УДК 634.11: 634.13: 631.8
DOI: 10.32782/2415-8240-2024-104-1-42-49

SOIL NUTRITIONAL REGIME IN APPLE AND PEAR PLANTATIONS WITH SOIL FERTILISATION

R. V. YAKOVENKO[1], *Doctor of Agricultural Sciences*
P. H. KOPYTKO[1], *Doctor of Agricultural Sciences*
O. V. YAKOVENKO[2], *Candidate of Economic Sciences*
V. H. CHEPURNYI[3], *Candidate of Agricultural Sciences*
V. I. NEVLAD[1], *Candidate of Agricultural Sciences*
[1] **Uman National University of Horticulture**
[2] **The Bohdan Khmelnytsky National University of Cherkasy**
[3] **The L. P. Symyrenko research pomology station of the Institute of Horticulture of NAAS of Ukraine**

Представлено аналітичний огляд вітчизняних і закордонних досліджень, щодо зміни поживного режиму ґрунту в насадженнях яблуні і груші за ґрунтового удобрення. Мінеральне живлення дерев є важливою складовою частиною обміну речовин у рослинному організмі, оскільки воно визначає ріст, розвиток рослинного організму, продуктивність насаджень і якість врожаю. Зміни забезпеченості насадження яблуні і груші головними макроелементами ґрунтового мінерального живлення сприє підвищенню врожайності насаджень. Тому, питання підтримання на оптимальному рівні поживного режиму ґрунту під плодовими насадженнями є актуальним і потребує подальшого вивчення та наукового пояснення, розробки та застосування оптимізованої систему ґрунтового удобрення.

***Ключові слова**: поживний режим ґрунту, елементи живлення, продуктивність насаджень, яблуня, груша, удобрення.*

Problem statement. Establishment and use of highly productive fruit plantations is only possible if optimal soil fertility parameters are created under them [1–3]. Along with the content of organic matter, the level of soil fertility is characterised by the presence of mineral nutrients [4]. Mineral nutrition of plants is an extremely important component of metabolism in the plant organism, as it determines the direction of biochemical transformations of various compounds, growth, development of the plant organism, plant productivity and crop quality [4–6]. Among the elements that the plant consumes in large quantities and with which soil reserves need to be replenished are macronutrients: nitrogen, phosphorus and potassium.

Research results. Nitrogen is the most quantitatively important element for fruit trees and is required in much greater quantities than other elements. Plants absorb nitrogen from the soil mainly in the form of mineral compounds with NH+4 i NO-3 ions, which are formed during the mineralisation of organic matters or introduced with fertilisers. Normal nutrition with the ammonium form of nitrogen occurs when plants

have a sufficient carbohydrate content, a neutral or alkaline soil reaction, and a high content of calcium and magnesium. The nitrate form of nitrogen is better absorbed in acidic soil conditions, i.e. in soil conditions in which woody vegetation, such as apple and pear trees, is more commonly grown. Plants can also partially absorb the amide form of this element from organic substances: amino acids, urea, asparagine. When fruit crops lack nitrogen for nutrition, their growth is weakened, and the total biomass accumulation and the ratio between the aerial part and the root system are reduced. This is a consequence of a decrease in photosynthesis productivity caused by a decrease in the assimilation surface area of leaves and the chlorophyll content in them [7, 8].

In fruiting apple and pear plantations, the optimal supply of nitrogen to plants is of great importance for maintaining high productivity of old fruit wood and the growth of new wood, for fruit setting and reducing fruit shedding during the harvest period, and for the differentiation of fruit formations. A particularly close correlation is observed between the level of nitrogen supply and the next year's harvest [9–11].

P. H. Kopytko [1] found that in traditional apple plantations, the best nutritional conditions, and, accordingly, the growth and fruiting of trees, are provided by optimal soil fertility parameters. Based on the results of long-term studies for the Forest-Steppe and Steppe zones, the optimal level of nitrate nitrogen after 14 days of composting in the 0–40 cm layer, mg/kg of soil, was established for: grey soils 15–20, dark grey podzolic soils 22–25, podzolic chernozems 25–31 and ordinary chernozem 34–35.

Nitrogen differs from other soil nutrients in its behaviour in the soil, high mobility, a large number of different forms, and the ability to undergo relatively rapid transformation, which is determined by a complex of edaphic, climatic, and agronomic factors [7]. D. Wrona and A. Sadowski [12] state that the annual nitrogen removal in an intensive orchard yielding 40 t/ha is 0.05 %, or only 20 kg. The same amount of nitrogen accumulates in the trees during the growing season of apple trees. Therefore, especially on fertile soils, fertiliser application should be moderate, as needed, with a dose of 50–60 kg/ha. This is confirmed by studies conducted in different soil and climatic zones [1, 13–15]. Excessive nitrogen nutrition of fruit crops prolongs the growing season, which leads to unripe tissue and, consequently, damage to tissues by low temperatures in winter and flowers by spring frosts in spring. Excessively high levels of nitrate nitrogen in the soil under fruit trees can block their nutrition with phosphorus, iron and other elements, causing physiological diseases and reduced productivity, and most importantly, harming the environment by leaching the nitrate form of nitrogen into deeper soil layers [1, 16–19].

In studies [12, 15, 20] conducted in intensive apple and pear plantations, the dynamics of available nitrogen in the soil indicates that nitrogen fertilisation should be carried out only in early spring, when nitrate nitrogen reserves are at a minimum. Later, as a result of the mineralisation of organic matter in the soil, sufficient nitrogen is released, which is intensively absorbed by the trees from May to July. Phosphorus is one of the main elements of plant nutrition. Phosphorus supply to plants is especially important for the normal course of reproductive processes, such as flowering and fruiting, but a lack of phosphorus can also affect the growth processes of the apple tree, even with a normal supply of other elements. The role of phosphorus in such vital

processes as photosynthesis and respiration, as well as in other functions of bioenergy and biosynthesis, is quite important [21, 22].

The availability of soil phosphorus to plants varies greatly and depends on a number of factors: particle size distribution, soil acidity, humus content, saturation with absorbent bases, moisture, soil temperature, plant phosphorus requirements, type and dose of fertiliser, and the duration of application. On soils with an optimal content of mobile phosphorus, it is recommended to apply phosphorus fertilisers in quantities equivalent to the removal rate to obtain high and economically profitable yields of fruit crops [23, 24].

Potassium, like nitrogen, is one of the most important nutrients for the development of fruit crops, although it is not chemically bonded in organic compounds. It plays an important role in carbohydrate and protein metabolism, activates enzymes and enzyme systems, promotes the use of nitrogen in ammonium form, maintains cell colloids in optimal physical condition, increases the water-holding capacity of the cytoplasm, and plant resistance to tissue dehydration under adverse environmental factors: drought, low temperatures, fungal diseases, etc. [1, 3, 24].

In China [25], a field experiment was conducted to determine the effect of periods and rates of potash fertiliser application in apple plantation and the results of the research were analysed in terms of yield, fruit quality, potash fertiliser use efficiency and nutrient content in leaves and fruits. The results showed that, compared to the no-potassium variant, all potassium fertiliser treatments contributed to a significant increase in yield by an average of 4.3–33.2 % and improved fruit quality.

In studies conducted at Uman National University of Horticulture [26–28], it was found that in apple and pear plantations, changes in the level of potassium in the soil depended on fertiliser rates and the intensity of nutrition of fruit trees with this element, with less than optimal supply of the root layer of the soil. Therefore, the use of potassium fertilisers in fruit crops, especially pears, requires further comprehensive study. Intensive fruit growing practices involve extensive use of pesticides to protect against pests, diseases and weeds. Under these conditions, a large amount of biotoxic chemicals and heavy metals enter the topsoil. Undergoing a series of transformations in the soil, they form substances that are more toxic to trees than the chemicals themselves. In case of significant accumulation, they can cause stressful situations that adversely affect microbiological processes in the soil, which leads to a decrease in soil biological activity [29, 30].

Thus, in the studies of H. M. Terenko it was found that long-term cultivation (45 years) of the orchard contributed to the accumulation of copper content in the leached black soil in the soil layer of 0–30 cm under the crowns of trees in the amount of 111, 130 mg/kg of soil, which is 22 times higher than in the field crop rotation, which is toxic for the cultivation of future trees. A similar situation with the accumulation of copper in dark grey podzolic soil was also established at Uman National University of Horticulture by P. H. Kopytko [17] in a 50-year-old apple tree plantation due to the systematic long-term use of copper-containing preparations.

Conclusions. Thus, soil fertility indicators determine the effectiveness of fertilisation systems in fruit crop plantations and need to be studied and substantiated

in specific soil and climatic conditions. In general, the analysis of information from the literature does not allow us to assert that the issue of the impact of complex fertilisation on the productivity of fruit crop plantations with changes in agrochemical properties that characterise soil fertility has been studied in full. Therefore, it is necessary to further study this issue in experiments with optimised fertilisation in intensive apple and pear plantations.

Література:

1. Копитко П. Г. Удобрення плодових і ягідних культур: навчальний посібник. Київ: Вища школа, 2001. 206 с.
2. Господаренко Г. М. Удобрення садових культур: навчальний посібник. Київ. 2017. 340 с.
3. Wojcik P. Zrównoważone nawożenie roślin ogrodniczych. Instytut Ogrodnictwa, Skierniewice. 2014.
4. Гродзинський А. М. Основи хімічної взаємодії рослин. Київ: Наук. думка, 1973. 206 с.
5. Майдебура В. І., Майдебура О. В., Заморський В. В. Якість та тривалість зберігання плодів яблуні в залежності від рівня мінерального живлення. *Зб. наук. пр. УДАУ*. 2005. Ч. 1. № 61. С. 536–548.
6. Rutkowski K., Łysiak G. P. Effect of Nitrogen Fertilization on Tree Growth and Mineral Content in Soil and Cherry Leaves (*Prunus cerasus* L.). *Agriculture*. 2023. Vol. 13. DOI: 10.20944/preprints202301.0199.v1.
7. Chen Q, Ding N, Peng L, Ge S. F., Jiang Y. M. Effects of different nitrogen application rates on 15N-urea absorption, utilization, loss and fruit yield and quality of dwarf apple. *Ying Yong Sheng Tai Xue Bao*. 2017. 28(7). DOI: 10.13287/j.1001-9332.201707.001.
8. Zrównoważone nawożenie roślin ogrodniczych / Opracowanie zbiorowe pod redakcją Dr. hab. P. Wójcika. Skierniewice 2014. 64 p.
9. Красноштан А. О. Мінеральні добрива в сучасному садовому біоценозі – реальність і проблеми. *Зб. наук. пр. УСГА*. 1997. С. 23–25.
10. Zodlik Z., Pacholak E. Effect of nitrogen fertigation on mineral elements content in “Sampion” and “Golden Delisious” leaves and fruits. *Ecological aspects of nutrition and alternatives for herbicides in horticulture*. 1997. P. 83–84.
11. Мельник О. В. Інтенсивний сад: закладання і догляд. *Новини садівництва.* 2017. №4. С. 4-10.
12. Wrona D., Sadowski A. Effect of nitrogen fertilisation and soil management on soil mineral nitrogen in the apple orchard. *Journal of Fruit and Ornamental Plant Research*. 2004. Vol. 12. P. 191–199.
13. Середа І. І., Мовчан Н. Ф. Вплив довгострокового застосування добрив на агрохімічні властивості темно-сірого опідзоленого ґрунту і продуктивність яблуні. *Садівництво*. 1998. Вип. 46. С. 95–98.
14. Манзій В. В. Продуктивність яблуні залежно від рівнів удобрення в Правобережному Лісостепу України: Автореф. дис.... канд. с.-г. наук. Умань. 2000. 17 с.

15. Малюк Т. В. Оптимізація азотного живлення інтенсивних насаджень груші на вегетативних підщепах в зрошуваних умовах Півдня України: автореф. дис. канд. с.-г. наук: спец.: 06.01.04 «Агрохімія». Харків. 2010. 21 с.
16. Dierend W., Spethmann W. Influence of N-fertilization on the droughts of apple rootstocks and one year apple trees. *Erwerbsobstbau*. 1996. Vol. 38 (3). P. 90–93.
17. Kopytko P., Karpenko V., Yakovenko R., Mostoviak I. Soil fertility and productivity of apple orchard under a long-term use of different fertilizer systems. *Agronomy Researh*. 2017. № 15(2). P. 444–455.
18. Малюк Т. В., Пчолкіна Н. Г. Екологічні проблеми зрошуваних садів на півдні України. *Агрохімія і ґрунтознавство*. 2013. Вип. 79. С. 21–23.
19. Zhang Y., Xie Y. S., Hao M. D., Ran W. Characteristics and evaluation of soil nutrients in apple orchards at the gully regions of Loess Plateau. *Plant Nutrition and Fertilizer Science*. 2010. Vol. 16. P. 1170–1175.
20. Gao Y. M., Tong Y. A., Lu Y. L., Ma H. Y. Effect of long-term application of nitrogen, phosphorus and potassium on apple yield and soil nutrient accumulation and distribution in orchard soil of Loess Plateau. *Journal of Fruit Science*. 2012. Vol. 29. P. 322–327.
21. Козак В. М. Агроекологічні основи збереження родючості грунтів в промисових насадженнях яблуні та їх якісна оцінка в садівництві України: автореф. дис. … д. с-г. наук: 06.01.03 «Агрогрунтознавство та агрофізика». Харків, 1999. 32 с.
22. Neilsen G., Yorston J. Soil disinfection and monoammonium phosphate fertilization increase precocity of apples on replant problem soils. *Amer. Soc. Hort. Sci*. 1991. Vol. 116 (4). P. 651–654.
23. Карпенчук Г. К., Копитко П. Г., Бондаренко А. О. та ін. Удобрення садів. К.: Урожай. 1991. 248 с.
24. Яковенко Р. Удобрення яблуні. *Садівництво по-українськи*. 2019. № 1 (31). С. 46–47.
25. Zuoping Z., Sha Y., Fen L., Puhui J., Xiaoying W., Yanan T. Effects of chemical fertilizer combined with organic manure on Fuji apple quality, yield and soil fertility in apple orchard on the Loess Plateau of China. *Int J Agric & Biol Eng Open Access*. 2014. Vol. 7 (2). P. 45–51.
26. Яковенко Р. В. Основи підвищення продуктивності яблуні і груші за оптимізованого удобрення: Автореф. дис. докт. с.-г. наук: 06.01.07 «Плодівництво». Умань, 2022. 40 с.
27. Яковенко Р. В., Трушев І. М. Щодо питань удобрення інтенсивних насаджень яблуні. *Зб. наук. пр. Уманського НУС*. 2023. № 102. Ч. 1. С. 101–108. DOI: 10.32782/2415-8240-2023-102-1-101-108.
28. Яковенко Р. В. Поживний режим ґрунту та врожайність насаджень груші залежно від оптимізованого ґрунтового удобрення за повторної культури. *Аграрні інновації*. 2023. № 17. С. 156–161. DOI: 10.32848/agrar.innov.2023.17.21.
29. Wang Q., Liu J., Cheng S. Heavy metals in apple orchard soils and fruits and their health risks in Liaodong Peninsula, Northeast China. *Environ Monit Assess*. 2015. № 187. DOI: 10.1007/s10661-014-4178-7.

30. Копитко П. Г. Деякі особливості поживного режиму ґрунту за інтенсивного використання засобів хімізації в садах. Мінеральне живлення і продуктивність плодових рослин. *Зб. наук. пр. УСГІ*. 1992. С. 4–20.

References:

1. Kopytko, P. G. (2001). Fertilization of fruit and berry crops: a study guide. Kyiv: Higher School. 206 p. [in Ukrainian].

2. Gospodarenko, G. M. (2017). Fertilization of garden crops: a study guide. Kyiv. 340 p. [in Ukrainian].

3. Wójcik, P. (2014). Złężone nawożenie roślin ogrodniczych. Instytut Ogrodnictwa, Skierniewice. [in Polish].

4. Grodzinsky, A. M. (1973). Fundamentals of chemical interaction of plants. Kyiv: Nauk. dumka. 206 p. [in Ukrainian].

5. Maidebura, V. I., Maidebura, O. V., Zamorskyi, V. V. (2005). The quality and storage duration of apple fruits depending on the level of mineral nutrition. *Coll. of scient. works of UDAU*, no. 61, pp. 536–548. [in Ukrainian].

6. Rutkowski, K., Łysiak, G. R. (2023). Effect of Nitrogen Fertilization on Tree Growth and Mineral Content in Soil and Cherry Leaves (*Prunus cerasus* L.). *Agriculture*, vol. 13. DOI: 10.20944/preprints202301.0199.v1.

7. Chen, Q, Ding, N, Peng, L, Ge, S. F., Jiang, Y. M. (2017). Effects of different nitrogen application rates on 15N-urea absorption, utilization, loss and fruit yield and quality of dwarf apple. *Ying Yong Sheng Tai Xue Bao*, no. 28(7). DOI: 10.13287/j.1001-9332.201707.001.

8. Złężyone nawożenie roślin ogrodniczych / Opracowanie szoriobe pod redakcją Dr. hab. P. Wójcika. Skierniewice 2014. 64 p. [in Polish].

9. Krasnoshtan, A. O. (1997). Mineral fertilizers in modern garden biocenosis – reality and problems. *Coll. of science Ave. USGA*, pp. 23–25. [in Ukrainian].

10. Zodlik, Z., Pacholak, E. (1997). Effect of nitrogen fertigation on mineral elements content in "Sampion" and "Golden Delicious" leaves and fruits. *Ecological aspects of nutrition and alternatives for herbicides in horticulture*, pp. 83–84. [in Ukrainian].

11. Melnyk, O. V. (2017). Intensive garden: planting and care. *Gardening news*, no. 4, pp. 4–10. [in Ukrainian].

12. Wrona, D., Sadowski, A. (2004). Effect of nitrogen fertilization and soil management on soil mineral nitrogen in the apple orchard. *Journal of Fruit and Ornamental Plant Research*, vol. 12, pp. 191–199. [in Ukrainian].

13. Sereda, I. I., Movchan, N. F. (1998). Effect of long-term application of fertilizers on agrochemical properties of dark gray podzolized soil and productivity of apple trees. *Gardening*, vol. 46, pp. 95–98. [in Ukrainian].

14. Manziy, V. V. (2000). Productivity of apple trees depending on the levels of fertilization in the Right Bank Forest Steppe of Ukraine: Author's abstract. thesis... candidate s.-g. of science. Uman. 17 p. [in Ukrainian].

15. Malyuk, T. V. (2010). Optimization of nitrogen nutrition of intensive pear plantations on vegetative rootstocks in irrigated conditions of the South of Ukraine: autoref. thesis Ph.D. s.-g. Sciences. Kharkiv. 21 p. [in Ukrainian].

16. Dierend, W., Spethmann, W. (1996). Influence of N-fertilization on the droughts of apple rootstocks and one-year apple trees. *Erwerbsobstbau*, vol. 38 (3), pp. 90–93.

17. Kopytko, P., Karpenko, V., Yakovenko, R., Mostoviak, I. (2017). Soil fertility and productivity of apple orchard under a long-term use of different fertilizer systems. *Agronomy Research*, no. 15(2), pp. 444–455. [in Ukrainian].

18. Malyuk, T. V., Pcholkina, N. G. (2013). Ecological problems of irrigated gardens in the south of Ukraine. *Agrochemistry and soil science*, issue 79, pp. 21–23. [in Ukrainian].

19. Zhang, Y., Xie, Y. S., Hao, M. D., Ran, W. (2010). Characteristics and evaluation of soil nutrients in apple orchards at the gully regions of Loess Plateau. *Plant Nutrition and Fertilizer Science*, vol. 16, pp. 1170–1175.

20. Gao, Y. M., Tong, Y. A., Lu, Y. L., Ma, H. Y. (2012). Effect of long-term application of nitrogen, phosphorus and potassium on apple yield and soil nutrient accumulation and distribution in orchard soil of Loess Plateau. *Journal of Fruit Science*, vol. 29, pp. 322–327.

21. Kozak, V. M. (1999). Agroecological basis of preserving soil fertility in commercial apple plantations and their qualitative assessment in horticulture of Ukraine: author's review. thesis ... d. s-g. Sciences. Kharkiv. 32 p. [in Ukrainian].

22. Neilsen, G., Yorston, J. (1991). Soil disinfection and monoammonium phosphate fertilization increase precocity of apples on replant problem soils. *Amer. Soc. Hort. Sci*., vol. 116 (4), pp. 651–654.

23. Karpenchuk, G. K., Kopytko, P. G., Bondarenko, A. O. Et al. (1991). Garden fertilization. K.: Harvest. 248 p. [in Ukrainian].

24. Yakovenko, R. (2019). Fertilization of apple trees. *Gardening in Ukrainian*, no. 1 (31), pp. 46–47. [in Ukrainian].

25. Zuoping, Z., Sha, Y., Fen, L., Puhui, J., Xiaoying, W., Yanan, T. (2014). Effects of chemical fertilizer combined with organic manure on Fuji apple quality, yield and soil fertility in apple orchard on the Loess Plateau of China. *Int J Agric & Biol Eng Open Access*, vol. 7 (2), pp. 45–51.

26. Yakovenko, R. V. (2022). Basics of increasing the productivity of apple and pear trees with optimized fertilization: Autoref. thesis dr. s.-g. Sciences. Uman. 40 p. [in Ukrainian].

27. Yakovenko, R. V., Trushev, I. M. (2023). Concerning the issues of fertilizing intensive apple plantations. *Coll. of scienct. Works of UNUS*, no. 102, part 1, pp. 101–108. DOI: 10.32782/2415-8240-2023-102-1-101-108. [in Ukrainian].

28. Yakovenko, R. V. (2023). Soil nutrient regime and yield of pear plantations depending on optimized soil fertilization during repeated cropping. *Agrarian innovations*, no. 17, pp. 156–161. DOI: 10.32848/agrar.innov.2023.17.21. [in Ukrainian].

29. Wang, Q., Liu, J., Cheng, S. (2015). Heavy metals in apple orchard soils and fruits and their health risks in Liaodong Peninsula, Northeast China. *Environ Monit Assess*, no. 187. DOI: 10.1007/s10661-014-4178-7. [in Ukrainian].

30. Kopytko, P. G. (1992). Some features of the nutrient regime of the soil during the intensive use of chemicals in gardens. Mineral nutrition and productivity of fruit plants. Coll. of scient. Works of USGI, pp. 4–20. [in Ukrainian].

Annotation

Yakovenko R. V., Kopytko P. H., Yakovenko O. V., Chepurnyi P. H., Nevlad V. I.
Soil nutritional regime in apple and pear plantations with soil fertilisation

The article presents an analytical review of domestic and foreign researches on changes in the soil nutrient regime in apple and pear plantations under soil fertilisation. The analysis has shown that the establishment and use of highly productive fruit plantations is possible only if the optimal soil fertility parameters are created under them. Mineral nutrition of trees is an extremely important part of plant metabolism, as it determines the growth, development of the plant organism, productivity of plantations and quality of the crop. Changes in the supply of apple and pear plantations with the main macronutrients of soil mineral nutrition contributed to an increase in plantation yields. In fruiting apple and pear plantations, the optimal supply of nitrogen to plants is of great importance for maintaining high productivity of old fruit wood and the growth of new wood, for fruit setting and reducing fruit shedding during the harvest period, and for differentiation of fruit formations.

Phosphorus supply to plants is especially important for the normal course of reproductive processes, such as flowering and fruiting, but a lack of phosphorus can also affect the growth processes of the apple tree, even with a normal supply of other elements. Potassium, like nitrogen, is one of the most important nutrients for the development of fruit crops, although it is not chemically bound in organic compounds. It plays an important role in carbohydrate and protein metabolism, activates enzymes and enzyme systems, promotes the use of nitrogen in ammonium form, maintains cell colloids in optimal physical condition, and increases plant resistance to tissue dehydration under adverse environmental factors (drought, low temperatures). Therefore, the issue of maintaining the optimal level of soil nutrition under fruit plantations is relevant and requires further study and scientific explanation of the development and application of an optimised soil fertilisation system.

Key words*: soil nutrient regime, nutrients, plant productivity, apple, pear, fertiliser.*