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Specific Aspects of Creating a Sustainably Functioning Ecosystem of an Organic Apple Garden in the South of Russia

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Abstract

The studies are related to the biological substantiation of the principles of selecting the main components for the organic apple garden ecosystem – cultivated plants of a certain pomological variety and naturally growing grasses of certain species composition that ensure its stable functioning in the south of Russia. The experiments were carried out during 2003-2017 in the conditions of laboratory and field experiments established in the territory of the "Kuban" instructional farm of the Kuban State Agrarian University (Krasnodar, Russia; soils – leached chernozems, climate – moderately continental). Selection of optimal apple tree varieties for specific territories is suggested to be performed on the basis of a preliminary assessment of the degree of compliance in the "genotype-environment" system using a physiological criterion. In the conditions of southern Russia, the grass stand (*Alopecurus myosuroides* Hudson; *Anisantha tectorum* (L.) Nevski; *Hordeum leporinum* Link), which is optimal for grassing down the spaces between rows of the garden, is formed in the third year after its establishment and remains for the entire period of operation. In case of skip-row use of such grasses even in nonirrigated plantations, against the background of the summer period climatic stressors, the parameters of water and temperature conditions of the soil, as well as the physiological parameters of the apple plants, are optimized. As a result, it is possible to form a specific ecosystem of the organic apple garden ecosystem (for example, Florina variety), which guarantees stable fruiting in different weather conditions. At the same time, the need to use various agricultural practices that correct the course of fruit crop formation is minimized.

Keywords: Ecosystem, organic garden, apple tree, pomological variety, naturally growing grasses, resistance, fruiting

INTRODUCTION

An important problem of modern gardening is to ensure its sustainable development and continuous progress. One of the ways to solve this problem will be industry environmentalization, involving the creation of organic plantations [1, 2, 3]. Their main goal is the production of ecologically friendly fruit products without genetically modified varieties, mineral fertilizers, chemical pesticides and pharmaceuticals due to the use of agronomic and biological methods of plant protection [4].

Establishment of organic plantations is very promising in the south of Russia –in the main region of industrial fruit growing with numerous zones characterized by a certain ecological status [5]. These include, in particular, resort, recreational, water protection areas, which exclude the possibility of using technological methods that cause pollution of the environment. Meanwhile, in organic gardens, the yield of fruit crops is 20-40% lower, and labor costs are 12-20% higher than in intensive industrial crops [1, 2]. These are important arguments, indicating the untimeliness of full refusal of traditional technologies for the cultivation of perennial fruit plants. Nevertheless, due to the advances in the field of plant biology and agronomy, organic farming is constantly evolving. The prospects of creating organic farms of intensive type are shown. In this case, the term "intensive" implies the mobilization of greater knowledge and the achievement of a higher degree of organization per unit area. Such farms use processing methods that enhance the beneficial effects of ecosystem functions, including biodiversity, soil fertility, and homeostasis [6]. At the same time, the symbiotic relationship of one or another technology with preservation of the natural basis is traced.

Many of these ideas have already found their application in world practice. According to the available data [2, 3], in most Europe countries the organic gardening of apple, pear and other crops is organized. Moreover, there are intentions to gradually increase the volume of production of organic fruit products. In this regard, it is very important to clarify the mechanisms for creating the sustainably functioning organic garden ecosystem that provides regular sufficiently high yields of organic fruits.

The purpose of the present studies was to substantiate the principles of selecting the main components for the organic apple garden in the south of Russia: pomological varieties and species composition of naturally growing grasses for grassing down the space between the rows using a certain method to ensure effective functioning of the agricultural ecosystem in the process of operation with minimal use of corrective actions.

METHODS

The studies were carried out during 2003-2017 in the conditions of laboratory and field experiments established in the territory of the "Kuban" instructional farm of the Kuban State Agrarian University (Krasnodar, Russia; 45°20'41" north latitude, 38°58'33" east longitude). The climate is moderately continental. The soils are leached chernozems.

Field experiments

Field experiment No. 1. The purpose of this experiment was to assess the adaptation degree of apple plants of various pomological varieties to the specific climatic conditions of the southern region of Russia. It was performed in 2012-2015 on nonirrigated plantations of apple trees based on MM 106 rootstock, established in 2006 according to the scheme 5.0 × 3.0 m. Apple varieties, which are immune to the scab, common in the industrial gardens of the Krasnodar Territory, were studied.

Field experiment No. 2. The purpose of this experiment was to study the change in the species composition of naturally growing grasses in an artificial ecosystem and their influence on certain physiological indices and fruiting of apple trees. It was performed in 2003-2017 on nonirrigated garden based on MM 106 rootstock, established in 2002 according to the scheme 5.0 × 3.0 m (system – organic). Apple tree of recognized Florina variety, being immune to the scab, was studied. The following ways of placing grasses between the rows were studied:

1) clean cultivation (control);
2) skip-row grassing;
3) inter-row grassing.

For the formation of grass stand in the second year after the garden establishment (2003), the soil was compacted between the rows using smooth water-filled rollers. Then, naturally growing grasses were periodically cut after reaching a height of 15-20 cm.

The experiment was repeated 6 times. A "tree-plot" was used as a single repetition.

Species composition of grasses were identified using the determinant [7].

Laboratory experiments

The removal of acid-soluble substances and lipids, as well as the separation of nucleic acids, were carried out according to Schmidt and Tannhauser. The concentration of nucleic acids in the solution was determined spectrophotometrically according to the Spirin method [8]; the parameters of water metabolism and photosynthetic activity of plants were determined using methods described in the special literature [9]. An analysis was repeated twice. The results of the experiments were processed using methods of mathematical statistics [10].

RESULTS

Apple plants of a specific pomological variety, adapted to the natural conditions of the southern region, during periods of vegetation and dormancy are characterized by a certain dynamics of the functional activity corresponding to the rhythm of the temperature changes of the given territory [5]. It is shown that the apple variety, which is "ideal" for the southern zone, during the year is characterized by the following changes in the indirect indicator of genotype activity – RNA/DNA nucleic acid ratios in apical meristems of shoots (one-year growth): a gradual increase in the period of transition of plants from the dormant period to the spring activity and at the beginning of vegetation, stable values in the summer months (under any weather conditions), a smooth decrease, starting from the second half of August, and approaching the minimum values (3.0-3.5) in the second half of November – early December (Figure 1).

Taking into account this fact, the activity indicator of the genotype of the "ideal" and tested varieties was compared. The obtained data indicate a sufficiently complete coincidence of the rhythms of changes in the functional activity of apple plants of both varieties: "Ideal" and Florina. At the same time, a complete mismatch of the dynamics of the RNA/DNA ratio during the year in the tops of shoots (one-year growth) of the Interpraise apple variety with the rhythm of the change in this index in a plant organism well adapted to the natural conditions of southern territories was revealed. This manifests itself in an excessive decrease in the activity indicator of vital functions of plants in the summer months.

An important component of the organic garden ecosystem is naturally growing grass. In the process of forming the grass stand, the species composition of the grasses in the space between the rows varied for several years (Table 1). So, in the first year of its formation at the beginning of the vegetative period, shoots of plants, which were more resistant to soil compaction, appeared. *Portulaca oleracea* L. and *Convolvulus arvensis* L. dominated among them (70% of the grass stand). Plants of other species were depauperated (height did not exceed 10 cm).

The next year recorded a change in the species composition of grasses. The grass stand predominantly included *Polygonum neglectum* Besser and cereal species *Sanguisorba officinalis* L., which belonged to ground cover plants. The grass stand of the third year was dominated by loose bunchgrass, requiring a limited number of cutting and in this connection, preferable for grassing between the rows of organic garden.

It is worthy of note that in the subsequent years of plantation exploitation the specified species composition of grasses was preserved.

The use of naturally growing grasses of certain species composition in the space between the rows of the nonirrigated organic garden at the beginning of the summer period leads to a significant decrease in the soil moisture content of the root layer (in 2014, to 46% field moisture capacity). At the same time, in the control variant, the value of field moisture capacity was 65%.

Grassing space between the rows with grasses of certain species composition has a significant effect on the physiological characteristics of apple plants. In particular, in the first half of the summer season, in the conditions of water deficiency, water loss in apple tree leaves in variants with grassing (inter-row and skip-row) was greater than in control – clean cultivation (Table 2).

At the same time, the use of naturally growing grasses in the space between the rows of the plantings of the southern region provides a noticeable decrease in soil temperature during the hot period of the summer season. Thus, at noon hours, the soil temperature in the plow layer with its handling according to the clean cultivation system is 35.0-37.5 °C (August 2014-2016). At the same time, with naturally growing grasses in the space between the rows, it decreases to 28.5-27.0 °C.

According to the results of the experiment, in case of grassing space between the rows using naturally growing grasses (inter-row and skip-row grassing), water loss of leaf tissues of the Florina variety decreases (in comparison with the control) from the middle of summer (see Table 2).

In addition, when using naturally growing grasses of certain species composition in space between the rows of the garden, even against the background of the growing effect of the summer season stressors, the net productivity of photosynthesis in the leaves of the Florina variety apple tree was much higher than in the control. The most prominent differences with the control for this indicator (75%) were fixed in the variant "skip-row grassing".

The advantage of plants of this variant for the indicator of photosynthetic activity is implemented n the formation of a higher economic yield (Figure 2).

The yield of the apple tree of the Florina variety at the skip-row grassing of space between the rows reached 23.5 and 21.0 tons/ha in the adjacent years 2013-2014, respectively. This indicator was 10-12% higher than in the "inter-row grassing" variant and 17.5-28.0% higher than the control values. Moreover, during the operation of the garden, in an optimal variant of the experiment, apple tree fruiting was stable at a level of 18-26 tons/ha, and its average yield was 23 tons/ha (Figure 3).

Table 1 – Dynamics of changes in the species composition of grasses in the organic apple garden ecosystem

Year after soil compacting	Grass species	% in the grass stand
The first (2003)	*Portulaca oleracea* L.	60
	Convolvulus arvensis L.	10
	Setaria viridis (L.) P. Beauv.	8
	Amaranthus blitoides S. Watson	12
	Echinochloa crusgalli (L). Beauv.	10
The second (2004)	*Polygonum neglectum* Besser	40
	Sanguisorba officinalis L.	30
	Setaria viridis (L.) P. Beauv.	15
	Convolvulus arvensis L.	13
	Alopecurus myosuroides Hudson	12
The third (2005)	*Alopecurus myosuroides* Hudson	50
	Anisantha tectorum (L.) Nevski	25
	Hordeum leporinum Link	10
	Poa pratensis L.	10
	Polygonum neglectum Besser	5
The fifteenth (2017)	*Alopecurus myosuroides* Hudson	25
	Anisantha tectorum (L.) Nevski	55
	Hordeum leporinum Link	10
	Poa pratensis L.	5
	Polygonum neglectum Besser	5

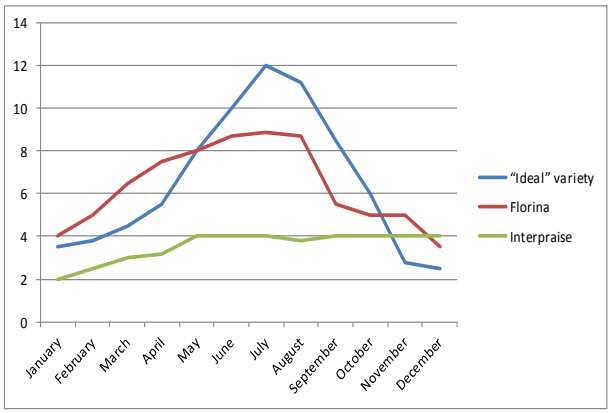

Figure 1. Assessment of the adaptability of apple varieties to the climatic characteristics of the southern region of Russia (average for 2012-2015)

Table 2 – Influence of the method of placing naturally growing grasses on the physiological characteristics of apple tree leaves in the organic garden ecosystem (2014)

a) $S_{X,}\%\geq 3.5$

Method of placing grasses	Loss of water in 3 hours, %			Net productivity of photosynthesis,g/m^2 day
	26.06	21.07	28.08	August
Clean cultivation (control)	11.6	13.0	4.5	8.9
Grassing skip-row inter-row	 12.8 15.4	 6.0 7.0	 2.3 3.3	 15.6 10.1

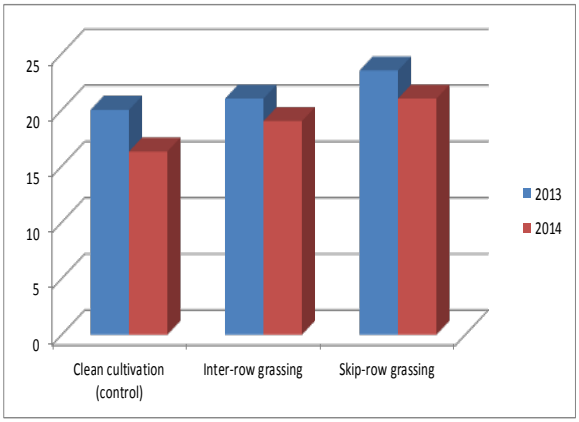

Figure 2. Specific features of fruiting of the Florina variety apple tree based on MM 106 rootstock, depending on the method of placing of naturally growing grasses

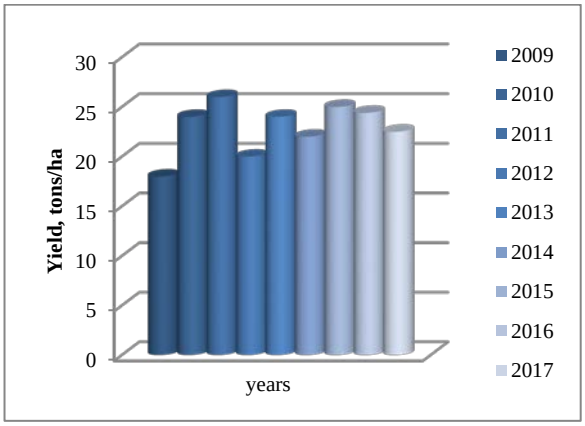

Figure 3. Dynamics of apple yield in the organic garden of the southern region of Russia

DISCUSSION

Important components of the artificially created garden ecosystem are plants of a certain species (crops) of the corresponding pomological variety. The stability of such ecosystem functioning will largely depend on the accuracy of the variety selection (even from the number of recognized varieties) with regard to the abiotic conditions of a particular area occupied by phytocenosis [1]. It is generally accepted that adaptation is the ability of the organism to adapt in its individual development to constantly changing external conditions. At the same time, the basis for the adaptability of plants to the environment is the correspondence of their internal biorhythms to the nature of climate change in a given area [5]. A universal criterion for the functional activity of apple plants, objectively reflecting the degree of their reaction to any external influence (including a combination of climatic factors) is the ratio of RNA/DNA nucleic acids, which is an indirect indicator of genotype activity determined in apical meristems of shoots (one-year growth). It is this indicator, in our opinion, that must be used to assess the degree of compliance in the "genotype-environment" system [5]. According to the results of the assessment, the introduced Florina variety apple tree (MM 106 rootstock), which is immune to the scab, is well adapted to the rhythm of the climate in the southern region of Russia. At the same time, an incomplete conformity of the Interpraise variety based on the same rootstock to the same ground conditions of the specified territory was revealed. Based on the data obtained, plants of this variety are likely to dramatically weaken the functional activity in the summer period in case of water deficiency and high temperatures, which are quite often in the area. Obviously, when creating a sustainably functioning agricultural ecosystem (organic apple garden), it is necessary to use plants of only those varieties that differ in genetic capabilities to survive in a particular area under any combination of weather conditions during vegetation and dormancy (for example, apple trees of the Florina variety). Such an approach to the selection of the variety will eliminate the need for additional agricultural practices that promote the regularity of fruiting.

An equally important component of the plant organisms of the organic garden ecosystem is naturally growing grass of certain species composition. It was previously noted that in case of soil compacting at the beginning of garden operation, favorable conditions were created for the appearance of species resistant to such soil compacting –loose bunchgrass that contributed to the improvement of the basic fertility parameters of leached chernozem [11]. At the same time, the choice of the optimal method for the placement of such grasses in the space between the rows is the most important factor in the regulation of the processes of fruit trees activity, which affects the size of the economic harvest and the stability of fruit production. The data obtained indicate that, with long-term use of naturally growing grasses in a nonirrigated garden, Florina variety apple trees exhibit protective-adaptive reactions caused by summer climatic stressors such as drought and high air temperatures. In particular, in unfavorable environmental conditions, in these variants of the experiment, the water-retaining capacity of the leaves was stronger than in the control. And the best results for optimizing this indicator were fixed when using inter-row grassing of space between the rows.

As is known, high-temperature stress causes a decrease in the intensity of plant photosynthesis [12]. Nevertheless, in the "skip-row grassing" variant, even in case of negative effect of heat, the net productivity of photosynthesis in the leaves of the apple tree was significantly higher than the control values. It is logical to assume that one of the reasons for this phenomenon (along with optimizing the water regime, etc.) might be the improvement of tree lighting, due to the greater albedo of the grass stand surface [13].

On the basis of the presented materials, the activation of photosynthetic activity of apple trees is associated with the possibilities of obtaining stable fruit yields at the level of 18-26 tons/ha and average yield of apple trees over the years of the garden operation of 23 tons/ha. At the same time, the most complete implementation of the adaptive potential of the used plants and natural resources of the territory is ensured, and the need for various corrective actions is minimized.

Conclusion

Stable functioning of a nonirrigated organic apple tree is achieved when creating a specific artificial ecosystem, the most important components of which are cultivated plants of a certain pomological variety and naturally growing grasses of certain species composition. Selection of apple varieties that are optimal for specific territories should be carried out on the basis of a preliminary assessment of the degree of conformity in the "genotype-environment" system using a diagnostic criterion –the ratio of RNA/DNA nucleic acids, determined in apical meristems of shoots (one-year growth) of plants during the periods of vegetation and dormancy. In the conditions of the southern region of Russia, the optimal for grassing garden grass stand with the predominance of *Alopecurus myosuroides* Hudson, *Anisantha tectorum* (L.) Nevski, *Hordeum leporinum* Link is formed in the third year after its establishment and remains for the entire period of operation. In case of skip-row use of such grasses even in nonirrigated plantations, against the background of the summer period climatic stressors, the parameters of water and temperature conditions of the soil, as well as the physiological parameters of the apple plants, are optimized. As a result, in years with various weather conditions, a stable fruiting of the apple tree (for example, Florina variety) is achieved at a level of 18-26 tons/ha. At the same time, the need to use various agricultural practices that correct the course of fruit crop formation (use of sown herbs, cutting, etc.) is minimized.

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