

The mineral fertilization with NPK 15:15:15 was applied and incorporated in the topsoil, 1/3 in autumn and 2/3 in early spring. Foliar fertilizers (Pentakeep - 2 L/ha and Cropmax - 4 L/ha) were sprayed three times, received when the fruit was 5 mm in diameter, and every two weeks after. The spraying of the trees was carried out using the atomizer with fine spraying.

Sampling and Analysis

Annually, four soil samples were taken from each plot at the beginning of the vegetation period, before fertilization, from the upper 0-20 cm layer and 20-40 cm by using manual sampling equipment. The samples were brought to the laboratory, air-dried, grounded, passed through a 2 mm sieve, homogenized and stored in boxes until the chemical analyzes were performed.

Available potassium content in soil (K-AL) has been determined by treating the soil sample with ammonium lactate acetate (AL), pH - 3.7 (Egner-Riehm-Domingo method), precipitation of calcium from the solution with oxalic acid (10%). Potassium was quantified by the flame-photometry method.

Leaves were harvested from each tree were the soil samples were taken, in middle of July, from the middle part of the annual shoots. The plant samples were washed with distilled water, buffered with filter paper and dried at ambient temperature, after which they were ground and stored in glass jars.

Total potassium content in leaves (Kt) was determined by mineralizing the sample with sulfuric and hydrochloric acid followed by flame photometry dosage of the solution. Calcium and magnesium content in leaves was determined through atomic absorption spectrophotometry method (AAS). For AAS, plant samples were calcined until whitish ash

and solubilized with 5 ml of hydrochloric acid (25%).
Statistical analysis was performed over the results using analysis of variance (ANOVA). Significant differences between means were identified using the least significant difference (LSD) test.

RESULTS AND DISCUSSIONS

In order to maintain and sustain soil fertility in potassium it’s recommended to follow other indicators, as: calcium and magnesium content and ratio between Ca, Mg and K. Buffer capacity of the soil is another indicator that influence the availability of the potassium in soil, knowing that there is a good correlation related to the soil properties and clay content (Shanker & Seth, 2018).

Soil fertilization and combined fertilization variants record increases in mobile potassium content for both depths. For the depth of 0-20 cm, the values are 214.1-239.8 ppm K-AL, values that fall within the state of optimal provision of the soil with potassium, compared to the depth of 20-40 cm where the values (128.5-172.3 ppm K-AL) show poor potassium supply for apple crops (Table 1)
As expected, the K-AL content for the exclusively foliar fertilization variants show insignificant differences compared to the control. The optimal values of the mobile potassium content in the soil for apple orchards are 200-300 ppm (Lăcătușu, 2016), and the K-AL in this study lies in the optimal range only in the 0-20 cm layer.

Table 1. Fertilization influence on potassium content (K-AL, ppm) in soil (three years mean)

Variants	K-AL ppm (0-20 cm)	Mean difference	K-AL ppm (20-40 cm)	Mean difference
V1 - Control	167.2	-	124.2	-
V2- 180 kg ha^{-1} NPK	214.1	46.9	157.9	33.7
V3 - 270 kg ha^{-1} NPK	223.6	62.4	164.5	40.3
V4 - Pentakeep	176.0	8.8	128.5	4.3
V5 - Cropmax	170.9	3.7	128.5	4.3
V6 - V2+Pentakeep	230.3	63.1	165.7	41.5
V7 - V3+Pentakeep	237.4	70.2	172.3	48.1
V8 - V2+Cropmax	227.8	60.6	158.2	34.0
V9 - V3+Cropmax	239.8	72.6	167.1	42.9
	*LSD 5%	41.16	*LSD 5%	24.00
	**LSD 1%	49.86	** LSD 1 %	28.41
	***LSD 0.1%	59.22	***LSD 0.1%	33.78

LSD - least significant difference

Foliar analysis for potassium, in apple leaves, highlighted a series of aspects related to the level of Kt % in plants, correlated with its content in the soil, strongly depended on the fertilization variants. Potassium content in apple leaves in July could be sorted into the low to medium potassium supply for all fertilization variants. The exclusively foliar fertilized variants raise leaves content in potassium to 1.01% Kt when using Cropmax and 1.11% Kt when using Pentakeep, statistically insignificant increases in potassium content.
During the period of vegetation, the nutrients content varies in apple leaves (Mengel & Kirkby, 2001). The analyses should be performed in early stage in order to determine tree nutrition disorders. It is difficult to adjust its deficiency or excess in the late growing cycle (Uçgun & Gezgin, 2017).
The researches carried out on the dynamics of potassium absorption and its content in apple leaves, shows that potassium concentration in leaves, in July, states in the low range (Papp et al., 2004), even the K-AL content in soil has increased over the experimental years. Similar values have been noted in an organic apple orchard in Hungary (Nagy & Holb, 2006).
The variant with the highest total potassium content is V7, with 1.35% Kt, which means an optimal supply, with a statistically very significant difference compared to the control. Thus, the total potassium (Kt) in plants, recorded for this fertilization option, correlates

with the mobile potassium (K-AL) content in the soil. It results that root fertilization in maximum NPK doses combined with foliar Pentakeep determines a normal active absorption of potassium (Table 2).

Table 2. Influence of differentiated fertilization on total potassium content in apple leaves (Kt, %)

Variants	Kt (%)	Percentage increase	Mean difference	Coefficient of Variation, %
V1 - Control	0.99	100	-	6.20
V2	1.19	120.2	0.20	13.40
V3	1.26	127.3	0.27	12.52
V4	1.11	109.4	0.12	9.56
V5	1.01	104.4	0.02	3.59
V6	1.19	120.2	0.20	11.04
V7	1.35	136.7	0.36	17.27
V8	1.17	118.5	0.18	20.18
V9	1.26	127.3	0.27	12.34

*LSD 5% - 0.20; **LSD 1% - 0.27; ***LSD 0.1% - 0.32

Increasing the concentration of potassium in soil leads to optimal accumulation of it in the plant (Kuzin & Solovchenko, 2021). Among the potassium content in the soil, at 20-40 cm depth, and the total potassium determined in the apple leaves, a positive relationship was identified; 88.04% of the variation in total potassium content in plant can be attributed to the variation of the accessible potassium in soil (Figure 1).

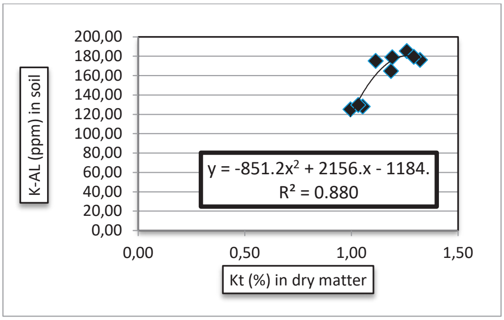

Figure 1. Dependence relationship between the available potassium in soil and total potassium in leaves

Calcium imprints the firmness of the fruit pulp, neutralizes organic acids, stimulates the formation of absorbent bristles on the root, favors the processes of fruit formation and ripening (Davidescu & Davidescu, 1999).
Regarding the calcium content in the apple leaves, it records values between 1.55 - 1.75%, that express an excessive state of insurance with this element (Lăcătușu, 2016) (Table 3).
The statistical analysis shows that increases/decreases of this element in plant tissue are not significant and not in direct relation with the fertilization options. The concentration of this element is determined by the high content of calcium carbonate in the soil (7.8% $CaCO_3$).

Table 3. The influence of fertilization on calcium accumulation (Ca, %) in leaves (three years mean)

Variants	Ca (%) Mean ± SD	Mean difference	Coefficient of Variation, %
V1 - Control	1.62 ± 0.16	0	9.62
V2	1.60 ±0.09	-0.021	5.70
V3	1.65 ±0.17	0.030	10.23
V4	1.65 ± 0.09	0.030	5.71
V5	1.55 ±0.33	-0.072	21.33
V6	1.58 ± 0.21	-0.041	13.30
V7	1.68 ± 0.21	0.060	12.59
V8	1.75 ± 0.14	0.130	8.13
V9	1.74 ± 0.13	0.120	7.55

*LSD 5% - 0.127;**LSD 1% - 0.132;***LSD 0.1% - 0.138

The analyses determined that calcium content in dry matter is optimal in this study, and for some variants of fertilization Ca recorded a high state of insurance of the trees. In an experiment Dilmaghani et al. (2004) noticed a range of potassium and calcium content in leaves that exceeded their critical limit values, even so the calcium concentration was low in fruits, due to its low mobility.
Magnesium has a major role in photosynthesis and is contained in tissues at values denoting a high state of supply, 0.70-0.83% (Davidescu & Davidescu, 1999). Although there are many studies on magnesium deficiency of apple trees, there is no information on the effect of high magnesium content.
Through fertilization with Pentakeep, the apple trees benefited of an intake of magnesium. Very significant increases were recorded for the fertilization variants V7 and for the exclusive fertilization with Pentakeep. For the rest of the fertilization options, the increases were insignificant (Table 4).
It is known that a high content of potassium in the soil can cause a decrease in the absorption of magnesium, resulting in a decrease in the

concentration of Mg in leaves. It has not been proven, in all cases, that a high concentration of this element in the soil can cause a decrease in potassium intake.

Table 4. The influence of fertilization on magnesium accumulation (Mg, %) in leaves (three years mean)

Variants	Mg (%) Mean ± SD	Mean difference	Coefficient of Variation, %
V1 - Control	0.70 ± 0.05	-	7.03
V2	0.72 ± 0.07	0.02	9.57
V3	0.77 ± 0.05	0.07	5.93
V4	0.83 ± 0.03	0.13	3.43
V5	0.70 ± 0.05	0	6.79
V6	0.75 ± 0.08	0.05	10.13
V7	0.82 ± 0.04	0.12	5.32
V8	0.72 ± 0.07	0.02	10.30
V9	0.66 ± 0.07	-0.04	10.41

*LSD 5% - 0.09;**LSD 1% - 0.10; ***LSD 0.1% - 0.12

K/Ca, K/Mg and Ca/Mg are indicators that refers to antagonism relationships between these cations and are a better expression of the nutrition state of the plants. In this study the K/Ca ratio has values between 0.61-0.80, K/Mg ratio has values between 1.34-1.91 and Ca/Mg ratio has values between 1.99-2.64 (Table 5). These ratios have under - optimal values compared to other studies, where K/Ca = 0.87, K/Mg = 3.9-6.0 and Ca/Mg = 4.55 (Füleky, 1999) due to the low content of potassium in leaves. It is recommended to use foliar fertilization in order to achieve optimal calcium in fruits (Mengel, 2002).

Table 5. Ratios of potassium, calcium and magnesium in apple leaves (three years mean)

Variants	K/Ca	K/Mg	Ca/Mg
V1 - Control	0.61	1.41	2.31
V2	0.74	1.65	2.22
V3	0.76	1.64	2.14
V4	0.67	1.34	1.99
V5	0.65	1.44	2.21
V6	0.75	1.59	2.11
V7	0.80	1.63	2.02
V8	0.67	1.63	2.43
V9	0.72	1.91	2.64

CONCLUSIONS

Soil fertilization causes significant increases in the potassium content of the soil.

The concentration of potassium in the plant recorded increases for all fertilization options, there is a positive correlation between the increase of the accessible potassium content in the soil and the increase in its content in the leaves.

The accumulation of calcium in plants is not influenced by the application of fertilizers, but is attributed to the high concentration of $CaCO_3$ in the soil. Its values denote good insurance with this element.

Fertilization with Pentakeep causes significant increases of magnesium content in apple leaves. All experimental variants have a high magnesium content that lies in the high state of insurance for apple trees. All three cations play a major role in obtaining high quality fruit.

REFERENCES

Cheng, L. (2013). Optimizing Nitrogen and Potassium Management to Foster Apple Tree Growth and Cropping Without Getting ‘Burned’. *NYFQ*, 21, 21–24.

Davidescu D., & Davidescu Velicica (1999). *Agrochemical Compendium* (in Romanian). Bucharest: Romanian Academy Publishing House.

Dilmaghani M.R., Malakouti M.J., Neilsen D., & Fallahi E. (2004). Interactive effects of potassium and calcium on K/Ca ratio and its consequences on apple fruit quality in calcareous soils of Iran, *Journal of Plant Nutrition,* Vol. 27(7), p. 1149-1162.

Fazio, G. Kviklis, D. Grusak, M.A. & Robinson, T. (2012). Soil pH, Soil Type and Replant Disease Affect Growth and Nutrient Absorption of Apple Rootstock. NYFQ, 20, 22–29.

Füleky, Gy. (1999). Nutrient Management, Mezőgazda Publishing House, Budapest.

Holb, I.J., Conda, I., & Vágó, I. (2009). Seasonal Dynamics of Nitrogen, Phosphorus, and Potassium Contents of Leaf and Soil in Environmental Friendly Apple Orchards. *Commun. Soil Sci. Plant* Anal., 40, 694–705.

Kuzin, A., & Solovchenko, A. (2021). Essential Role of Potassium in Apple and Its Implications for Management of Orchard Fertilization. *Plants*, *10*, 2624.

Lăcătușu, R. (2016). *Agrochemistry* (In Romanian). Iasi: RO Terra Nostra Publishing House.

Malvi, U. (2011). Interaction of micronutrients with major nutrients with special reference to K. Karnataka, *J. Agric. Sci*., 24, 106–109.

Mengel, K. (2002). Alternative or complementary role of foliar supply in mineral nutrition. *Acta Horticulturae*, Vol. 594, p. 33–47.

Mengel, K., & Kirkby E. A. (2001) - Principles of plant nutrition. 5.ed. Dordrecht: Kluwer Academic Publishers, 849p.

Nagy, P.T., & Holb I.J. (2006). Study on the macronutrient content of apple leaves in an organic apple orchard, *Journal of Central European Agriculture,* Vol.2, p. 329-336.

Neilsen, G.H., & Neilsen, D. (2011). Consequences of K, magnesium sulphate fertilization of high density Fuji apple orchards. Can. *J. Soil* Sci., 91, 1013–1027.

Papp, J., Nyéki, J., & Soltész, M. (2004). Fruit production and research in Hungary - An overview. *International Journal of Horticultural Science*, 10(4), 7–11. https://doi.org/10.31421/IJHS/10/4/499

Raese, J.T. (1995). Effect of low soil pH from different fertilisers on performance of apple and pear trees. In Plant-Soil Interactions at Low pH: Principles and Management. Developments in Plant and Soil Sciences; Date, R.A., Grundon, N.J., Rayment, G.E., Probert, M.E., Eds.; Springer: Dordrecht, Germany; Volume 64, pp. 803–807.

Ragel, P., Raddatz, N., Leidi, E.O., Quintero, F.J., & Pardo, J.M. (2019). Regulation of K^+ Nutrition in Plants. *Front. Plant* Sci., 10, 281

Shanker M., & Seth A. (2018). Potassium availability in soils and the use of the Q/I approach - moving from theory to nation-wide realization, *20th EGU General Assembly*, EGU2018, p.9716

Szewczuk, A., Komosa, A., & Gudarowska, E. (2008). Effect of soil potassium levels and different potassium fertilizer forms on yield and storability of 'Golden delicious' apples. *Acta Sci. Pol. Hortorum Cultus*, 7, 53–59.

Uçgun, K., & Gezgin, S. (2017). Interpretation of Leaf Analysis Performed in Early Vegetation in Apple Orchards*, Communications in Soil Science and Plant Analysis*, 48:14, 1719-1725

Zavalloni, C., Marangoni, B., Tagliavini, M., & Scudellari, D. (2001). Dynamics of Uptake of Calcium, K and Magnesium into Apple Fruit in a High Density Planting. *Acta Hortic*., 564, 113–121.

Zhang, F., Niu, J., Zhang, W., Chen, X., Li, C., Yuan, L., & Xie, J. (2010). K nutrition of crops under varied regimes of nitrogen supply. *Plant Soil.* 335, 21