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Advantages of Growing and Storaging of Organic Apples

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***Abstract*—Organic horticulture is one of the advanced directions for the development of the agro-industrial sector in Russia. The aim of the work is to develop a set of measures to optimize agroecological and biotechnological techniques that guarantee the preservation of the crop and the quality of apple products without toxicological effects on the environment and humans. To achieve the stated goal, the tasks were solved to ensure microbiological control of the phytosanitary state of the soil, to use grape seed meal for reducing of harmful toxic substances, to improve the soil structure and nutrition of apple trees, to use biological products for processing fruits and to use low frequency electromagnetic fields to reduce fruit contamination. Agrochemical indicators, the activity of microbiological processes, the quantitative and qualitative composition of the microbiota of the arable horizon of the apple orchard agroecosystem are studied. It has been established that lower levels of humus and gross nitrogen in the garden soil are combined with low values of the total microbial pool and ammonifying microorganisms. A comparative assessment of the morphological characteristics of apples, the prevalence of apple scab and the yield of the garden with two options for applied treatment: chemical and integrated. An improved technology is proposed for storing the harvest of eco-friendly apples through the use of a complex including spraying with a phytopreparation and the effect of a low frequency electromagnetic field. The possibility of influencing the activity of microbiome of the fruit surface using the low frequency electromagnetic field in the range from 18 Hz to 100 Hz is determined. A software has been developed and registered that can be used directly for analytics and forecasting the quality of long-term storage of products.**

Keywords—organic garden, apples, biosorbent, microflora, biological protection.

I. INTRODUCTION

Despite the achievements of traditional agriculture, namely fruit farming, in providing mankind with fruits and raw materials, global environmental problems (environmental pollution, accumulation of pesticides, toxic and carcinogenic compounds), largely determined by this type of activity, require urgent measures. Of extreme importance in solving problems in organic horticulture is the proper organization of the protection of fruit crops and, in the future, fruit products, based on systems that reduce anthropogenic impact and reduce the use of chemicals. The idea of preserving and developing the "green zone around a person" is embodied in the international plant protection program GREEN BELT. Our research allows us to join this program with the goal of preserving and increasing the yield of fruits with a careful attitude to the ecosystem and concern for human health.

Modern high chemicalization of horticultural production has a number of negative consequences, such as toxic environmental pollution, reduced soil fertility, and deterioration in product quality. All this ultimately has a negative effect on human health. Currently, due to the increasing biologization and ecologization of horticultural production, biological preparations based on microorganisms serve as a safe alternative to chemical pesticides, and their use in integrated technology for growing and subsequent storage is one of the most relevant, scientific and social areas. The recent interest of Russian producers in environmentally friendly production, the development of organic gardens, will be accompanied by an increase in demand for safer biological products and technologies for both consumers and the ecosystem.

Krasnodar Krai is the country's leading agricultural region. Fruit farming is one of its most important components. The relevance of the topic for the region is confirmed by its compliance with the Krasnodar Krai Target Program "Development of Agriculture and Regulation of Agricultural Products, Raw Materials and Food Markets" (2015), which goals and objectives are increasing requirements for the environmental safety of agricultural production, problems of maintaining soil fertility, and effective use of production potential and labor resources, increase the competitiveness of farms and reduce production costs. The practical implementation of the principles of environmental safety brings the system into a state of balanced protection of the interests of the natural environment, people and economic components. To maintain a high level of environmental safety, a combination of many factors is necessary: the creation of innovative technology with a unique technique, the use of modern equipment and compliance with quality standards. Organic safety is a global trend, based on the principle of harmonization of relations between the natural environment and humans.

Currently, agricultural enterprises are trying to abandon the use of chemical pest and disease control agents, not only because of the negative impact on beneficial biota, but because of direct harm to human health. Demand for biological remedies exceeds the supply; it is satisfied only by 10-20%. The purpose of this research is to develop a set of measures to optimize agroecological and biotechnological

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techniques that guarantee the preservation of the crop and the quality of apple products without toxicological effects on the environment and humans.

In the last decade, the world community has come to understand the effectiveness of organic farming and, in particular, organic fruit farming. The International Federation of Ecological Agriculture Movements provided information on the use of more than 43 million hectares of agricultural land for the needs of organic farming, with the volume of grown products worth more than $ 80 billion. Organic farming products have an annual growth trend of 10-15%. The contribution of agriculture of the Russian Federation to the global market of organic products is only 0.2%, but has enormous potential for the development, using more than 10 million hectares of land suitable for these purposes.

Apple growing in Russia has a long history and improving the production technology is very important. Sociologists have identified good prospects for increasing the area under apple orchards and increasing the turnover of apples in the future until 2023 [1]. Agricultural enterprises of the Union State "Belarus-Russia" outlined measures to reduce diseases and extend the shelf life of apples [2]. The Russian apple market tends to grow slowly [3]. The dependence of shelf life on the varietal characteristics of apples is revealed. Specialists pay much attention to the development of organic horticulture, which allows them to market high-quality products [4]. Software was developed with the participation of the authors that allows one to evaluate the content of vitamin C and dry matter during long-term storage of apples [5]. Within the framework of the organic fruit growing program, the use of microbiological preparations, soil microorganisms and innovative potential for the cultivation of fruits in certain regions is envisaged [6]. The choice in favor of organic fruit farming largely depends on the factor how much the cost and profitability of growing organic and ordinary apples will differ [7]. Foreign experts believe that with the help of soil microorganisms it is possible to improve the nutrition of the roots of apple orchard trees [8]. The organization of integrated protection treatment of apple plantings allows you to effectively deal with pathogens of diseases of apple scab and powdery mildew [9]. Experts say that biological products are close in effectiveness to the chemical means of protection treatment. From January 1, 2020, the provisions of the Federal Law on the Production of Organic Products come into force in Russia. Some sections of the Law are still being finalized, including legislative mechanisms to support organic producers. Prior to the development of the main Law, normative documentation was in force in Russia that defined the terminology of organic products, the rules for production and certification and standardization – GOST R 56104-2014, R 57022-2016 and 33980-2016.

The purpose of this research is to develop a set of measures in order to optimize agroecological and biotechnological techniques that guarantee the croppreservation and the quality of apples without toxicological effects on the environment and humans. To achieve the stated goal, the following tasks were solved: microbiological control of the phytosanitary state of the soil, the use of biosorbents to reduce the content of harmful toxic substances, the improvement of the soil structure and nutrition of apple trees, the use of biological products that are safe for humans, the use of herbal products and low frequency electromagnetic field to reduce fruit contamination during storage.

The scientific novelty of the performed work is to confirm the benefits of growing apples in an organic garden, through the efficient use of a range of measures, including the processing of apples with an herbal product and low frequency electromagnetic field (LF EMF) before laying them for storage. By improving the phytosanitary condition of trees and fruits, the possibility of reducing the prevalence and development of apple scab diseases has been established. For the first time, a hypothesis has been formulated for the effect of LF EMF on the biological systems of the apple orchard, which leads to a change in the properties of free and bound water at the energy level.

II. METHODS

The studied objects are the apple trees of the Idared variety and their fruits. The studies were carried out in the field and laboratory conditions. Together with specialists from the laboratory for the creation of microbiological plant protection products and the collection of microorganisms of the All-Russian Research Institute of Plant Biological Protection of the Russian Academy of Sciences, studies were conducted to evaluate the effectiveness of new biological products for alternaria blight and scab in the conditions of the apple orchard of the "Krasny Sad" agricultural enterprise, Rostov Region.

In order to integrate the biological means of protecting apple trees, the quantitative and qualitative composition of the microbiota of the garden upper soil horizon was previously examined. The number of soil microorganisms was determined by direct microscopic method and sowing from dilutions of the soil suspension into solid and liquid nutrient media, the activity of soil enzymes phosphatase, dehydrogenases, invertase, urease, catalase and proteases, as well as respiration, ammonifying, nitrifying, cellulose-depleting ability by conventional methods. Microbial communities were characterized using succession and mineralization coefficients. As a control experiment, a section of virgin soil was used to compare the microbiological parameters.

The effectiveness of biological remedies was evaluated against a natural infectious background in the Idared variety of apple trees. We tested new experimental samples of biological products based on the bacteria *Bacillus subtilis BZR 336g* (RF patent No. 2553518 from 05/20/2015) and *Pseudomonas chlororaphis 245F* against alternaria blight and apple scab. Control trees were sprayed with water. The treatment was carried out by drip irrigation and knapsack spraying in 4 main phases: at the beginning of leaves' blooming, immediately after flowering, when the fruit is at the size of a walnut and 1 month before harvesting.

We visually evaluated 100 leaves and 50 fruits from 3-4 trees. The prevalence (P %), the development of the disease (R %), the biological effectiveness of the drugs (BE %) were calculated according to standard formulas using a 5-point scale for measuring of the lesion intensity due to apple scab of leaves and fruits. Treatments with chemical fungicides were performed as needed: during initial phases.

In the process, modern electrophysical methods were used to determine the valuable components in the fruits. Mathematical processing of data on the chemical and

technological parameters of apples of the new ahrvest was carried out using specially designed software.

Preliminary storage processing of apples was carried out in a complex. We experimentally selected the optimal concentration of the herbal preparation and then sprayed it over. As a phytopreparation, an aqueous extract from a mixture of dry leaves and walnut pericarp was used, obtained by infusing in saturated water for 1-2 hours. Previously, the storage chamber was subjected to a low frequency electromagnetic field (LF EMF). Subsequently, the frequency of EMF treatment was also experimentally selected.

Statistical processing was performed using the Statistica 6.0 for Windows application package. To identify significant differences in the compared parameters, the nonparametric Wilcoxon-Mann-Whitney U-test was used. Differences were considered significant at a significance level of $p < 0.05$.

III. RESULTS

World experience indicates the need for wider use of biological products in the system of protective measures in gardens. Nevertheless, we have not found the optimal scheme for protecting fruit crops, aimed at using and stimulating natural biological resources, maintaining ecological balance and obtaining clean products, in the available literature. This gives us the opportunity to offer our comprehensive solution. The basis of garden protection is the use of biological agents, optimization of the number of treatments, microbiological indicators for monitoring of the phytosanitary condition of soil and trees and the introduction of biosorbent in soil in early spring. The agrochemical indicators, the activity of microbiological processes, the quantitative and qualitative composition of the arable horizon microbiota in the garden agroecosystem of the agricultural enterprise “Krasny Sad” in the Rostov Region were previously investigated. We took a plot of virgin lands for the comparison.

TABLE I. QUANTITATIVE AND QUALITATIVE COMPOSITION OF MICROBIOCENOSES, ENZYMATIC ACTIVITY AND AGROCHEMICAL INDICATORS OF ARABLE HORIZONS IN THE SOILS OF THE APPLE ORCHARD AND VIRGIN LANDS

Microbiological and agrochemical indicators	**Apple orchard**	**Virgin land**
Succession coefficient	280-1100	2500-3100
Mineralization coefficient	1. 9 - 2.4	0.6 – 1.0
Ammonifying microorganisms, million CFU/g ADS*	43-248	50-370
Aminoautotrophic microorganisms, million CFU/g ADS	103-288	12-176
Humus decomposing microorganisms, million CFU/g ADS	2.0-12.0	1.9-2.0
Nitrogen-fixing, %	30-60	82-98
Cellulose-decomposing, %	76-80	86-97
Actinomycetes, thousand CFU/g ADS	5.0 – 8.5	6.1 – 11.1
Micromycetes, thousand CFU/g ADS	50.0-84.5	10.0-14.0
Proteinases, in mg of tyrosine	0.45	0.51
Urease, in mg of NH_3	0.34	0.58
Phosphatase, in mg of phenolphthalein	3.01	5.04
Dehydrogenase, in mg of formazan	0.09	0.11
Catalase, in ml of O_2	6.8	6.4
Humus, %	3.14	4.50
Gross nitrogen, %	0.2	0.3
Humus reserves, %	63.07	84.75

**ADS – absolutely dry soil*

As can be seen from the data in table 1, the minimal anthropogenic impact on the virgin soils of the garden leads to an increase in the succession coefficient. Aminoautotrophic microorganisms and micromycetes predominate in the soil of the apple orchard, but the humus content is reduced due to the more dynamic activity of humus-degrading microorganisms.

The studied arable horizons of the chernozems of the garden agroecosystem and the virgin area by humus content can be classified as low-humus; however, in garden soil this indicator is lower. The organic residues of cultivated crops in agroecosystems cannot compensate for the processes of humus mineralization that occur in them more intensively. The chernozems of Krasnodar Krai and Rostov Region are characterized by a gradual decrease in humus with the soil depth, which determines the thickness of the humus horizons and high reserves of total humus. This indicator takes a lower value also in garden soil. Another important soil characteristic is the total nitrogen content. The content of total nitrogen in soils is directly related to humus reserves. And as studies have shown, the gross nitrogen content is higher in virgin soil.

Generalized and averaged data from microbiological studies indicate that the microbiocenosis of the arable layer of the garden ecosystem and the virgin land is 90% or more represented by bacteria. Along with actively functioning groups of microorganisms, a significant number of passive groups are found in all communities, which, obviously, determines the maintenance of the homeostatic state of eco-subsystems. The microbial pool is significantly higher in the virgin area, as evidenced by the succession coefficient. In garden soil, there is a high level of mineralization of organic matter, an increase in the number of microorganisms – transformers of nitrogen-containing compounds and humus.

Studies of the activity of soil enzymes of anthropogenic (garden) and natural (virgin) ecosystems have shown that soils located under a perennial fallow are characterized by a higher activity of hydrolytic enzymes, while in agricultural use it decreases. The increased enzymatic activity of virgin soil can be explained by a higher content of root mass per unit volume of this soil. On the other hand, tough competitive relationships between soil microbiota in a natural ecosystem lead to increased activity of the enzyme systems of microorganisms and the root system of meadow plants.

Thus, the analysis of the obtained agrochemical and microbiological indicators allows us to consider significant changes associated with agricultural activities, Lower levels of humus and gross nitrogen in the garden soil are combined with low values of the total microbial pool and ammonifying microorganisms. The use of mineral fertilizers in the cultivation of the garden is associated with an acceleration of the decomposition of humus, which, in turn, is explained by the increased development of autochthonous microbiota, including the humus-decomposing kind.

In order to determine the most significant and informative microbiological indicators, a step-by-step discriminant analysis was performed based on the criterion of one-way analysis of variance of F-distribution. The F values for a variable indicate its statistical significance between different indicators. The most informative are those whose contribution to discrimination is greater than the rest. The performed one-way analysis of variance with the "ecosystem" factor showed that for the vast majority of microbiological characters there are significant differences between the studied ecosystems and the proportion of factor variability of the indicators was quite high. Subsequent discriminant analysis showed that the compared ecosystems of the garden and virgin lands differ statistically significantly. Subsequently, the "significance" of the examined traits was checked in the framework of discriminant analysis (Table II)

TABLE II. THE RESULTS OF EVALUATING THE ROLE OF MICROBIOLOGICAL INDICATORS OF SOIL MICROBIOTA IN GARDEN AND VIRGIN ECOSYSTEMS

Microbiological indicators	Lambda criterion	F-distribution	Probability of the null hypothesis of the trait significance
Humus-decomposing	0.034	8.41*	0.00
Nitrogen-fixing	0.042	14.02*	0.00
Succession coefficient	0.037	9.97*	0.00
Ammonifying	0.035	6.21*	0.01
Mineralization coefficient	0.033	7.02*	0.00
Aminoautotrophic	0.030	4.99*	0.01
Cellulose-decomposing	0.020	2.40	0.12

** sign to the right of F-distribution values indicates the significance of differences in average values dry soil*

As follows from the data in Table II, out of the seven counted signs, six were informative: the number of humus-decomposing, nitrogen-fixing, ammonifying, aminoautotrophic microorganisms and succession and mineralization coefficients. Therefore, these significant indicators can be recommended for monitoring the subsequent characterization of the state of the garden ecosystem, as well as for use in assessing the phytosanitary condition of the soil and determining the number of treatments with protective remedies.

It should be noted that micromycetes are higher in garden soil. The following representatives of the genera dominated in the communities of soil micromycetes of the apple orchard: *Mucor, Penicillium, Aspergillus, Alternaria, Verticillium, Cladosporium* and others. Representatives of genera causing apple diseases were also discovered: *Venturia, Podosphera, Gymnosporangium*.

In order to improve the phytosanitary condition of the soil in early spring, while cultivating the garden soil, we introduced a biosorbent, which is a grape seed meal, a secondary resource of agricultural production (Russian patent for invention No. 2651172). We have experimentally shown that fat-free fine-dispersed grape seed meal has hydrophilic properties that provide favorable conditions for the life of soil microorganisms on the surface, and its use contributes to the rational and waste-free processing of secondary raw materials. Over time, the sorbent decomposes under the action of enzymes of soil microorganisms into ecologically non-toxic products of their metabolism.

When implementing the strategy of environmental protection measures in horticultural cooperatives, the environmental consequences of biological recultivation methods are diagnosed and evaluated. Recultivation of soil in gardens with the help of biosorbent can also increase its fertility. Effective methods of increasing fertility include the introduction of organic components based on crushed bulrush, bark, leaves and straw into the soil. The use of peat and secondary resources (in processing agricultural raw materials) for the production of humic acids and humates is very promising.

According to the results of microbiological studies, activation of indigenous microorganisms in the organic garden system was discovered. Undoubtedly, this will enhance the mechanisms of biota self-regulation in the future, which will directly or indirectly contribute to the agroecological regulation of the harmful and beneficial organisms ratio. The relative simplicity in creating a controlled garden agroecosystem is that apple trees are perennial crops and there is no need to form an agrobiocenosis anew every year, given the changing structure. Gradually improving emerging agrobiological conditions will cause a slowdown in the development and spread of harmful and opportunistic species of organisms, enhance the potential of the self-regulation mechanism, the impact of each technique, method, remedy and the whole system. Over time, the complex of proposed measures will ensure phytosanitary stabilization of the garden agroecosystem. This will lead, on the one hand, to a reduction in the cost of protecting the garden and, on the other hand, to a decrease in the pesticidal load on the agroecosystem. A balanced combination of stabilization factors will allow you to effectively put into practice an acceptable level of sustainable development of the system.

Morphological, biochemical, organoleptic and technological characteristics were studied in apple samples of the new harvest. It should be noted that the obtained average values fully corresponded to the indicators of the Idared apple variety. Table III presents a comparative assessment of the morphological characteristics of apples, the prevalence of apple scab and the yield of the orchard with two options for applied protection: chemical and integrated.

TABLE III. COMPARATIVE ASSESSMENT OF THE MORPHOLOGICAL PARAMETERS OF APPLES, THE PREVALENCE OF APPLE SCAB, THE YIELD OF DIFFERENT OPTIONS FOR GARDEN TREATMENT

Treatment option	Number of trees	Apple weight, g	Apple diameter, mm	Color, %	Apple scab prevalence	Apple scab progress, %	Apples on one tree	Yield, t/ha
Chemical	100	179.1	80.4	69.2	40.7	10.7	15.1	6.65
Integrated	100	192.02	81.0	71.2	36.0	6.2	20.2	8.24

As can be seen from the data in table 3, when using integrated protection treatment, the productivity of the apple orchard increases by 1.2 times. It should be noted that the indicators of weight, diameter, color, yield of apples and the number of fruits on one tree were higher in the garden, where they carried out integrated protection with biological preparations. The results of microbiological studies also indicate an improvement in the phytosanitary state of trees and fruits, because the prevalence and development of apple scab has decreased.

Apples that reached harvest maturity were sprayed with a phytopreparation in order to inhibit the development of microorganisms that cause spoilage, packaged in standard containers and placed in a refrigerator with a temperature of 0...+4 °C and a humidity of 85-95%.

In the process, we conducted a study of the influence of the low frequency electromagnetic field for cold sterilization of apple fruits. Previously, for the first tim ever, with the participation of the authors, it was established that it was possible to influence the activity of soil microiota and plant materials using an electromagnetic field in the range from 18 Hz to 100 Hz. Lower frequencies pose a danger to the working staff.

Unlike previously performed studies, the authors proposed using an amplitude and frequency modulated electromagnetic field for processing the objects under study, while checking how the biosystems response.

It has been established that treatment of biological systems with low frequency electromagnetic field changes the properties of free and bound water at the energy level. When an object enters stochastic resonance, the polarization of the biomolecules changes. A change in the water structure of microorganisms, under the influence of an electromagnetic field, can lead either to an increase in their activity or to a complete degradation.

Low-intensity EMF affects the permeability of cell membranes, changes the ionic composition and the course of oxidative processes in mitochondria. Thus, depending on the frequency of exposure, the magnetotropism of biological objects leads to the stimulation or inhibition of biological processes. With a certain frequency, the storage was processed by LF EMF. Previously, it was experimentally found that the maximum decrease of 45% of the microbial contamination of apples is observed when they are processed by LF EMF with a frequency of 18.2 Hz for 40 minutes.

During 6 months of storage, apples were taken out every 2 weeks to determine the dynamics in their morphological, biochemical, organoleptic and technological characteristics. Based on the obtained data on the dynamics of vitamin C content in the products and the index of natural weight loss, the authors developed a software for short-term and long-term forecasting of the chemical and technological parameters of apples during their storage [5]. This enables the operator to calculate the vitamin C content in apples for a specific storage date or to determine the weight loss. The developed program for predicting the vitamin C content and apple weight loss will allow producers to control important technological indicators of apple quality at any time without resorting to complex chemical and biochemical methods of analysis.

The performed studies have revealed the benefits of storing apples harvested in the organic farm “Red Garden” of the Rostov region.

IV. Conclusion

Agrochemical indicators, activity of microbiological processes, quantitative and qualitative composition of the arable horizon microbiota of the apple orchard agroecosystem were studied. It has been established that lower levels of humus and gross nitrogen are combined with low values of the total microbial pool and ammonifying microorganisms in the garden soil.

The role of microbiological indicators of soil microbiota in the separated ecosystems of the apple orchard and virgin soil is estimated. The following indicators turned out to be the most informative in the assessment: the number of humus-decomposing, nitrogen-fixing, ammonifying, aminoautotrophic microorganisms and succession and mineralization coefficients, which are recommended for monitoring the state of the apple orchard ecosystem, as well as for use in assessing the phytosanitary state of the soil and determining the number of treatments with protective remedies.

A comparative assessment of the morphological characteristics of apples, the prevalence of apple scab and the yield of the garden with two options for applied protection treatment: chemical and integrated, was conducted. An improved technology for storing the apple harvest, grown with the use of integrated protection by using a complex that includes spraying a phytopreparation and the effect of a low frequency electromagnetic field, is proposed.

It was found that the indicators of weight, diameter, color, yield and the number of fruits on one tree are higher in the apple orchard, where got had integrated protection treatment with biological preparations. As a result of processing, the phytosanitary condition of trees and fruits was improved, and the prevalence and development of apple scab decreased.

The possibility of influencing the activity of microbiota of the fruit surface using the low frequency electromagnetic field in the range from 18 Hz to 100 Hz is determined. It has been established that treatment of biological systems with LF EMF changes the properties of free and bound water at the energy level. When an object enters stochastic resonance, the polarization of the biomolecules changes. A change in the water structure of microorganisms, under the influence of an electromagnetic field, can lead either to an increase in their activity or to a complete degradation. As a result, we proposed a set of measures, including the processing of apples with a phytopreparation and LF EMF before placing them for storage. Growing and storing organic apples using an integrated approach and the proposed technology will help to improve the environmental component of fruit products consumers.

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