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УРОЖАЙНІСТЬ І ЯКІСТЬ ПЛОДІВ ЯБЛУНІ СОРТУ КАЛЬВІЛЬ СНІГОВИЙ ЗА РІЗНОГО УДОБРЕННЯ В ПОВТОРНО ВИРОЩУВАНОМУ НАСАДЖЕННІ

Анотація. *Розглянуто результати довготривалих досліджень формування врожаю і якості плодів яблуні сорту Кальвіль сніговий на насіннєвій підщепі за повторного вирощування на фонах мінерального живлення, створених тривалим удобренням (протягом 50 років) попереднього саду на темно-сірому опідзоленому ґрунті в Правобережному Лісостепу України. Впродовж усього періоду вирощування першого і другого покоління яблуні в дослідному саду застосовувалися органічне (40 т/га гною ВРХ), мінеральне удобрення ($N_{120}P_{120}K_{120}$) та їх поєднання (20 т/га гною + $N_{60}P_{60}K_{60}$), які вносили в старому насадженні раз у два роки восени під оранку в міжряддях на 18-20 см, а в новому повторному – гній, фосфорні та калійні добрива так само, а азотні половинними дозами щорічно навесні під культивацію на глибину 10-12 см. У результаті досліджень встановлено, що органічні добрива краще ніж мінеральні забезпечували формування вищих показників родючості ґрунту (вміст гумусу і рухомих елементів живлення, реакцію ґрунтового середовища, біологічну активність ґрунту) й відповідно підвищувалася урожайність дерев – за всі роки плодоношення сумарний урожай плодів за органічного удобрення був більший від контрольного без удобрення на 35 %, а за органо-мінерального і мінерального – на 27 і 18%. Середня маса яблук була більшою на удобрюваних деревах, а якісні показники істотно не відрізнялися.*

Ключові слова: *яблуня, підщепа, сорт, удобрення, врожайність, якість плодів.*

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УРОЖАЙНОСТЬ И КАЧЕСТВО ПЛОДОВ ЯБЛОНИ ПРИ РАЗНОМ УДОБРЕНИИ В ПОВТОРНО ВЫРАЩИВАЕМОМ НАСАЖДЕНИИ

Аннотация. *Рассмотрены результаты многолетних исследований по изменению показателей плодородия почвы, урожайности и качества плодов яблони сорта Кальвиль снежный на семенном подвое при повторном выращивании насаждения на фонах почвенного плодородия, созданых длительным удобрением (в течение 50 лет) предыдущего сада на темно-серой оподзоленной почве в Правобережной Лесостепи Украины. В течение всего периода выращивания первого и второго поколения яблони в опытном саду применялись органическое (40 т/га навоза из-под ВРС), минеральное удобрения ($N_{120}P_{120}K_{120}$) и их сочетание (20 т/га навоза + $N_{60}P_{60}K_{60}$), вносимые в старом насаждение раз в два года осенью под вспашку в междурядьях на 18-20 см, а в новом повторном – навоз, фосфорное и калийное удобрения так же, а азотное половинными дозами ежегодно весной под культивацию на глубину 10-12 см. В результате исследований установлено, что органическое удобрение в большей мере, чем минеральные, обезпечивали формирование болие високих показателей почвенного плодородия (содержания гумуса и подвижных форм элементов питания, реакции почвенной среды, ее беологической активности) и соответственно повышалась урожайность деревьев – за все годы плодоношення суммарный урожай плодов при органическом удобрении был більше контрольного без удобрения на 35 %, а при органо-минеральном и только минеральном – на 27 и 18 %. Средняя маса яблок была больше на удобряемых деревьях, а качественные показатели существенно не отличались при различном удобрении.*

Ключевые слова: *яблоня, подвой, сорт, удобрение, урожайность, качество плодов.*

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YIELD AND QUALITY OF CALVILLE SNOW APPLE TREE VARIETY UNDER DIFFERENT FERTILIZATION IN THE REPEATEDLY CULTIVATED PLANTATIONS

Abstract. *The results of long-term research on the formation of yield and quality of apple trees of Calville Snow variety on the seedling rootstocks under repeated cultivation on the mineral nutrient backgrounds created by long-term fertilization (during 50 years) of the previous garden on the dark gray podzolized soil in the Right-bank Forest-Steppe of Ukraine are considered. During the whole period of cultivation the first and second generation of apple trees in the experimental garden, the organic fertilizer (40 t/ha of cattle manure), mineral fertilizer ($N_{120}P_{120}K_{120}$) and their combination (20 t/ha of manure + $N_{60}P_{60}K_{60}$) were used and applied in the old plantation biennially in autumn under the plowing in the row spacing of 18-20 cm, and in the new repeated plantation the manure, phosphate and potash fertilizers were used in the same way and the nitrogen ones – with half doses annually in spring under cultivation to a depth of 10-12 cm. As a result of the research it was found that organic fertilizers provided better formation of soil fertility indices than mineral fertilizers (the content of humus and moving nutrients, the soil environment reaction, biological activity of soil) and correspondingly the yield of the trees increased – for all the years of fruiting, the total fruit yield under organic fertilization was greater than the control one without fertilization by 35%, and under the organic and mineral and mineral one – by 27 and 18%. The average weight of apples was higher on the fertilized trees, and qualitative indices did not differ significantly.*

Key words: *apple, rootstock, variety, fertilization, yield, fruit quality.*

Target setting. It is very important to use scientifically grounded system of agrotechnical measures, in particular rational, the most effective fertilizer for preservation and increase of soil fertility during the long-term cultivation of fruit trees, especially after the uprooted old gardens, in order to maintain the constantly high productivity of fruit plantations and appropriate receiving of sufficient quantity of fruit of proper quality. According to the scientific research and gardening practice, the problem of such fertilization of fruit crops can be solved only in long stationary garden experiments, where the soil fertility changes under the complex influence of soil formation processes in tree planting and applied fertilizers and the corresponding reaction of fruit plants on such changes depending on biological peculiarities of various variety and rootstock combinations [4, 5, 8, 20].

Scientific researches and issues analysis. The most effective and rational application of organic and mineral fertilizers in fruit crop plantations, grown repeatedly in the same place for a long time, depending on the changes in soil properties under the influence of fertilization, as well as on the characteristics of rootstocks and age periods of life and fruiting, remains poorly known [14, 18]. It is possible to solve this problem only in the long-term stationary experiments as the influence of different fertilizer systems on the change of soil properties is manifested under their the long-term application [2, 10, 13]. And in a short period of various fertilization, changes may not be noticeable [18]. Under the enrichment with nutrients and the improvement of other fertility indices of fertilized soil, the productivity of apple plantations grows quite noticeably, but it is not the same under different fertilizers, which depends on moisture supply of fruit trees and many other factors that affect the mineral nutrition of plants together with fertilizers. This is evidenced by the results of studies conducted under various soil and climatic conditions of growing apple orchards [3, 4, 6, 11, 13, 16, 21]. Most of these studies have been carried out over a long period of time for the cultivation of vigorous trees on the seed rootstock with large areas of nutrition in the gardens of less intensive constructions compared with the present more intense ones. In modern conditions of farmer gardening, under the cultivation of short-cycle fruit plantations and more frequent changes with the new ones on the former uprooted old gardens, it is important to better study the optimization of fertilization of the re-cultivated ones due to the possible influence of soil fatigation on their productivity [12]. Therefore, the purpose of our research is to establish the level of yield and quality of apple fruit, depending on the changes in the soil fertility indices under the long-term various fertilization of repeatedly cultivated plantations.

Research methodology. The research was carried out in the apple orchard of Uman National University of Horticulture on a dark gray, podzolized soil with humus content in the layer of 0-20 cm – 2,41%, in the layer of 20-40 cm – 2,28%, and nitrogen content (at a nitrification capacity of 14 – daily composting) 16.4, 15.9 mg/kg of soil respectively, P_2O_5 and K_2O (by Egner-Riem-Domingo method) – 154 and 136 and 269 and 254 mg/kg of soil, pH 5.2, 5, 3, the amount of absorbed bases is 25.0 and 26.0 mg-eq/100 g of soil.

The experiment was founded by Professor S.S. Rubin in 1931 and was conducted during 50 years of cultivation of vigorous apple trees of Calville Snow variety on the seedling rootstock with a spacing of 10x10 m. After that it was reconstructed by uprooting the old trees in 1982 and planting new ones in 1984, with the preservation of the previous sections of the investigated variants, where vigorous trees of the same variety with a spacing of 7x5 m are planted. The scheme of long-term experiment (since 1931) included the following options: No fertilizers (control), Manure 40 t/ha (organic fertilizer system), Manure 20 t/ha + $N_{60}P_{60}K_{60}$ (organic and mineral system), $N_{120}P_{120}K_{120}$ (mineral system). In the old experimental garden all fertilizers were applied biennially in autumn under plowing in row spacing at a depth of 18-20 cm. In the new re-cultivated one manure, phosphorous and potash fertilizers were applied in the same way, and nitrogen ones were applied annually in half doses in spring before or at the beginning of trees vegetation (depending on the weather conditions and the state of soil) under cultivation or disking in row spacing at a depth of 10-15 cm. The soil in the experimental garden was kept under the fallow system. All the studies, measurements and calculations were performed according to the proven and standardized methods described in the methodological literature and in the state standards [1, 7, 9, 15, 17].

Research results. During the 86-year period of growing apple trees of two rotations (1931-1982 and 1984-2016), systematic fertilization contributed to increasing the humus content of soil, more under than the organic, slightly less under the organic and mineral and least under the mineral systems of long-term fertilization. The provision of trees with nitrate nitrogen under the nitrification capacity of soil in the mineral fertilizer ($N_{120}P_{120}K_{120}$) was higher than the lower limit of the optimal level, which is 22-25 mg/kg of soil in the layer of 0-40 cm, and on the plots with organic and organic and mineral fertilizer systems it exceeded its upper limit [4]. The movable joints of phosphorus on all experimental plots were significantly higher than the optimal level for apple tree, which is in the range of 70-100 mg/kg of soil. The movable forms of potassium in the fertilized soil were significantly larger than in the unfertilized plots of the control option, where in the root-containing layer of 0-60 cm, the K_2O content was insufficient to provide the apple tree with potassium nutrition at an optimal level, which is in the heavy-gray, dark gray, podzolized soils, ranges within 230-280 mg/kg. At the same time under the organic fertilizer system, the content of movable forms of potassium most often reached 280 mg/kg of soil.

Depending on the levels of soil mineral nutrition on the plots of the investigated fertilization options, the young, experimental trees began to bear fruit with various intensity. Thus, in the first period of growth and fruiting on all fertilized plots, the number of flowers was significantly higher than on the control unfertilized ones – 80-120 pcs/tree under the smallest significant difference of 50 pcs, and the load of trees with fruits was also significantly larger by 24-29 fruits for HIP_{05} = 11 (Table 1). In the studied variants with different fertilizers, the intensity of flowering and the loading of fruit trees did not differ significantly.

In the second period of fruiting and growth, a similar pattern of flowering was preserved, and the formation of fruits was already better on the plots of organic and organic and mineral fertilizer systems with higher levels of soil fertility, but there was no significant difference between these indices of fruiting. Compared with the control option without fertilization, significantly more flowers on the trees were only in the option with manure fertilization – for 220 pcs (8.2%). The number of fruit on the tree on all the fertilized plots was significantly higher than on the control ones without fertilization, at 55-91 pcs (13,1-21,6%), but depending on the different fertilizers, there were no significant differences, but the trees in the variant with organic fertilizers had some more fruit.

In the third period of fruiting, the flowering of trees in all the options did not differ significantly. Under the organic and organic and mineral fertilizer systems there were by 2.9 and 2.5% more flowers on the trees, and under the mineral one – by 2.2% less than on the unfertilized control ones. The fruits were mostly on the trees in the option with manure fertilization – 81 pcs. (14.7%), which is significantly higher than the number of unfertilized control plots. In the other fertilization options, the differences were not significant: under the organic and mineral fertilization they were more than 8.9%, and under mineral one only 2.4%.

The yield capacity of the investigated variety Calville Snow has changed in accordance with the flowering intensity and the fruit formation under different fertilizer application. Thus, in the first period of growth and fruiting it was quite low for seven years, gradually increasing from 1-2 to 15-20 kg of fruit from one tree, and on average, on the whole area of the experiment it was 4.4 tons/ha. At the same time, there was no significant difference between the levels of yield in experimental options with fertilizers, but in the control ones it was significantly lower (Table 2).

In the period of fruiting and growth, backgrounds of mineral nutrition created by long-term systematic fertilization, to a greater extent contributed to the growth of fertile formations and the strengthening of physiological processes, aimed at differentiating the generative organs, which resulted in the increase in the yield of experimental trees. It was significantly higher under the organic and organic and mineral fertilizer systems compared with its value in the control option without fertilization, at 39.2 and 34.4% respectively, and with the mineral system – by 15.2 and 11.3%. In the latter option the yield was also significantly higher than the controlled one by 20.8%.

In the third period of fruiting, yields in all studied fertilizer variants were significantly higher at 11.2-32.7% of the control, and for organic and organo-mineral fertilizers, it also exceeded substantially by 18.3 and 10.3% of the yield in the variant mineral system. There was no significant difference between the levels of yield on plots fertilized with organic fertilizers and in combination with mineral ones.

In the third period of fruiting, yields in all the studied fertilizer options were significantly higher at 11.2-32.7% of the control, and under the organic and organic and mineral fertilizers it also exceeded substantially by 18.3 and 10.3% of the yield in the mineral system opltion. There was no significant difference between the levels of yield on plots fertilized with organic fertilizers and in combination with mineral ones.

It should be noted that for the entire 27-year period of fruiting, the total yield of Calville Snow fruits in the control option without fertilization amounted to 315 t/ha, with organic fertilizers – 425 t/ha, with organic and mineral fertilizers – 400 t/ha, and with mineral fertilizers – 371 t/ha, that is, the yield of fertilized trees in general exceeded its level of the unfertilized ones by 35, 27 and 18% respectively.

The more effective impact of organic fertilizers on

1. Intensity of flowering of trees and their fruit loading in the repeatedly cultivated plantations of the Calville Snow apple tree variety on the seedling rootstock under different fertilizers

Fertilizer option	Indices at different age periods of fruiting					
	period of growth and fruiting (1990-1996)		period of fruiting and growth (1997-2003)		fruiting period (2004-2016)	
	number of flowers, thousand pcs./ tree	number of fruits, pcs./tree	number of flowers, thousand pcs./ tree	number of fruits, pcs./tree	number of flowers, thousand pcs./ tree	number of fruits, pcs./ tree /
No fertilizer (control)	0,45	88	2,67	421	2,75	551
Manure 40 t/ha	0,57	117	2,89	512	2,83	632
20 t/ha Manure + N_{60} P_{60} K_{60}	0,53	112	2,82	481	2,82	600
N_{120} P_{120} K_{120}	0,58	116	2,85	476	2,69	564
LSD_{05}	*0,05*	*11*	*0,21*	*46*	*0,22*	*53*

2. Yield of the repeatedly cultivated plantations the Calville Snow apple tree variety on the seedling rootstock under for different fertilization, t/ha

Fertilizer option	Indices at different age periods of fruiting		
	period of growth and fruiting (1990-1996)	period of fruiting and growth (1997-2003)	fruiting period (2004-2016)
No fertilizer (control)	3,5	12,5	15,6
Manure 40 t/ha	4,8	17,4	20,7
20 t / ha manure + + N_{60} P_{60} K_{60}	4,5	16,8	19,3
N_{120} P_{120} K_{120}	4,7	15,1	17,5
LSD_{05}	*0,9*	*1,4*	*1,8*

3. Qualitative indices of fruit of the Calville Snow apple tree variety in the repeatedly cultivated plantations under different fertilization (average for 2004-2016).

Fruit quality indices	Parameters of indices in the studied options				
	No fertilizer (control)	Manure 40 t/ha	20 t/ha of manure + N_{60} P_{60} K_{60}	N_{120} P_{120} K_{120}	LSD_{05}
Average weight of fruit, g	113,9	125,6	125,0	120,3	6,7
Total yield of fruits of the highest and first commercial grades,%	82,1	85,1	85,0	84,1	6,8
Content of dry soluble substances,%	12,4	12,7	12,3	12,6	0,6
Sugar content,%	11,3	11,7	11,6	11,4	0,5
Acid content,%	0,46	0,45	0,47	0,47	*0,03*

increasing the productivity of experimental apple trees was caused by many factors, in particular, with 40 tons of manure it was introduced more into the soil than with mineral nitrogen fertilizers up to 30 kg/ha, potassium – up to 80, calcium – 160 and magnesium – 50 kg/ha and practically all of the micronutrients necessary for plant nutrition. In addition, soil fertility indices such as humus, biological activity, physical and chemical properties, in particular, the moisture supply of trees improved to a greater extent. The content of available compounds and forms of nitrogen, phosphorus and potassium was constantly at the highest level. Such a positive effect of organic fertilizers to some extent ensured the higher productivity of trees under organic and mineral fertilizers in comparison with mineral fertilizers.

Enriched backgrounds of mineral nutrients created with long-term systematic fertilization, and the fruit yield increase also contributed to the improvement of some indices of their quality. On average, during the years of fruiting, the fruits of the Calville Snow variety on the seedling rootstock were the largest under the organic and organic and mineral fertilizer systems and, accordingly, their average weight significantly exceeded by 10.3 and 9.7% its value in the control option, as well as on 4,4 and 3,9% in comparison with mineral fertilizers, in which the average mass did not differ significantly from the control (Table 3).

Commercial quality indices of fruits show that the highest and the first commercial grades were the major part of the obtained yield, but significant differences between them in the experimental options have not been found. The chemical composition of fruits changed more in separate research years depending on weather conditions, especially in the late summer and early autumn, which influenced the intensity of apples ripening. And the content of such studied ingredients in fruit as: dry soluble substances, sugars and organic acids also changed depending on the different fertilizers, but the average data of the analyzes for all years of research were similar and did not differ significantly.

Conclusions. 1. On the repeatedly cultivated planting of the Calville Snow apple tree variety on the area of the uprooted 50-year-old experimental apple orchard, a long-term systematic organic fertilization under the biennial application of 40 t/ha of cattle manure provided the formation of the highest fertility indices of dark gray podzolized soils and the corresponding increase in the yields on 35% compared with the control one without fertilization and 14.6% compared to mineral fertilization ($N_{120}P_{120}K_{120}$ in a year).

2. Organic and mineral fertilization under the application of the half-doses of organic and mineral fertilizers (20 t/ha of manure $N_{120}P_{120}K_{120}$ in a year) is close to organic and provides the increase of fruit yields in comparison with the value in the control option without fertilization and with mineral fertilizers by 18.3 and 10.3% respectively.

3. Formation of higher yields on the created higher backgrounds of mineral nutrition of trees takes place by intensifying the processes of fruiting (flowering, planting and preservation of fruit on the trees till the ripening period), as well as by increasing their size (average mass). Qualitative characteristics of fruits (marketability, chemical composition) do not change significantly under different fertilization of trees.

4. Under the organic gardening technology only organic fertilizers should be applied, and under the traditional intensive technology they can be successfully combined with mineral fertilizers, especially in modern conditions, due to the lack of organic fertilizers.

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