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EFFECTIVENESS OF THE APPLICATION OF GROWTH-STIMULATING BIOPRODUCTS IN INTENSIVE APPLE ORCHARDS

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ABSTRACT

The article investigates the influence of traditional mineral fertilizers (N_{60} $P_{60}K_{60}$) and biofertilizers on the indicators of preservation, growth, individual productivity and yield of apple fruits in 2022 – 2024 in the intensive semi-dwarf apple orchard of Vinnytsia National Agrarian University. The largest number of planted apple fruits on one tree was found when fertilizing with the Bionorma nitrogen preparation – 330 pieces. This was 23.9% more than in the control variant without fertilizer application, where 251 fruits were planted. Also, many fruits were formed on the variant with complex mineral fertilizer N_{60} $P_{60}K_{60}$ – 317 fruits, which was 20.8% more than on the control. The July and August fruit fall was insignificant compared to June. In particular, 0.3-1.1% of all laid fruits were lost in July. The greatest losses were observed on the control variant without fertilizers and with the application of mineral nitrogen N_{60}, and the smallest – on the variants with the application of biofertilizers Bionorma nitrogen and Bionorma garden. The most intensive growth in fruit diameter was observed on the variants with the application of biofertilizer Bionorma phosphorus and on the control without fertilizers – 48.3% each, from 3.0 to 5.8 cm. A strong negative correlation was found between the number of apple fruits on the tree and their diameter ($r = – 0.8029$). The largest apple harvest from one tree was established on the variant of applying complex mineral fertilizer N_{60} $P_{60}K_{60}$ – 23.90 kg, which amounted to 39.617 t/ha.

Keywords: apple tree, intensive orchard, mineral fertilizers, biological products, yield.

INTRODUCTION

Apple is the most popular and widespread pome fruit crop in temperate countries, which is able to adapt to growing in different climatic conditions, one of the most widely cultivated in the world, the fruits of which contain useful elements, are well stored and easily transported. All this contributes to the great export potential of this crop (Aglar, et al., 2016). In most developed countries of the world, the industrial establishment of intensive apple orchards on weakly growing clonal rootstocks is expanding. This type of plantation begins to bear fruit already in the 3rd year after planting, while classical ones – in the 6th-8th year, rapidly increasing industrial fruit yields and increasing the economic efficiency of production more than twice (Amarante, et al., 2008).

The high export potential of apple fruit production can be ensured by obtaining organic products. And this requires significant changes in the technology of growing apple trees, in particular in the direction of fertilizer application and protection of plantations from harmful organisms. One of the important components in the technology of growing fruit crops is the introduction of new generation biological products, which are characterized by higher efficiency and environmental safety and are aimed at stimulating and regulating the growth and development of trees, protecting them from the effects of pests and diseases, and also helping plantations overcome stressful conditions: drought, frost, waterlogging, storms and other adverse environmental factors (Vdovenko et al., 2018).

The practical interest in biological preparations is due to the fact that they allow for the production of organic fruit products, and are also safe for warm-blooded animals, humans, and pollinating insects. They also exhibit high selectivity, do not pollute the environment, and do not lead to soil degradation (Monarkh & Pantsyreva, 2019).

Today, biological preparations are also used to enrich the rhizosphere of plants with beneficial microorganisms, which are responsible for the effective nutrition of fruit crops with nutrients from the soil. Plant nutrition depends on which type of microorganisms dominates in the rhizosphere (Pantsyreva et al., 2023; Kaletnik et al., 2022).

Populating the root zone, microorganisms convert unavailable forms of nitrogen, phosphorus, and potassium in the soil into forms available to the plant, inhibit the development and destroy pathogenic microflora – pathogens of crop diseases, and produce phytohormones that directly affect plant growth and development, their resistance to external stresses, and therefore yield (Farionik et al., 2023).

Biological preparations are capable of increasing the yield and quality and environmental safety of fruits by 15–25%, have a positive effect on the preservation of soil fertility, form biologically active compounds – phytobiotics, phytohormones, amino acids and vitamins (Pantsyreva et al., 2020; Kaletnik et al., 2023).

It has been established that the highest efficiency of biological preparations is achieved when growing crops on mineral agro-backgrounds that do not exceed physiologically and agronomically appropriate indicators. At the same time, the coefficients of plant absorption of nutrients from fertilizers increase significantly, which has a positive effect on yield Kaletnik et al., 2024).

The effect of preparations under these conditions is equivalent to the effect of mineral nitrogen at the level of 30–60 kg/ha, phosphorus – 20–30 kg/ha, depending on the crop. Constant application of mineral fertilizers and intensive tillage reduces the number of soil microorganisms. Therefore, regular application of microbiological preparations allows soil biota to recover faster. Stimulating preparations are widely used as growth regulators. The use of such substances allows to activate plant growth processes, which leads to an increase in yield.

The entire set of groups of biological products that can be used on fruit plantations can be divided into biofertilizers, biopesticides, anti-stress agents and biological products of complex action. By the nature of use on certain crops, they can be divided into universal, which are used on many species, and specific, which are intended for one crop or similar crops (Table 1).

Table 1. System of groups of biological preparations for orchards.

Group of biological products	Type of biological product	Active ingredient
Biofertilizer (bioactivator)	Universal	*Azotobacter chroococcum, Azotobacter vinelandii, Azospirillum brasilense, Azospirillum lipoferum*
Biofertilizer (bioactivator)	Universal	*Bacillus megaterium* i *Bacillus amyloliquefaciens, Trichoderma harzianum*
Biopesticide (biofungicide)	Universal	*Pseudomonas fluorescens, Pseudomonas aureofaciens, Pseudomonas putida*
Biopesticide (biofungicide)	Universal	*Trichoderma harzianum, Trichoderma lignorum, Trichoderma viride*
Biopesticide (bioinsecticide)	Universal	Avermectins produced *Streptomyces avermitilis*
Complex growth biostimulant	Specialized	*Pseudomonas fluorescens, Paenibacillus polymyxa, Bacillus subtilis, Streptomyces* sp.
Anti-stressor	Universal	*Pseudomonas fluorescens, Pseudomonas putida, Paenibacillus polymyxa*

The use of biofertilizers in planting fruit crops is based on improving their nitrogen and phosphorus nutrition. In particular, preparations based on free-living and associative nitrogen-fixing bacteria are designed to improve the nitrogen nutrition of a wide range of agricultural crops. The composition of nitrogen-fixing bacteria is characterized by a complex effect on plants. Free-living nitrogen fixers of the Azotobacter genus of bacteria are able to fix atmospheric nitrogen and accumulate it in the upper soil layer, enriching it with nitrogen in a form available to plants.

Microorganisms of the genus *Azospirillum* are associative nitrogen-fixing bacteria that colonize the rhizosphere and rhizoplane of plants. They fix atmospheric nitrogen in close proximity to the root, promote its assimilation by the plant, increase the ability of roots to retain water, and enhance plant growth as a whole.

The combination of free-living and associative nitrogen-fixing bacteria complement each other's action, ensuring the most effective accumulation of nitrogen compounds as a result of their biological nitrogen fixation and contributing to an increase in the content of available nitrogen in the soil up to 40 kg/ha and a decrease in the rate of nitrogen mineral fertilizers.

Another representative of biofertilizers is a preparation of soil spore bacteria and micromycetes, which are characterized by high phosphate-mobilizing activity, designed to improve the phosphorus nutrition of agricultural crops. The effectiveness of such a biofertilizer is ensured by the complex action of spore bacteria Bacillus megaterium and Bacillus amyloliquefaciens and micromycetes Trichoderma harzianum. Microorganisms Bacillus megaterium and Trichoderma harzianum mobilize inorganic phosphorus through the synthesis of a complex of organic and inorganic acids, bacteria Bacillus amyloliquefaciens mobilize organic phosphorus compounds by producing enzymes – phosphatases.

Biopreparations of protective and stimulating action with increased antibacterial and antifungal activity for protection against phytopathogenic microorganisms – pathogens of diseases of cultivated plants are developed on the basis of Pseudomonas bacteria. These bacteria are able to produce antibiotics of the phenazine group, pyrrolnitrin and sulfacezin, which inhibit the development of phytopathogens of both bacterial and fungal origin. Phenazines induce the formation of active oxygen species inside the cells of all phytopathogenic microorganisms, which leads to their death. Pyrrolnitrin disrupts the osmotic pressure of fungal phytopathogen cells, leading to their autolysis.

Biofungicides based on Pseudomonas bacteria provide protection for cultivated plants, including fruit plants, from potential pathogens of bacterial and fungal origin: phytopathogenic fungi of the genera *Fusarium, Phytium, Helmintosporiumm, Cladosporium, Colletotrichium, Botrytis, Rhizopus, Sclerotinia, Septoria* and bacteria of the genera *Erwinia, Xanthomonas, Pseudomonas.*

The antibiotic sulfacetamide has bacteriostatic activity, disrupting the synthesis of tetrahydrofolic acid, which is necessary for the synthesis of purines and pyrimidines in a bacterial cell, the main structural elements of its DNA.

Biofungicides for protecting plants from diseases caused by pathogens of fungal origin are developed on the basis of spores and mycelia of representatives of the genus Trichoderma fungi. The effectiveness of the drug is ensured by a wide range of properties of micromycetes of the genus Trichoderma, the action of which is aimed at combating pathogens of fungal diseases.

Bioinsecticides are developed on the basis of natural avermectins – specific neurotoxins that are able to penetrate the body of insect pests by intestinal or contact and affect their nervous system. Avermectins are produced by the beneficial soil fungus *Streptomyces avermitilis*. An effective drug against garden pests: aphids, mites, leafrollers, mealybugs, scoops.

Biological products for protecting cultivated plants from adverse environmental conditions constitute a new type of group – anti-stress agents (Mazur et al., 2020; Pryshliak et al., 2022). Such products include several types of microorganisms with synergistic action, which ensure the comprehensive restoration of the plant organism.

Representatives of the genus *Pseudomonas* synthesize phytohormones of the auxin group, the action of which is aimed at the restoration and development of the plant root system. The bacteria *Paenibacillus polymyxa*, due to their tendency to form biofilms on the root surface, create a protective layer around the underground part of the plant, protecting it from the penetration of any pathogenic forms of soil bacteria and fungi. Associative nitrogen fixers *Azospirillum lipoferum* replenish nitrogen reserves in the fertile soil layer, and due to their ability to establish themselves in the rhizoplane of the plant, these bacteria actively supply nitrogen to the root surface and provide enhanced nitrogen nutrition of plants. Microorganisms of the species *Pseudomonas putida* have the ability to decompose pesticide and agrochemical residues in the soil, thus neutralizing the aftereffects of these drugs for subsequent crops in the crop rotation. This ensures the restoration and protection of the plant organism after the action of stress factors: exposure to high and low temperatures, drought, soil salinity, excess pesticides and agrochemicals (Bassi et al., 2018; Kolisnyk et al., 2024).

The synergistic action of 4 types of bacteria ensures rapid recovery of the plant organism, the plant is reliably protected from stress factors that may affect it during the growing season. Thanks to the introduction of bacteria with beneficial agronomic properties, the normal soil microbiota is restored, and the process of soil disinfection from pesticide and agrochemical residues also occurs (Amarante et al, 2013; Titarenko et al., 2024).

The complex stimulating effect of biological products on fruit plantations can be manifested in the protection of plantations from diseases and the simultaneous stimulation of plant growth and nutrition (Tkach et al, 2024;

Kaletnik et al, 2024). Such biological products contain three types of bacteria and a representative of the genus Streptomyces, which together provide full protection of garden crops, especially in the initial stages of the growing season. Prevention of disease in garden crops is ensured by the action of the bacterium *Paenibacillus polymyxa*, which covers the surface of the plant root with a biofilm that is impermeable to pathogenic forms of microorganisms. *Pseudomonas luorescens* ensures full development of the root system, synthesizes phytohormones auxins, which contribute to the rapid increase in the area of the underground part of the plant, and therefore improve its water and mineral nutrition, increase vegetation indicators and yield. Plant protection occurs primarily due to the active production by the drug's bioagents (*Bacillus subtilis, Streptomyces* sp.) of a number of antibiotic compounds that provide resistance to fusarium, septoria, ramulariosis, late blight, root and soft rot, as well as other common diseases of garden crops caused by fungi of the genera *Fusarium, Septoria, Aspergillus, Phytophthora, Colletotrichium, Botrytis, Rhizopus* and bacteria of the genera *Erwinia, Clavibacter* and *Xanthomonas*.

It has been scientifically proven that the use of soils for gardens causes their more powerful degradation than under arable land. This is caused by intensive and monotonous soil cultivation, long-term monoculture of garden plants, repeated application of pesticides and mineral fertilizers, large-scale alienation of fruit biomass and during pruning of branches. Mineral fertilizers introduce cadmium, lead, zinc, manganese, arsenic and other toxic elements into the soil. Therefore, to reduce degradation processes in soils, improve the quality and environmental safety of the resulting products, which will meet the requirements of organic production, it is necessary to switch from the use of traditional mineral fertilizers to their alternatives: organic, biological, microfertilizers and others (Bakhmat et al., 2023; Pantsyreva et al. 2023; Didur et al. 2024). Since in conditions of shortage of organic fertilizers it is impossible to provide them to the entire horticultural industry, an important emphasis should be placed on biofertilizers (Honcharuk et al., 2022; Tkachuk et al., 2025; Mazur et al., 2023). But their effectiveness in horticulture has been practically not studied, especially in comparison with traditional mineral fertilizers (Puyu et al., 2020; Razanov et al., 2024; Hontaruk et al., 2024).

Experimental

Field observations were conducted in 2022–2024 in the intensive semi-dwarf apple orchard of Vinnytsia National Agrarian University. The apple variety is Jonathan. The soil in the orchard is gray podzolized medium loam. The influence of traditional mineral fertilizers and biofertilizers of the Bionorma series, produced by the Bionorma company, on the indicators of preservation, growth, individual productivity and yield of apple fruits was studied. Among the mineral fertilizers, ammonium nitrate was applied at a rate of 60 kg/ha of mineral nitrogen, double superphosphate at a rate of 60 kg/ha of mineral phosphorus and nitroammofosk at a rate of 60 kg/ha of mineral nitrogen, phosphorus and potassium. Mineral fertilizers were applied by scattering in the tree trunk circles in the spring with their incorporation into the soil. Biofertilizers of the Bionorma series included: Bionorma nitrogen at a rate of 10 l/ha, Bionorma phosphorus at a rate of 10 l/ha, Bionorma garden at a rate of 5 l/ha. Biofertilizers were applied by spraying the soil around the trunk circles with a working fluid consumption of 200 l/ha with subsequent incorporation into the soil. The preparations were applied in the spring.

The accounting plot included one row of trees and was 60 m^2 in four replications. The following observations and accounts were made: the total number of fruits laid on one tree, the percentage of June, July and August fruit fall were counted. The dynamics of the average diameter of fruits in June, July, August, September were measured. The indicators of individual tree productivity were determined: the number of fruits before harvesting was counted; the average weight of one fruit was determined by weighing. The yield of fruits from a tree was determined by the method of direct continuous picking and weighing. The correlation-regression dependence between the studied factors was calculated.

Bionorma nitrogen is a preparation of free-living and associative nitrogen-fixing bacteria to improve nitrogen nutrition of crops. Contains free-living nitrogen-fixing bacteria: *Azotobacter chroococcum, Azotobacter vinelandii,* associative nitrogen-fixing bacteria *Azospirillum brasilense, Azospirillum lipoferum.*

Bionorma phosphorus is a preparation of soil spore bacteria and micromycetes, characterized by high phosphate-mobilizing activity, designed to improve phosphorus nutrition of crops. Contains spore bacteria *Bacillus megaterium* and *Bacillus amyloliquefaciens* and micromycetes *Trichoderma harzianum.*

Bionorma garden is a preparation containing three species of bacteria and a representative of the genus Streptomycetes. All of them together provide complete protection of garden crops, especially in the initial stages of vegetation and improve the growth and nutrition of garden crops due to the content in the preparation of living cells of microorganisms *Pseudomonas fluorescens, Paenibacillus polymyxa, Bacillus subtilis, Streptomyces sp.*

RESULTS AND DISCUSSION

One of the important factors in the formation and preservation of apple fruit yield is the total number of fruits set on one tree and the intensity of their fall (Baugher et al., 2017). We found the largest number of apple fruits set on one tree when fertilized with Bionorma nitrogen – 330 pieces. This was 23.9% more than in the control variant without fertilizer, where 251 fruits were set. Also, many fruits were formed on the variant with complex mineral fertilizer $N_{60}P_{60}K_{60}$ – 317 fruits, which was 20.8% more than in the control. The smallest number of fruits was formed on the variants with the application of biological fertilizer Bionorma phosphorus and Bionorma garden – 191 fruits each, which was 23.9% less than in the control. Also, fewer fruits were set than in the control on the variants of fertilization with mineral nitrogen fertilizer N_{60} – 215 fruits and mineral phosphorus fertilizer P_{60} – 207 fruits (tab.2).

Table 2. Intensity of premature apple fruit drop depending on fertilization.

Fertilizer option	Total number of fruits laid on one tree, pcs.	June fruit drop, %	July fruit drop, %	August fruit drop, %	Fruits left, pcs.	
					pcs.	%
N_{60}	215	14,0	1,1	2,8	177	82,1
P_{60}	207	12,9	0,8	2,6	173	83,7
$N_{60}P_{60}K_{60}$	317	14,0	0,4	1,3	267	84,3
Nitrogen bionorm	330	12,6	0,3	1,2	283	85,9
Bionorm phosphorus	191	17,5	0,5	1,7	153	80,1
Bionorm garden	191	15,7	0,3	1,2	158	82,8
Without fertilizer (control)	251	22,6	1,1	1,6	188	74,7

However, the total number of fruits laid by a tree on one tree does not determine the final yield, since fruit trees are characterized by the shedding of unformed fruits. This process is due to the tree shedding an excess amount of fruits due to a lack of moisture, nutrients and other unfavorable vegetation conditions. The tree remains with as many fruits as it can provide in sufficient quantity for their full ripening. June, July and August fruit shedding are distinguished. The greatest fruit shedding in June was detected in the control variant without fertilizer application – 22.6% of the total number of laid fruits. The least fruit fell on the variants with the application of biofertilizer Bionorm nitrogen – 12.6% and mineral phosphorus P_{60} – 12.9% of the total number of laid fruits. Among the variants with fertilizer application, the greatest number of fruit fell in June, where Bionorm phosphorus fertilizer was applied – 17.5%. July and August fruit drop was insignificant, compared to June. In particular, in July 0.3-1.1% of all laid fruits were lost. The greatest losses were observed in the control variant without fertilizers and with the application of mineral nitrogen N60, and the smallest – in the variants with the application of biofertilizers Bionorma azot and Bionorma sad. August fruit drop was 1.2-2.8%. It was greatest in the variant with the application of mineral nitrogen N60 and mineral phosphorus P60, and the smallest - with the application of biofertilizers Bionorma azot, Bionorma sad and complex mineral fertilizer $N_{60}P_{60}K_{60}$. In general, taking into account the losses of fruits that fell during summer fall, the largest number of fruits was preserved until the end of the growing season in the variant with the application of biofertilizer Bionorma nitrogen – 283 fruits and complex mineral fertilizer $N_{60}P_{60}K_{60}$ – 267 fruits. This was 33.6% and 29.6% more, respectively, than in the control without fertilizer. The smallest number of fruits remained before harvesting in the variant with the application of mineral nitrogen N_{60} and mineral phosphorus P_{60} – 177 and 173 fruits, respectively. This was 5.6% and 8.0% less than in the control. In general, the largest percentage of apple fruits was preserved from laid fruits until harvesting in the variant with the application of biofertilizer Bionorma nitrogen – 85.9% and complex mineral fertilizer $N_{60}P_{60}K_{60}$ – 84.3%. This was 11.2% and 9.6% more, respectively, than in the control variant without fertilizer application, where the share of preserved fruits was 74.7%. Among the variants with fertilizer application, the least number of fruits was preserved until the end of the growing season when applying the biofertilizer Bionorm Phosphorus – 80.1%. But this was also 5.4% more than in the variant without fertilizer application. An important factor influencing the formation of apple fruit productivity is the intensity of their growth, which is manifested in the increase in the size of apples. We studied the dynamics of changes in the diameter of apple fruits during the period from June to September, as an indicator of the formation of their productivity. In June, the largest diameter of apple fruits was observed in the variant of mineral nitrogen application N_{60} – 5 cm, and the smallest – in the variant of biofertilizer application Bionorma Phosphorus and in the control without fertilizer application – 3 cm. In the remaining variants, the diameter of the fruits was about 4 cm (Table 3).

Table 3. Dynamics of apple fruit diameter growth depending on fertilization.

Fertilizer option	Fruit diameter, cm				Percentage of fruit diameter growth from June to September
	June	July	August	September	
N_{60}	5,0	5,5	5,7	6,0	16,7
P_{60}	4,0	4,5	6,0	6,2	35,5
$N_{60}P_{60}K_{60}$	4,0	4,3	5,0	5,2	23,1
Nitrogen bionorm	4,0	4,5	5,0	5,5	27,3
Bionorm phosphorus	3,0	4,5	5,6	5,8	48,3
Bionorm garden	4,0	4,6	6,0	6,5	38,5
Without fertilizer (control)	3,0	4,2	5,5	5,8	48,3

In July, the largest diameter of apple fruits was maintained in the variant of applying mineral nitrogen N_{60} – 5.5 cm, and the smallest - in the control variant without fertilizer - 4.2 cm and with the application of complex mineral fertilizer $N_{60}P_{60}K_{60}$ – 4.3 cm. In August, the largest diameter of apples was observed in the variants of applying mineral phosphorus P60 and biofertilizer Bionorma Sad – 6.0 cm each. The smallest diameter of apples was observed in the variant of applying complex mineral fertilizer $N_{60}P_{60}K_{60}$ and biofertilizer Bionorma Azot – 5.0 cm each. In September, the largest diameter of apples was achieved by fruits from the variant of applying biofertilizer Bionorma Sad – 6.5 cm, and the smallest - from the variant of applying complex mineral fertilizer $N_{60}P_{60}K_{60}$ – 5.2 cm. In the control variant without fertilizer application, the fruit diameter was 5.8 cm. This was 10.8% less than the fruit diameter from the variant of applying the biofertilizer Bionorma Sad; 6.5% less than from the variant of applying mineral phosphorus P_{60} and 3.3% less than from the variant of applying mineral nitrogen N_{60}. In the remaining variants, the diameter of apple fruits was 5.2-10.3% less than in the control, with the exception of the variant of applying the biofertilizer Bionorma Phosphorus, where the fruit diameter was the same as in the control. During the period June - September, the diameter of apple fruits increased by 16.7-48.3%. The most intensive growth in fruit diameter was observed in the variants of applying the biofertilizer Bionorma Phosphorus and in the control without fertilizers - 48.3% each, from 3.0 to 5.8 cm. But on these variants the diameter of the fruits in June was the smallest compared to other variants. Also, a high intensity of growth in the diameter of apple fruits during the studied period was established on the variants of applying the biofertilizer Bionorma Sad – 38.5%, from 4.0 to 6.5 cm and applying mineral phosphorus P_{60} – 35.5%, from 4.0 to 6.2 cm. It was on the variant of applying the biofertilizer Bionorma Sad in September that the largest diameter of apple fruits was established among all variants. The least intensive growth in the diameter of apple fruits over four months was found on the variant of applying mineral nitrogen N_{60} – 16.7%, from 5.0 to 6.0 cm. But on this variant the diameter of fruits in June was the largest among all variants. We found a strong negative correlation between the number of apple fruits on the tree and their diameter (r = –0.8029).

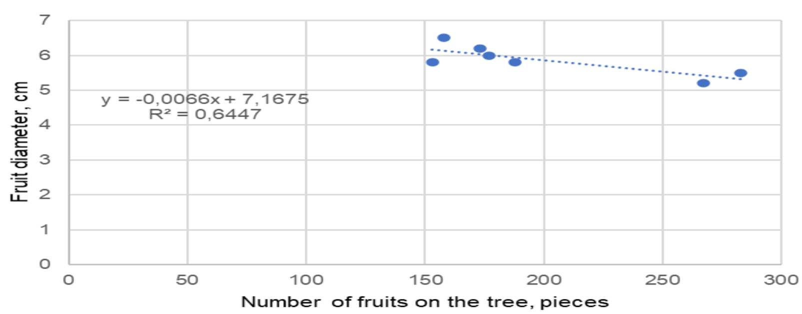

Figure 1. Correlation-regression relationship and regression equation between the number of fruits on a tree and their diameter.

This indicates that the more apple fruits are formed on the tree, the smaller the fruit diameter. The coefficient of determination R^2 = 0.6447 shows that the fruit diameter depends on the number of fruits on the tree by 64%. The graphical relationship between the studied factors and the regression equation are presented in Fig. 1.

The indicators of individual fruit productivity are their number on the tree and the average weight of one fruit. The largest number of fruits on one tree was established on the variant of applying the biofertilizer Bionorma nitrogen –

283 fruits, which was 95 apple fruits more than on the control variant, where there were 188 fruits. Also, many apple fruits were found on the variant of applying the complex mineral fertilizer $N_{60}P_{60}K_{60}$ – 267 pieces. This was 79 fruits more than on the control. The smallest number of fruits was found on the variants of applying the biofertilizer Bionorma phosphorus – 153 fruits, which was 35 fruits less than on the control and on the variant of applying the biofertilizer Bionorma garden – 158 fruits, which was 30 fruits less than on the control (Table 4).

Table 4. Individual productivity and yield of apples depending on fertilization.

Fertilizer option	Number of fruits on the tree, pcs.	Average weight of one fruit, g	Marketability of fruits, %	Harvesting apples from the tree, kg	Apple yield, t/ha
м	177	122	90	21,59	35,788
P_{60}	173	100	95	17,23	28,562
$N_{60}P_{60}K_{60}$	267	90	95	23,90	39,617
Nitrogen bionorm	283	78	95	21,99	36,451
Bionorm phosphorus	153	106	95	16,26	26,954
Bionorm garden	158	137	95	21,57	35,756
Without fertilizer (control)	188	81	85	15,22	25,229

The largest weight of one fruit was found in the variant of applying biofertilizer Bionorma garden – 137 g, which was 40.9% more than in the control variant, where fertilizers were not applied (81 g) and when applying mineral nitrogen N_{60} – 122 g, which was 33.6% more than in the control. The smallest weight of one fruit was established in the variant of applying biofertilizer Bionorma nitrogen – 78 g, which was 3.7% less than in the control variant. The largest harvest of apples from one tree was established in the variant of applying complex mineral fertilizer $N_{60}P_{60}K_{60}$ – 23.90 kg, which was 39.617 t/ha. This was 36.3% more than the yield of apples in the control variant without fertilizer, where the harvest of apples from one tree was 15.22 kg, and the yield was 25.229 t/ha. It was in the control variant that the lowest harvest of apples and yield per hectare was. With the application of Bionorm nitrogen biofertilizer, the harvest of apples from one tree was 21.99 kg, and the yield was 36.451 t/ha. The result obtained was 8.0% less than when fertilizing the garden with a complete complex fertilizer $N_{60}P_{60}K_{60}$, but 30.8% more than in the control. Similar to the variant with the biofertilizer Bionorma nitrogen was the yield of apples with the application of the preparation Bionorma sad: the harvest of apples from one tree was 21.57 kg, and from one hectare – 35.756 t. This was 29.4% more than in the control. Fertilization with mineral nitrogen N60 resulted in the harvest of apples from one tree of 21.59 kg, and the yield – 35.788 t/ha, which was 29.5% more than in the control. The application of mineral phosphorus in the norm P60 ensured the harvest of apples from one tree of 17.23 kg or 28.562 t/ha, which was 11.7% more than in the control.

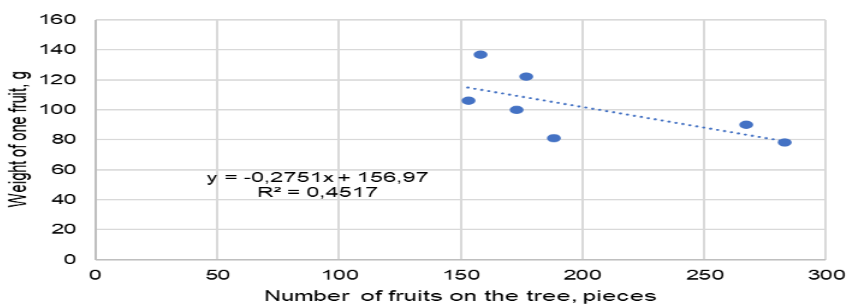

Figure 2. Correlation-regression relationship and regression equation between the number of fruits on a tree and the weight of one fruit.

The lowest increase in yield was provided by the biofertilizer Bionorma phosphorus – 6.4% compared to the control, which was 16.26 kg/tree or 26.954 t/ha. We also observed the marketability of the obtained apple fruits. We established a high marketability of fruits when fertilizers were applied. For most variants, the marketability of fruits was 95%, only for the variant of fertilization with mineral nitrogen N60 the marketability of fruits was 90%, and for the control variant without fertilizers it was the lowest – 85%. We found a strong negative correlation between the number of apple fruits on a tree and the weight of one fruit (r = –0.6721). This indicates that the more apple fruits are formed on a tree, the less weight of one fruit they have. The coefficient of determination R2 = 0.4517 shows that the weight of one fruit depends on the number of fruits on the tree by 45%. The graphical relationship between the studied factors and the regression equations are presented in Fig. 2.

We also found an average positive correlation between the number of apple fruits on a tree and the weight of fruits from one tree (r = 0.5919). This indicates that the more apple fruits are formed on a tree, the greater the harvest from one tree. The coefficient of determination $R^2 = 0.3504$ shows that the yield of apples from one tree depends on the number of fruits on the tree by 35%. The graphical relationship between the studied factors and the regression equation are presented in Fig. 3.

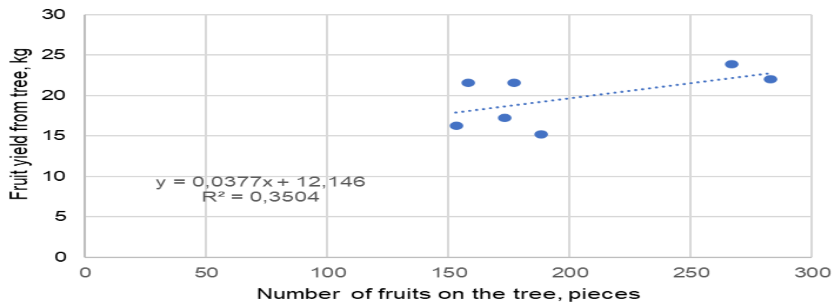

Figure 3. Correlation-regression relationship and regression equation between the number of fruits on a tree and the yield of fruits from a tree.

It was found that the Bionorm phosphorus fertilizer variant had the smallest number of set fruits and fruits before harvesting; the Bionorm garden fertilizer variant also had the smallest number of set fruits and fruits before harvesting, but the largest diameter of apples and the largest weight of one apple before harvesting; the fertilizer variant with nitrogen mineral fertilizer at the rate of N_{60} was characterized by the largest percentage of apple dropping in July and August. The control variant without fertilizer application was characterized by the largest percentage of fruit dropping in June and July, as well as the smallest percentage of fruit preservation, had the smallest weight of one fruit, the smallest percentage of fruit marketability and the lowest fruit yield.

CONCLUSIONS

- So, when fertilizing an intensive apple orchard with classic mineral fertilizers and biofertilizers of the Bionorm series, the highest fruit yield is ensured by applying a complex mineral fertilizer at the rate of $N_{60}P_{60}K_{60}$ – 39.617 t/ha. When replacing mineral fertilizers with the biological fertilizer Bionorm nitrogen, the fruit yield decreases by 8.0% and amounts to 36.451 t/ha. This biological fertilizer provides apple yield 1.8% higher than the application of mineral nitrogen N60 and 26.1% higher than the application of mineral phosphorus P_{60}.
- High apple yield with the application of the biofertilizer Bionorm nitrogen is ensured by the largest number of laid fruits, the smallest percentage of their falling off during June – August, the highest percentage of fruit preservation before harvest and the largest number of them before harvest from one tree.

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