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INFLUENCE OF MINERAL FERTILIZERS AND BIOPRODUCTS ON THE AGROCHEMICAL PROPERTIES OF DARK CHESTNUT SOIL AND QUALITY OF APPLE FRUITS IN THE CONDITIONS OF THE SOUTH-EAST OF KAZAKHSTAN

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Abstract

Aport is a unique apple tree that, mainly grown in Almaty, Kazakhstan. The apple is highly favored by the local community in Kazakhstan because of the taste qualities, the smell characteristics and the size that is unusually big for an apple, which surpasses all other apple varieties grown locally. Cultivation of Aport is highly responsive to the application of mineral and organic fertilizers, and sensitive to soil water availability. An experiment was conducted in Spring 2009 season in the young Aport garden, with experimental plot of 0.75 hectares. Apple trees spacing were 5m (between rows) x 3m (between trees). Fertilizers were applied 2 times/year with, (i) half the dose in spring and, (ii) half the dose in summer during active shoot growth. Foliar treatment with bioproduct MERS were applied 2 times/year similar with the fertilizer application. Plus, water irrigated with drip irrigation system. Soil samples at 2 depth (0-30cm and 30-60cm) were collected from the experimental plots, and subjected to soil nutrient analyses NPK. Study data indicated low in available nitrogen (N) between 4,28-7,76 meq/100g (opt: 6-10 meq/100g), low-medium available phosphorous (P) with 2,8-3,15 meq/100g, and medium potassium (K) content with 42-48 meq/100g.

Studies were conducted on individual quality indicators against the background of daily and periodic irrigation: vitamin "C", total sugar (glucose+fructose), titrated acidity, soluble dry matter. The content of vitamin "C" against the background of two types of irrigation in the variant of joint application of MERS with ½ of the dose of the calculated norm NPK - 7.86 -7.98%, control tests of total sugar had the same tendency variants N60P55K55 and N60P55K55 + MERS contained 11.64 - 12.22% of total sugar, against the background of periodic irrigation, and against the background of daily irrigation 12,11 - 12,73%, respectively. The results of soluble dry matter on the background of periodic irrigation vary within 12.13 - 13.27%, and on the background of daily irrigation it was within 12.33 - 13.00%.

Keywords: agriculture, soil science, agrochemistry, fruit growing, apple tree, Aport variety fertilizer, biological product, fruit quality, irrigation.

1.0 Introduction

Modern day apple cultivation often requires significant amount of inorganic fertilizers (in the form of NPK). Application of such fertilizer often result good yield, however it is not sustainable [1]. Nitrogen and phosphorus are essential nutrients for plant growth and development. In irrigated apple orchard systems, the magnitude and timing of plant demand for nitrogen (N) and retention of N in the root zone to allow root interception are important factors for efficient management of N fertilizer. While N application can supply sufficient nutrients to improve plant production, it also leads to a worldwide concern about environmental contamination resulting from excessive nitrate leaching. Large quantities of chemical fertilizers are used to replenish soil N and P, resulting in high costs and severe environmental contamination [2].

Based on numerous experiments, it can now be considered an established fact that the need of agricultural plants for phosphorus and potash fertilizers is manifested only when nitrogen is provided [3-6]. A high reaction to nitrogen, especially in intensive gardens, was noted in studies conducted in Belgium. The yield of apple trees with full mineral fertilizer was 19% higher than in the control, and with phosphorus-potassium - 19% lower. Summing up the results of almost 30 years of work of experimental stations in the USA on fertilizing fruit plants, noted that on a number of soil differences, fruit plants did not react to the application of several mineral elements of nutrition or reacted only to nitrogen. At the same time, for most fruit breeds, high yields were obtained without adding potassium, even on soils that are poor in content of this element. According to scientists, trees that were fertilized with phosphorus fertilizers usually either did not differ in yield from those that were not fertilized, or the increase was small [5,7,8].

In the experiments of Pennsylvania, only nitrogen gave positive results for fertilizing apple trees in the first years, later, when adding phosphorus and potassium to nitrogen, the trees became more productive than when applying a single nitrogen fertilizer. In most experiments conducted in the United States [8,9], apple trees reacted positively to nitrogen fertilizers, and for German conditions, based on 30 years of experience in the garden, it is concluded that there was no reaction to phosphorus and the plants' acute need for potassium [10]. High responsiveness of fruit trees to nitrogen and potash fertilizers and weak to phosphoric ones was established in experiments in Poland [11]. The apple tree and other fruit trees did not react much to phosphoric and potash fertilizers in the experiments of American researchers.

The most important issue of the system of fertilization of fruit plants is the development of optimal doses and ratios of fertilizers that ensure a high yield of fruits. Therefore, it is necessary to conduct research related to optimizing the mineral nutrition of apple plants. At the same time, it is necessary to set maximum doses of fertilizers, which will ensure maximum plant productivity, stable fruiting, high quality and environmental safety of fruits.

2.0 Materials and methods

It is well known that the South-East of Kazakhstan is a favorable area for the cultivation of many fruit crops, the region has the main areas of intensive gardens. In recent years, 800 hectares of orchards have been laid in the Almaty region, of which 155 are apple trees of the Aport variety.

The climate of the foothill zone of the South-East of Kazakhstan is sharply continental, with frequent frosts and recurrent cold in April and early May. The amount of precipitation per year is about 500 mm. The average annual air temperature is +8.6°C. Duration of the frost-free period is on average 150 days. The sum of the effective temperatures is 3100-3300°C, which is sufficient for normal growth and development of fruit crops (Figure 2).

The soil cover of the Almaty region is represented by various types of soils with different mechanical composition. In most of the soils of this region are well provided with mobile forms of nutrient elements, are in relatively good terrain conditions, are available for irrigation, mechanized processing and are favorable for the cultivation of fruit crops.

The experiment is based on dark chestnut soil, which is medium-loam in mechanical composition, and has a fully developed profile, clearly differentiated into genetic horizons. The arable soil layer contains 3.31-3.86 % humus, 0.18-0.20 % total nitrogen, 0.19-0.20 % total phosphorus. The soil of the site is moderately provided with mobile forms of nutrient elements. The content of mobile phosphorus in the arable layer is 30-40 mg/kg of soil, exchange potassium 350-390 mg/kg. Amount of absorbed bases (cation exchange capacity) is 20-21 mg-eq. per 100 g of soil. The reaction of the soil solution is slightly alkaline, close to neutral (pH 7.3-7.4). The soil is weakly and medium-compacted, the volume mass is 1.1-1.2 kg/cm3, the lowest moisture content is 26.6 %.

The following scheme for applying fertilizers to the crop is applied:

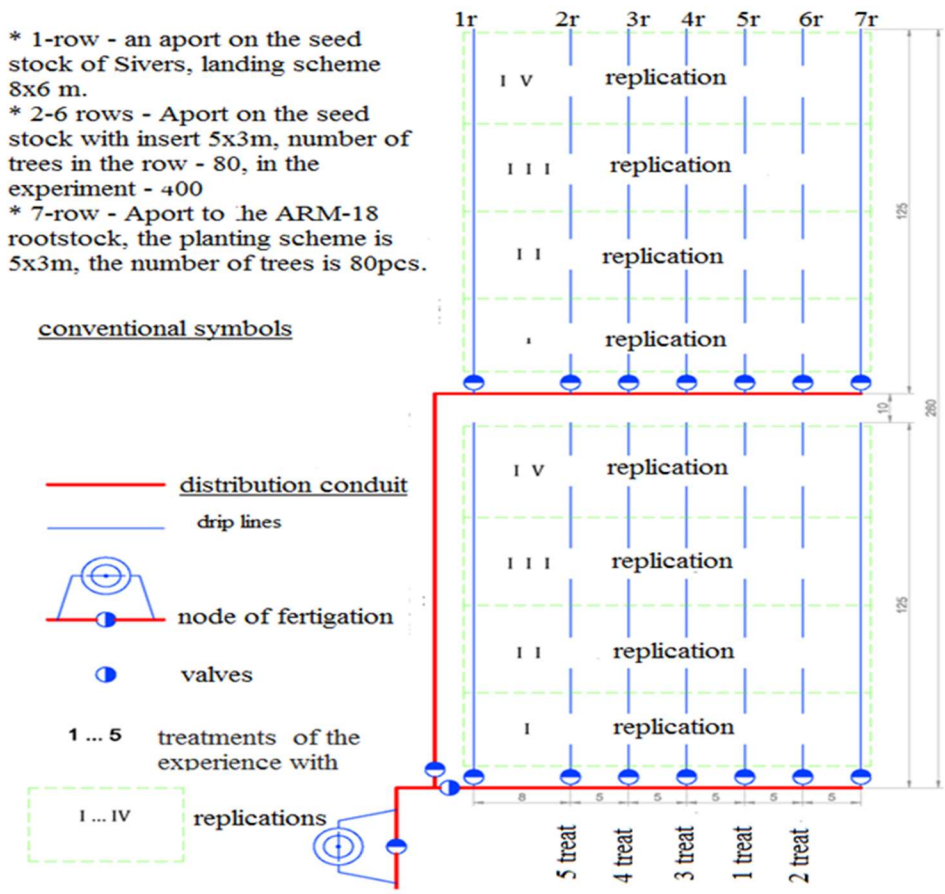
1. Control (without fertilizer)
2. N110P110K120
3. N55P55K60
4. N55P55K60 + Rosasol
5. N55P55K60 + MERS

The planting scheme is 3,5x0,6 m. Number of trees in the plot is 5, in the variant - 15.

MERS microfertilizer is an element of the latest generation, which is based on compounds of chlorophyll-vitamin-phytoncidal compositions of vegetation and substances of the groups: Fe, Mo, Cu, Zn, Mn, Co, B. Thanks to this highly effective drug.

Rare fertilizer “Rosasol” of the Belgian company is a full range of water-soluble fertilizers containing both nitrogen, phosphorus, potassium (NPK) and trace elements: boron (B), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), as well as sulfur (S2O3), magnesium (Mg). They are characterized by low chlorine content, which better meets the needs of agricultural crops (4% of total nitrogen, including 4% of nitrate nitrogen, 5.8% of magnesium oxide (MgO), 17.3% of sulfur dioxide, 3.6% of manganese (Mn).

Nutrient status of soils by phases during vegetation in soil samples using methods for humus content according to I.V. Tyurin, the content of gross forms of nitrogen, phosphorus, and potassium from one sample according to Ginzburg and Shcheglova with further determination of nitrogen by Kjeldahl, phosphorus colorimetrically, and potassium on a flame photometer, and mathematical processing of yield data using methods of dispersion analysis by B.A. Dospekhov.



The diagram of scheme experience on fertilizers and drip irrigation apple varieties Aport

3.0 Results and discussion

Fertilizers had a positive effect on the content of easily hydrolyzed nitrogen in the soil. Based on the data, it can be noted that for all variants of the experiment, the content of easily hydrolyzed nitrogen is due to the use of plants, as well as their partial leaching into deeper root-inhabited layers of the soil. For example, in the case of a variant using the calculated norm of mineral fertilizers, the nitrogen content is 5.88 mg/100g of soil. On variants with the use of half of the calculated norm of mineral fertilizers together with the bioproduct MERS, the nitrogen content of 7.76 mg/100g of soil (data average for 0-60 cm of the horizon, for 2016-2018.)

The intensity of nitrogen reduction is correlated to a certain extent with the level of nutrient absorption and the magnitude of production processes.

The source of direct phosphorus nutrition of plants is mainly mineral phosphates, which are formed as a result of the splitting of its difficult-to-dissolve mineral compounds and the mineralization of organic forms of phosphorus in the soil.

In the experiment, the content of mobile phosphates in the control variant is 2.31 mg/100 g of soil. All fertilized variants contributed to an increase in the content of phosphates in the soil. Of the studied fertilizers, the greatest accumulation of mobile phosphates in the initial phases of growth

and development is provided by variants with N110P110K120, as well as the joint use of MERS with a ½ of the dose calculated norm of NPK. At the same time, the content of mobile phosphorus in soils was slightly lower in comparison with the above-mentioned variants in the variants using N55P55K60 and N55P55K60 + Rosasol.

The intensity of the decrease in mobile phosphates in dark chestnut soil is to a certain extent associated with the consumption of plants, as well as the processes of phosphorus retrogradation of fertilizers.

Exchange potassium is the main source of plant nutrition, as water-soluble potassium in soils contains very little. Replenishment of exchange potassium reserves occurs due to the gradual restoration of equilibrium between the exchange and fixed forms, which are displaced under the influence of plants. This leads to the fact that with prolonged cultivation of plants with high productivity, a decrease in its non-exchangeable forms occurs in the soil.

On dark chestnut soil, the effect of mineral fertilizers contained from 42 to 48 mg/100 g of exchange potassium soil, and on the control variant 36 mg/100 g of soil.

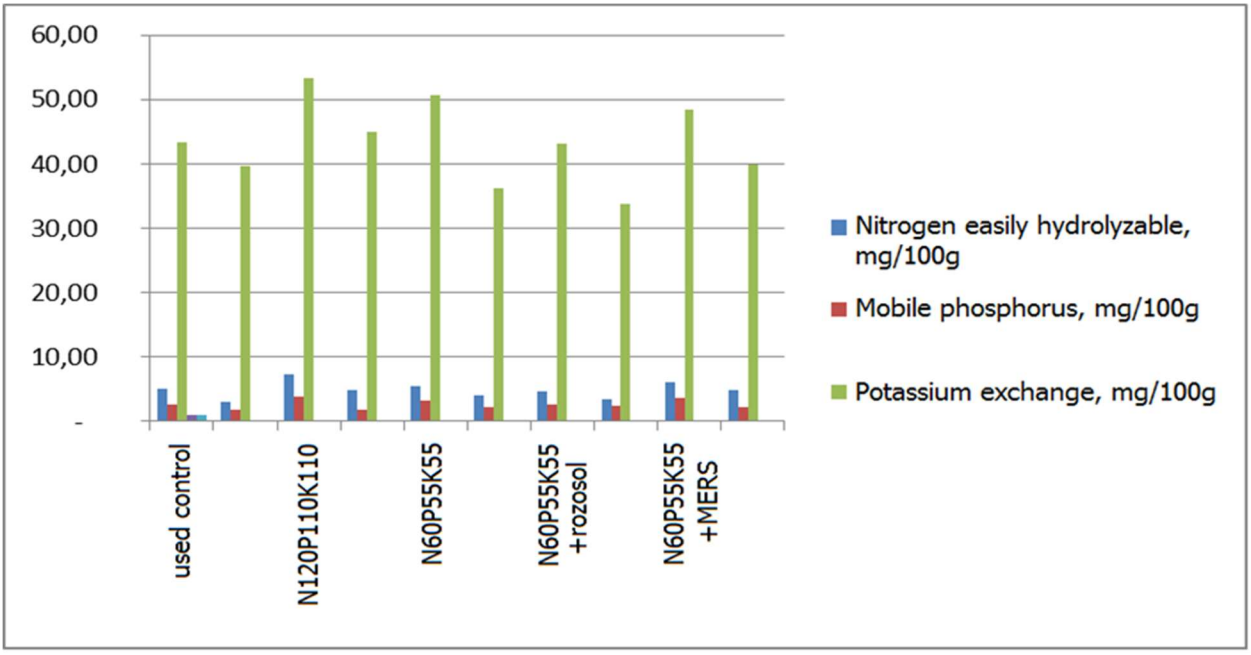


Figure 1. Content of nutrients in dark chestnut soil is average for 2016-2018 (0-30; 30-60 cm)

Under the influence of fertilizers, the agrochemical properties of the soil improve, the yield increases, the structure of the crown improves by increasing the formation of fruit-bearing organs, and the parameters of the crown are limited, which, of course, should lead to a reduction in labor costs for pruning trees.

Studies have shown that under the influence of fertilizers and bioproducts, the chlorophyll content in apple tree leaves increased, their optical properties improved, the number of roots increased, and their deeper placement along the soil profile was observed.

In general, there was a tendency to improve growth processes for most of the studied indicators on all backgrounds of mineral nutrition in comparison with the control without the use of fertilizers.

The best results for most indicators were obtained when using N110P110K120 against the background of periodic irrigation. The variant with application of N55P55K60 also exceeds the control in most indicators, but is significantly inferior to the variant with N110P110K120. Non-root spraying of trees with the drug MERS against the background of N55P55K60 proved to be quite good.

Table 1. Growth and development of young Aport trees under different irrigation and nutrient regimes

Experiment variants	Accretion in stem diameter, mm	Tree height, cm	Number of annual shoots, pcs/tree	Total accretion of annual shoots, m/tree	Number of rings, pcs/tree.	Number of leaves, pcs/tree	Leaf surface area, m^2/tree
Daily irrigation							
Control (without fertilizer)	8,5	171	13	3,5	42	353	0,92
$N_{110}P_{110}K_{120}$	8,8	170	18	5,0	49	412	1,13
$N_{55}P_{55}K_{60}$	9,5	174	16	4,2	52	404	1,15
$N_{55}P_{55}K_{60}$ + rozosol	8,7	184	16	4,3	35	345	1,03
$N_{55}P_{55}K_{60}$ + MERS	9,7	183	18	4,9	43	419	1,34
HCP 0,05	0,9	5,3	1,9	0,7	11,2		
Periodic irrigation							
Control (without fertilizer)	7,7	160	14	2,9	40	295	0,89
$N_{110}P_{110}K_{120}$	9,5	182	17	4,3	45	375	1,04
$N_{55}P_{55}K_{60}$	9,3	185	14	4,1	42	359	1,02
$N_{55}P_{55}K_{60}$ + Rozosol	8,0	171	13	3,5	41	317	0,92
$N_{55}P_{55}K_{60}$ + MERS	9,5	174	16	4,4	48	391	1,18
HCP 0,05	1,0	10,2	2,4	0,8	$F_{Ф.} < F_{Т.}$		

According to the number of leaves per tree, the best results against the background of daily irrigation were obtained when applying N110P110K120 - 412 pcs/tree and when applying N55P55K60 with two-time non-root treatment with the drug MERS - 419 pcs/tree. With 353 leaves under control without fertilizer. Against the background of periodic irrigation, the best variants were also those with a surface application of N110P110K120 - 375 pcs/tree and

N55P55K60 with treatment with the drug MERS - 391 pcs/tree, at 295 pcs/tree in the control variant.

The largest area of the leaf surface of tree was formed against the background of daily irrigation when applying N55P55K60 -1.15 m2/tree and when foliar treatment with the drug MERS on the background of N55P55K60 -1.34 m2/tree at about 0.92 in the control without fertilizer. Against the background of periodic irrigation on the area of the leaf surface, the variants N110P110K120 - 1.04 m2/tree were distinguished and N55P55K60 with foliar treatment with MERS – 1.18 m2/tree, at 0.89 m2/tree on the control.

Quality indicators of Aport apple fruit

Mineral nutrition is one of the factors that contribute to improving the quality and resistance to physiological diseases.

Studies were conducted on individual quality indicators against the background of daily and periodic irrigation: vitamin "C", total sugar (glucose+fructose), titrated acidity, soluble dry matter. As a result of studies, the content of vitamin "C" against the background of two types of irrigation shows an increase of 1-1.25 % compared to the control, the best indicators were in the variant of joint application of MERS with ½ of the dose of the calculated norm of NPK - 7.86-7.98 %. The results of control tests of total sugar had the same tendency and the use of mineral fertilizers did not show a distinctive high growth. Variants N60P55K55 and N60P55K55 + MERS contained 11.64-12.22 % of total sugar, when the control of its content was in the aisles - 10.76 % against the background of periodic irrigation, and against the background of daily irrigation, these variants also differed in the content of total sugar showing 12.11-12.73 %, respectively, and in the control variant - 11.35 % (Figures 2,3).

The content of titrated acidity on the fruit of the Aport apple can be said to have not changed the difference between the control and the isolated variant was 0.01-0.03 %, thus showing that the use of liquid mineral fertilizers and bioproducts does not affect these properties in the fruit of Aport. The results of soluble dry matter against the background of periodic irrigation vary between 12.13-13.27 % in the variants of N60P55K55 and N60P55K55 + MERS, respectively, the control variant content was 11.77 %. And against the background of daily irrigation, the content of soluble dry matter varies between 12.33-13.00 %, N60P55K55 + Rososol and N60P55K55 + MERS, respectively, exceeding the control by 0.53-1.2 % (Figures 2,3).

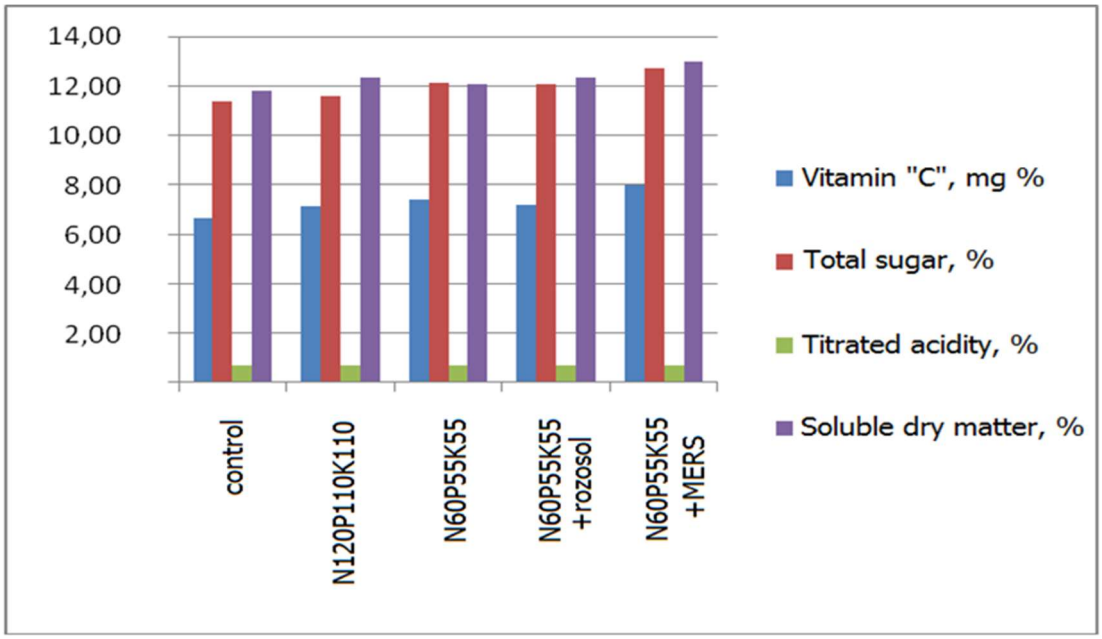


Figure 2. Results of biochemical analyses against the background of daily irrigation (average for 2016-2018)

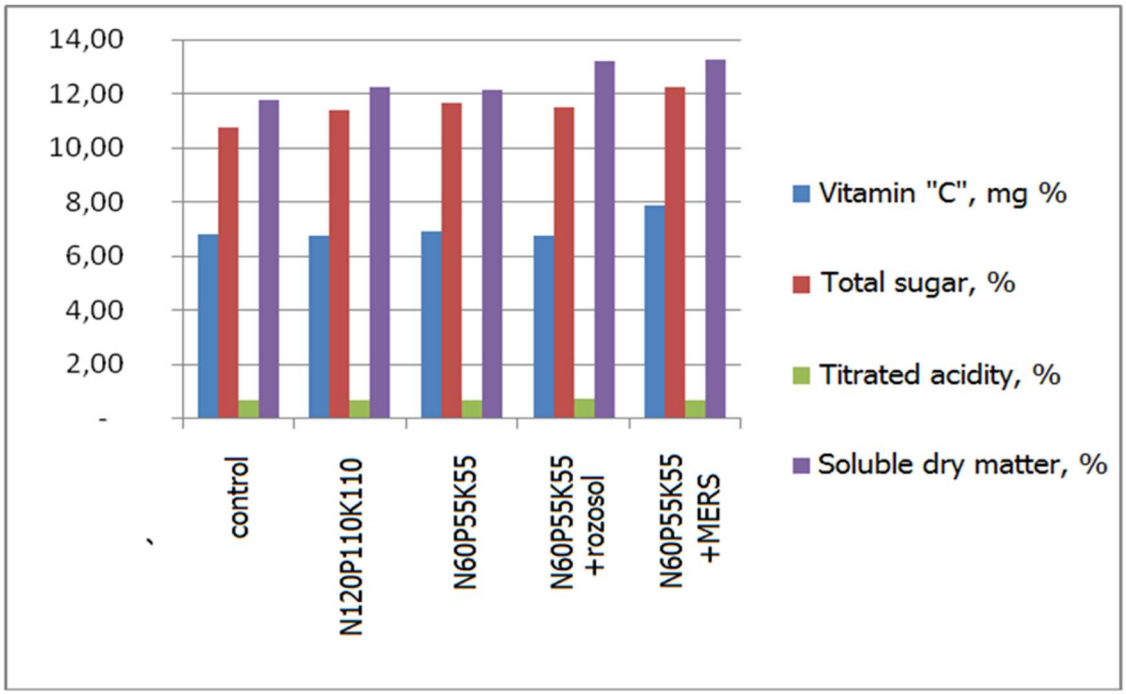


Figure 3. Results of biochemical analyses against the background of periodic irrigation (average for 2016-2018)

4.0 Conclusion

The study revealed a significant impact of mineral fertilizers and bioproducts on mineral nutrition, growth, development and fruiting of apple plants. The use of fertilizers primarily affects the

vegetative development and fruiting of plants, does not have a significant negative effect, but does not provide a significant improvement in these indicators.

Fruit-bearing plants need fertilizers that enrich the soil with nutrients, improve the physical properties of the soil, water and air modes, and supply plants with carbon dioxide. Soil analysis data for an average of 3 years showed that the most favorable nutrient status was formed in the variants with the application of N110P110K120, where the content of mobile hydrolyzable nitrogen, phosphorus and exchange potassium retained an average and high degree of security.

At the same time, the supply of apple plants with mineral nutrition elements remains within the optimal range, and the quality of the fruit is high. A dose of N110P110K120 fertilizers and a joint application of N55P55K60 + MERS is rational and economically feasible for apple tree plantations. According to physiological indicators, periodic irrigation of the Aport garden was significantly more effective than daily irrigation.

The use of mineral fertilizers both on the background of periodic and daily irrigation does not affect much, in terms of taste quality and content of ascorbic acid, Aport is an advanced grade and in the variants of N55P55K60 and N55P55K60 + MERS, these indicators were not significant but higher than in comparison with the control.

Thus, with daily irrigation when applying mineral fertilizers N110P110K120 and N60P55K55 + MERS helps to improve the agrochemical properties of the soil and obtain high-quality apple fruit.

5.0 Acknowledgement

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