SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua

Scientific Horizons, 24(2), 93-98

UDC 634.11:631.8

DOI: 10.48077/scihor.24(2).2021.93-98

THE CONTENT OF CHLOROPHYLL AND NUTRIENTS IN APPLE LEAVES DEPENDING ON LONG-TERM FERTILISER

Roman Yakovenko[1], Petro Kopytko[1], Vadym Pelekhatyi[2]*

[1]Uman National University of Horticulture

20305, 1 Instytutska Str., Uman, Ukraine

[2]Polissia National University

10008, 7 Staryi Blvd., Zhytomyr, Ukraine

Article's History:

Received: 30.04.2021

Revised: 20.05.2021

Accepted: 19.06.2021

Suggested Citation:

Yakovenko, R., Kopytko, P., & Pelekhatyi, V. (2021). The content of chlorophyll and nutrients in apple leaves depending on long-term fertiliser. *Scientific Horizons*, 24(2), 93-98.

Abstract. An indicator of the condition of plants, depending on the growing conditions, is the state of their leaf apparatus, which is described by the content of chlorophyll and nutrients in the leaf. The leaf of an apple-tree provides synthesis of organic substances, productivity of fruit trees depends on features of its vital activity. As a method of diagnosing the mineral nutrition of fruit crops, the chemical analysis of the leaves is important, the indicators of which reflect the levels of plant nutrients. The results of studies of chlorophyll content and nutrients in the leaves of apple trees of Calville Blanc d'hiver on seed and Idared on seed and vegetative M4 rootstocks in re-grown plantations on mineral nutrition, created by long-term (over 86 years) application of various systems of comfort podzolized soil. Long-term use of organic and organo-mineral fertiliser systems contributed to an increase in chlorophyll content (*a+b*) in the leaves of Idared apple trees on seed and clone M4 rootstocks and Calville Blanc d'hiver on seed rootstock at different age periods of growth and fructification, which conditioned their further productivity. The content of macronutrients in the leaves of the studied cultivar combinations depended on the age of plantations and fertiliser options. In the most productive period of fructification in the leaves of Idared trees on seed and vegetative rootstocks, the nitrogen content in the areas of fertiliser options was within optimal limits. Among the studied rootstocks in the variant without fertilisers, the highest nitrogen content in the leaves was described by trees on the seed rootstock. In the leaf of the Calville Blanc d'hiver variety, the nitrogen content on the seed rootstocks in the studied variants was within the optimal range, and among the fertiliser variants the highest was for the application of mineral fertilisers. The content of phosphorus and potassium in the leaves of the trees of the studied rootstock combinations in the areas of fertiliser variants was within optimal limits

Keywords: Calville Blanc d'hiver, Idared, leaf, soil fertiliser, green pigments, age periods of fructification

*Corresponding author

INTRODUCTION

The chemical composition of the vegetative organs of a plant reproduces the conditions of its nutrition, and its quantitative and qualitative features are crucial for plants to pass the corresponding phases of vegetation [1]. An indicator of the state of plants, depending on the growing conditions, is the state of their leaf apparatus, which is characterised by the content of chlorophyll and nutrients in the leaf. The apple leaf provides the synthesis of organic substances, and the productivity of fruit trees depends on the characteristics of its vital activity [2-4].

The pigmental system of leaves is one of the most important indicators of photosynthetic activity of plants. Its main components are green pigments – chlorophylls "*a*" and "*b*". Their accumulation in leaves, as well as in the entire plant, further affects the synthesis of biomass and, accordingly, the formation of tree harvest [5; 6]. In the studies [7; 8] on determining the content of chlorophyll in apple leaves, it was established that its concentration depends both on the cultivar, rootstock, period of determination, and on the conditions and level of mineral nutrition of fruit plants. It was also found that with a decrease in the rootstock spread, the chlorophyll content in the leaves of apple trees decreases [9].

Chemical analysis of leaves is important as a method for diagnosing mineral nutrition of fruit crops, the indicators of which reflect the levels of mineral nutrition elements in plants. Using this method, one can determine the excess of fertilisers applied, as well as their digestibility by trees. The content of the main elements of mineral nutrition in the organs of fruit trees depends on the cultivar, rootstock, age of plantings, load of trees with fruits [2; 10-12]. Optimal levels of content indicators of N, P_2O_5 and K_2O in the leaves of apple trees are, respectively, 1.8-2.5, 0.13-0.29, and 0.9-1.8% [13; 14].

Studies of the impact of long-term (since 1931) application of various fertiliser systems on the chemical composition of apple tree leaves that are re-grown on the site of an uprooted orchard are relevant. The passage of physiological processes in leaves has a significant connection with the accumulation of plant mass, so they play a leading role in the formation of the expected and future (laying generative formations) harvest. A decrease in the content of chlorophyll in the leaves negatively affects the condition of the plant, leads to a weakening of the shoots' growth. Enriched mineral nutrition backgrounds formed from long-term fertilisation have different effects on the physiological state and overall productivity of plantings. No studies were conducted on the content of pigments (the sum of chlorophylls "*a*" and "*b*") and nutrients (N, P_2O_5, and K_2O) in leaves during the age periods of growth and fructification of apple trees of various cultivar-rootstock combinations, depending on the long-term use of organic, organo-mineral, and mineral fertiliser systems. The experiment in which the research was conducted is a scientific object that is a national heritage "A unique research agroecosystem of the apple orchard of the Uman National Horticultural University".

The purpose of the study was to establish the effect of long-term fertiliser on the content of chlorophyll and nutrients in the leaves when re-growing apple trees of various cultivar-rootstock combinations.

MATERIALS AND METHODS

To study this question, the authors of the paper conducted research in a long-term experiment with various apple orchard fertiliser systems at Uman National University on dark gray podzolised soil with a humus content in layers of 0-20 and 20-40 cm, respectively, 2.41 and 2.23%, nitrogen (by nitrification capacity with 14-day composting) – 13.4 and 12.9 mg/kg of soil, P_2O_5 and K_2O (according to the Egner – Riem – Domingo method) 18.4 and 14.6, 28.9 and 27.4 mg/100 g of soil, pH – 5.2 and 5.3, the sum of the absorbed bases – 25.0 and 26.0 mg-eq/100 g of soil.

The experiment was founded by Professor S.S. Rubin in 1931. It was carried out over a 50-year period, after which it was reconstructed by uprooting old trees in 1982 and planting new ones in 1984, while preserving the previous variants and plots with the studied fertiliser systems, on which apple cultivars Idared and Calville Blanc d'hiver were planted on the seed rootstock and Idared on the vegetative M4 with a feeding area of 7x5 m. The scheme of long-term research included four options: without fertilisers (control), $N_{120}P_{120}K_{120}$, Manure 40 t/ha, 20 t/ha of manure + $N_{60}P_{60}K_{60}$.

During the research period, manure and phosphorous and potash mineral fertilisers were applied in the specified doses every other year in autumn while plowing the soil in row spacing, nitrogen – annually in spring while cultivating in half the norms. The soil in the experimental orchard was kept by a steam system. The content of chlorophyll in the leaves was determined by spectrometric method with extraction with ethanol, and elements of mineral nutrition – with wet combustion [15].

RESULTS AND DISCUSSION

Research data (Table 1) indicate that long-term fertilisation systems of apple plantations had different effects on the content of pigments in the leaves. During the period of growth and fructification (1994-1997), the amount of chlorophyll (*a*+*b*) in the leaves of the Idared apple tree on seed and clone M4 rootstocks was the highest in the variant with organic fertilisers, respectively, 283.0 and 269.6 mg/100 g of raw weight.

***Table 1**. The effect of rootstocks and fertiliser on the content of the sum of chlorophylls (a+b) in the leaves of the Idared apple tree, mg/100 g of raw weight*

Rootstock	Fertiliser variant	Indicators in different age periods of fructification		
		Growth and fructification period, 1990-1996	Fructification and growth period, 1997-2003	Fructification period, 2004-2016
Seed	Without fertilisers (control)	230.6	159.2	143.7
	Manure 40 t/ha	283.0	163.3	150.1
	20 t/ha of manure + N_{60} P_{60} K_{60}	266.4	174.5	152.0
	N_{120} P_{120} K_{120}	260.7	172.5	149.3
Clone M4	Without fertilisers (control)	228.5	155.1	140.7
	Manure 40 t/ha	269.6	160.5	152.1
	20 t/ha of manure + N_{60} P_{60} K_{60}	257.0	168.3	151.8
	N_{120} P_{120} K_{120}	250.7	165.7	150.1
	HIP_{05}	*10.3*	*6.1*	*5.9*

The period of fructification and growth (1997-2003) was characterised by a decrease in the amount of chlorophylls in all experimental variants, and the highest content was with organo-mineral fertiliser. During the period of full fructification of trees, the content of the sum of chlorophylls (*a+b*) significantly decreased compared to previous periods, and among the studied variants, it was the highest in the variant with the introduction of organo-mineral (152.0 mg/100 g), and on Clone M4 – in areas with the application of organic fertilisers (152.1 mg/100 g). Analysing the data on the amount of chlorophylls in the areas of the control variant (without fertilisers), there is a greater accumulation of chlorophyll in the leaves of trees on the seed rootstock compared to the vegetative one.

Analysing the data on the amount of chlorophylls in the variant without fertilisers, it can be noted that trees on the seed rootstock were distinguished by a significantly higher accumulation of chlorophyll in the leaves. In the leaves of the Calville Blanc d'hiver cultivar during growth and fructification, significantly more accumulation of the amount of chlorophylls was observed in the variant with organic fertilisers (255.2 mg/100 g) compared to other variants (Table 2). The introduction of organo-mineral fertilisers contributed to a greater accumulation of the amount of chlorophylls (*a+b*) in the leaves during fructification and growth and fructification. A significant excess of the indicator was noted only with the control.

***Table 2**. The content of the sum of chlorophylls (a+b) in the leaves of Calville Blanc d'hiver apple trees on the seed rootstock, depending on fertiliser mg/100 g of raw weight*

Fertiliser variant	Indicators in different age periods of fructification		
	Growth and fructification period, 1990-1996	Fructification and growth period, 1997-2003	Fructification period, 2004-2016
Without fertiliser (control)	234.9	141.7	140.5
Manure 40 t/ha	255.2	170.0	147.3
20 t/ha of manure + N_{60} P_{60} K_{60}	235.4	175.0	151.7
N_{120} P_{120} K_{120}	236.7	167.6	148.1
HIP_{05}	*11.4*	*7.2*	*5.1*

In the experiment, along with studying the content of pigments, the chemical composition of apple leaves was also studied depending on the fertiliser systems. The level of basic nutrients in trees plays an important role in the formation of the current year's harvest, and even more in the laying and differentiation of fruit formations for the next year's harvest, especially nitrogen. As the research results showed (Table 3), apple

leaves contained different amounts of nitrogen, phosphorus, and potassium in the fertilised areas of the experiment with fertiliser systems. The highest nitrogen content during the growth and fructification period of trees (1994-1996) was identified in the leaves of the Idared apple tree on both types of rootstocks in the version with half the norms of manure and full mineral fertiliser.

***Table 3**. The content of nutrients in the leaves of Idared apple trees depending on rootstocks and fertiliser in repeated cultivation, %*

Rootstock	Fertiliser variant	Indicators in different age periods of fructification								
		Growth and fructification period, 1990-1996			Fructification and growth period, 1997-2003			Fructification period, 2004-2016		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Seed	Without fertiliser (control)	2.72	0.35	1.74	2.06	0.40	1.28	2.22	0.17	0.98
	Manure 40 t/ha	2.89	0.37	1.85	2.17	0.42	1.34	2.37	0.20	1.02
	20 t/ha of manure + $N_{60}P_{60}K_{60}$	3.01	0.37	1.69	2.17	0.39	1.32	2.34	0.19	1.03
	$N_{120}P_{120}K_{120}$	2.91	0.35	1.74	2.11	0.39	1.30	2.30	0.18	1.04
Clone M4	Without fertiliser (control)	2.81	0.38	1.68	2.11	0.41	1.20	2.16	0.18	0.92
	Manure 40 t/ha	3.02	0.40	1.84	2.20	0.45	1.26	2.25	0.20	1.02
	20 t/ha of manure + $N_{60}P_{60}K_{60}$	3.07	0.35	1.80	2.22	0.42	1.25	2.27	0.21	1.04
	$N_{120}P_{120}K_{120}$	2.90	0.37	1.89	2.19	0.44	1.23	2.26	0.22	1.01
	HIP_{05}	*0.14*	*0.03*	*0.07*	*0.12*	*0.04*	*0.05*	*0.12*	*0.03*	*0.04*

In general, the nitrogen content at all the studied sites in the leaves of apple trees of this cultivar was significantly higher compared to the optimal content. The phosphorus content on all fertiliser backgrounds practically did not change, and compared to the optimal content, it was much higher. Fertilisation caused a significant increase in the potassium content in the leaves on the seed stock when applying organic fertilisers, and on M4 – mineral fertilisers compared to the control.

During the period of fructification and growth (1997-2003), a decrease in nitrogen content was observed for all experimental variants, and the highest content was observed for the application of organic and organo-mineral fertilisers on both types of rootstocks, respectively, 2.17, 2.20, and 2.22%. The phosphorus content decreased slightly compared to the previous period, although the indicators were higher than the optimal content. Potassium in the leaves was within the optimal level, and the introduction of 40 t/ha of manure contributed to a significant increase in this indicator in the leaves of the Idared cultivar on both types of rootstocks.

Analysing the data on the nitrogen content in the leaves, it can be noted that in 2004-2016 (the period of full fructification) in variants with systematic long-term fertilisation of the orchard with organic, organo-mineral, and mineral fertilisers which included nitrogen, its indicators exceeded the optimal levels for apple trees. In the control variant, the nitrogen content in the leaves was also within the optimal range, but significantly lower than in other variants. The content of P_2O_5 in the leaves of the apple tree was within the optimal level. Analysing the content of P_2O_5 in the leaves of Idared trees on seed and vegetative M4 rootstocks, one can note almost the same value (close to the lower limit of the optimal level). The potassium level in the leaves of experimental apple varieties was also within the optimal level, and the highest level was found in organic, organo-mineral, and mineral fertiliser systems, which significantly exceeded the indicators in the control version. The content indicators of K_2O in the control version were almost at the lower limit of the optimal level.

The highest content of nitrogen, phosphorus, and potassium in the leaves of the Calville Blanc d'hiver cultivar during the growth and fructification period of trees was in the variant of 20 t/ha of manure + $N_{60}P_{60}K_{60}$ (Table 4). All the studied variants in this period had higher indicators compared to the optimal ones. During the period of fructification and growth, significantly higher indicators of nitrogen and potassium in the leaves were with mineral fertiliser system ($N_{120}P_{120}K_{120}$), and phosphorus – with organic and organo-mineral fertiliser systems. During the period of full fructification, a similar effect of fertilisers on the content of nitrogen, phosphorus, and potassium in the leaves of the Calville Blanc d'hiver cultivar was observed as during the period of fructification and growth. In these studies, there is a tendency to decrease in the nitrogen and potassium

content in the leaves of the Idared apple tree on seed and vegetative M4 rootstocks and Calville Blanc d'hiver on the seed rootstock with increasing tree age. This is also confirmed by the data of other researchers [2; 10].

***Table 4**. The content of nutrients in the leaves of the Calville Blanc d'hiver tree on the seed rootstock depending on the fertiliser in repeated cultivation, %*

Fertiliser variant	Indicators in different age periods of fructification								
	Growth and fructification period, 1990-1996			Fructification and growth period, 1997-2003			Fructification period, 2004-2016		
	N	P_2O5	K_2O	N	P_2O5	K_2O	N	P_2O5	K_2O
Without fertiliser (control)	2.94	0.40	1.76	2.76	0.32	1.21	2.30	0.20	1.01
Manure 40 t/ha	3.05	0.43	2.01	2.85	0.36	1.27	2.47	0.21	1.12
20 t/ha of manure + N_{60} P_{60} K_{60}	3.10	0.41	1.79	2.92	0.36	1.26	2.45	0.25	1.14
N_{120} P_{120} K_{120}	3.09	0.39	1.89	3.01	0.31	1.31	2.50	0.23	1.15
HIP_{05}	*0.15*	*0.06*	*0.05*	*0.14*	*0.04*	*0.03*	*0.12*	*0.02*	*0.03*

CONCLUSIONS

Chlorophyll content (*a+b*) in the leaves of Idared cultivars on the seed and vegetative rootstock M4 and Calville Blanc d'hiver on the seed rootstock changed depending on the age of the plantings. Most of it was during the period of growth and fructification, and least of all – during the period of fructification. The use of various fertiliser options contributed to an increase in the chlorophyll content in the leaves. In the most productive period of fructification, the amount of chlorophyll (*a+b*) in the leaves of Idared apple tree on the seed rootstock was significantly higher in the variant with the introduction of organo-mineral (152.0 mg/100 g), and on the clone M4 – in areas with the application of organic fertilisers (152.1 mg/100 g). In the leaves of Calville Blanc d'hiver cultivar on the seed rootstock, a greater accumulation of the amount of chlorophylls was observed in the variant with the introduction of organo-mineral fertilisers, where the excess of control was 8.0%.

The content of macronutrients in the leaves of the studied cultivar-rootstock combinations also depended on the age of plantings and fertiliser options. During the fructification period, the nitrogen content in the leaves of Idared trees on seed and vegetative rootstocks in the areas of fertilised variants was within optimal limits at the level of 2.30-2.37 and 2.25-2.27%, respectively. Among the studied rootstocks in the fertiliser-free variant, trees on the seed rootstock were characterised by a high nitrogen content in the leaves. In the leaves of the Calville Blanc d'hiver cultivar on the seed rootstock, the nitrogen content on the studied variants was within the optimal range, and among the fertiliser options for applying mineral fertilisers. The content of phosphorus and potassium in the leaves of trees of the studied cultivar-rootstock combinations in the areas of fertiliser options was within optimal limits.

REFERENCES

[1] Gibson, J.P., & Gibson, T.R. (2006). *Plant ecology – Infobase publishing*. Philadelphia: Chelsea House Publishers.
[2] Tanasiev, V. (1985). Accumulation of mineral nutritional elements in apple organs under the influence of fertilizers. In *Modern problems of fruit growing intensification* (pp. 34-38). Kishinev.
[3] Yu, R., Zhu, X., Cao, S., Xiong, J., Wen, X., Jiang, Y., & Zhao, G. (2019). Estimation of chlorophyll content in apple leaves based on imaging spectroscopy. *Journal of Applied Spectroscopy*, 86, 457-464.
[4] Lee, Y., Kweon, H.J., Park, M.-Y., & Lee, D. (2019). Field assessment of macronutrients and nitrogen in apple leaves using a chlorophyll meter. *Hort Technology*, 29(3), 300-307. doi: 10.21273/HORTTECH04217-18.
[5] Havryliuk, O., & Kondratenko, T. (2020). The intensity of photosynthesis of the surface of columnar apple-tree in the conditions of Kyiv. *Scientific reports of NUBIP of Ukraine*, 2(84). doi: 10.31548/dopovidi2020.02.013.
[6] Hurianova, Yu., & Riazanova, V. (2012). Formation of leaf area and chlorophyll content in leaves with mineral nutrition. *Bulletin of Michurinsk State Agrarian University*, 4, 30-31.
[7] Fallahi, E., Mahdavi, S., Kaiser, C., & Fallahi, B. (2019). Phytopigments, poline, chlorophyll sndex, yield and leaf nitrogen as impacted by rootstock, training system, and girdling in "Aztec Fuji" apple. *American Journal of Plant Sciences*, 10(9), 1583-1598. doi: 10.4236/ajps.2019.109112.
[8] Nachtigall, G.R., & Dechen, A.R. (2006). Seasonality of nutrients in leaves and fruits of apple trees. *Soils and Plant Nutrition*, 63(5), 493-501. doi: 10.1590/S0103-90162006000500012.

[9] Yakovenko, R. (2007). Content of green pigments in apple leaves of different rootstock combinations depending on long-term application of fertilizers. In *Abstracts of the scientific conference of young scientists* (pp. 144-145). Uman.
[10] Sergeeva, N., Nenko, I., & Kiseleva, K. (2013). Anatomo-morphological structure and chlorophyll content in apple-tree leaves when using fertilizers and bioactive substances. *Agricultural Biology*, 5, 80 84.
[11] Nabi, B.B., Dar, MA, ul Ain, Q., & Jan, R. (2018). Effect of nitrogen, phosphorus and potassium on leaf nutrient status of high density apple cv. Silver Spur under temperate conditions of Kashmir. *The Pharma Innovation Journal*, 7(4), 86-90.
[12] Kuzin, A., Kashirskaya, N., Kochkina, A., & Kushner, A. (2020). Correction of potassium fertigation rate of apple tree (*Malus domestica* Borkh.) in Central Russia during the growing season. *Plants*, 9(10), article number 1366. doi: 10.3390/plants9101366.
[13] Melnyk, O. (2018). Intensive garden: Laying and care. Leaf analysis. *Gardening News*, 3, 21-24.
[14] Wójcik, P. (2009). *Nawozy i nawożenie drzew owocowych*. Warszawa: Hortpress.
[15] Yeshchenko, V.O. (Ed.). (2014). *Fundamentals of scientific research in agronomy*. Vinnytsia: TD "Edelveys i K".

ВМІСТ ХЛОРОФІЛУ ТА ЕЛЕМЕНТІВ ЖИВЛЕННЯ В ЛИСТІ ЯБЛУНІ ЗАЛЕЖНО ВІД ДОВГОТРИВАЛОГО УДОБРЕННЯ

Роман Володимирович Яковенко[1], Петро Григорович Копитко[1], Вадим Миколайович Пелехатий[2]

[1]Уманський національний університет садівництва
20305, вул. Інститутська, 1, м. Умань, Україна

[2]Поліський національний університет
10008, б-р Старий, 7, м. Житомир, Україна

Анотація. Показником стану рослин залежно від умов вирощування є стан їх листкового апарату, який характеризується вмістом у листку хлорофілу та елементів живлення. Листок яблуні забезпечує синтез органічних речовин, від особливостей його життєдіяльності залежить продуктивність плодових дерев. Важливе значення, як метод діагностики мінерального живлення плодових культур має хімічний аналіз листя, показники якого відображають рівні забезпеченості рослин елементами мінерального живлення. Розглянуто результати досліджень вмісту хлорофілу та елементів живлення в листі дерев яблуні сорту Кальвіль сніговий на насіннєвій і Айдаред на насіннєвій і вегетативній М4 підщепах у повторно вирощуваному насадженні на фонах мінерального живлення, створених довготривалим (понад 86-річним) застосуванням різних систем удобрення на темно-сірому опідзоленому ґрунті. Довготривале застосування органічної та органо-мінеральної систем удобрення сприяло підвищенню рівня суми хлорофілів (*a+b*) у листі дерев сортів яблуні Айдаред на насіннєвій і клоновій М4 підщепах і Кальвіля снігового на насіннєвій підщепі в різні вікові періоди росту й плодоношення, що зумовлювало їх більшу продуктивність. Вміст макроелементів у листі досліджуваних сортопідщепних комбінувань залежав від віку насаджень і варіантів удобрення. У найбільш продуктивний період плодоношення в листі дерев сорту Айдаред на насіннєвій і вегетативній підщепах вміст азоту на ділянках удобрюваних варіантів був у оптимальних межах. Серед досліджуваних підщеп у варіанті без добрив, вищим вмістом азоту у листі характеризувалися дерева на насіннєвій підщепі. У листі сорту Кальвіль сніговий на насіннєвій підщепі вміст азоту на досліджуваних варіантах був у межах оптимального, а серед варіантів удобрення найвищим був за внесення мінеральних добрив. Вміст фосфору та калію в листі дерев досліджуваних сортопідщепних комбінувань на ділянках варіантів удобрення знаходився в оптимальних межах

Ключові слова: Кальвіль сніговий, Айдаред, листок, ґрунтове удобрення, зелені пігменти, вікові періоди плодоношення