MINISTRY OF AGRICULTURE, REGIONAL DEVELOPMENT AND ENVIRONMENT

OF THE REPUBLIC OF MOLDOVA

STATE AGRICULTURAL UNIVERSITY OF MOLDOVA

DOCTORAL SCHOOL OF THE PARTNERSHIP OF AGRICULTURAL RESEARCH AND EDUCATION INSTITUTIONS

As a manuscript

UDC: 634.11: 631.526.32 (478)

BÎLICI INNA

EVALUATION OF NEW APPLE VARIETIES GROWN IN THE SUPER-INTENSIVE CULTIVATION SYSTEM IN THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

411.06 – ORCHARDING

The abstract of the doctoral thesis on agricultural sciences

CHISINAU, 2020

The dissertation has been done within the Horticulture Department I of the State Agricultural University of Moldova.

Academic supervisor: Valerian BALAN, Habilitated Doctor, professor

The members of the committee for the public defence of the dissertation were approved by the SAUM Senate by resolution no. 7 of 8th July 2020 as follows:

1. BUCARCIUC Victor, Habilitated Doctor of Agriculture, research professor, PASEI, **chairman**

2. BALAN Valerian, Habilitated Doctor of Agriculture, professor, **member**

3. ISTRATE Mihai, Habilitated Doctor of Agriculture, professor, Iasi UASVM, **reviewer**

4. BUJOREANU Nicolae, Habilitated Doctor of Agriculture, research associate professor, Institute of Genetics, Physiology and Plant Protection (IGFPP), **reviewer**

5. PEŞTEANU Ananie, Doctor of Agriculture, associate professor, SAUM, **reviewer**

The presentation of the dissertation takes place on _____, at _____o'clock, at the meeting of the Committee for the Public Defence of Dissertations of the Department of Horticulture I of the State Agrarian University of Moldova, at the address 46, Mircesti Street, MD 2049, the municipality of Chisinau, in auditorium 201, telephone: (+373 22) 432 304, fax: (+373 22) 312265.

The doctoral thesis and the abstract can be found at the Republican Agricultural Scientific Library of the State Agricultural University of Moldova and on the website of the National Agency for Quality Assurance in Education and Research (ANACEC) (http://www.anacip.md).

The abstract was submitted on "_____" _____ 2020

Academic supervisor: Valerian BALAN, Habilitated Doctor, professor

Author: Bîlici Inna

CONTENTS

THE PURPOSE AND OBJECTIVES OF THE RESEARCH

The apple tree is a strategic species for the Moldovan fruit-growing sector; that is why sustainable cultivation systems need to be promoted in order to produce qualitative fruit. In order to reach this goal, high-density fruit tree cultivation systems are successfully introduced in areas where the climate, soil and biocenosis meet best the requirements of apple tree growing; and in order to increase the economic yields per area unit, sustainable technologies with low consumption of conventional and polluting energy are adopted. Modern orchards, which are characterized by early fruiting (2-3 years) and short operation life (12-15 years), allow the periodic and rapid replacement of different varieties, as well as the implementation of new processes in order to obtain harvests which would correspond to the quality standards [2; 4*; 9; 12; 20].

The density of trees has changed from 400-600 trees/ha in the 70s to 2500-4000 trees/ha. The diversity of the existing biological material, which is the result of the numerous variety/rootstock combinations, the level at which trees are planted, as well as the forms of the narrow canopies, with reduced volume, contributed to this growth [5; 16; 19]. At the same time, it is appropriate to examine the components that define the cultivation system, the way they interact, and to identify the theoretical elements that determine the productivity of an orchard. Owing to the fact that new varieties have been applied, it is necessary to prove their practical importance, and to improve the technology of high-dense orchard tending in order to obtain a big and qualitative crop.

In the fruit tree growing domain, the controlling of the number of fruit is achieved by the cutting of fruit, and by their manual, mechanical and chemical thinning. All these methods aim at maintaining the physiological balance between the growth and fruiting. Integrated in a balanced system of cutting, fertilization and irrigation, the chemical thinning is considered an economical and advantageous method, which has beneficial effects on fruit size and bud formation [1; 2; 4; 6; 12; 18; 22; 2. 3; 24; 26]. The regulation of the fruit number of an apple tree constitutes a very important task in the modern orcharding in the sense of obtain a sustainable harvest, and the efficiency of thinning varies depending on the environmental conditions during the care delivery and the physiological condition of the plants [15; 27].

Currently, one of the main objectives of the horticultural research is the improvement and exploitation of new productive varieties, adapted to environmental conditions [2; 9; 11; 13]. Thus, the practical implementation of the fruit number regulation technologies is of current major importance with respect to high-dense orchards. The development of new tending methods and technologies to obtain sustainable fruit crops based on the utilisation of highly productive varieties remains a relevant field of scientific research.

The purpose of the paper is to increase the productivity of apple orchards by identifying highly productive varieties and developing methods to maintain a balance between growth and fruiting.

Objectives: to identify the behaviour of new apple varieties regarding their growth and fruiting capacity in order to use the most valuable ones to obtain constant, good, qualitative yields; to determine the intensity of the physiological growth and fruiting processes, in correlation with the agrobiological potential in the apple varieties Granny Smith, Gala Buckeye Simmons, Golden Delicious Reinders, Red Velox and Fuji Kiku, grafted on M9, in the fruit orchards in the Republic of Moldova; to develop methods of apple trees forming and pruning which would exploit efficiently the natural growth and fruiting potential of a variety, in order to obtain competitive intensely coloured fruit which would have superior biochemical properties; to determine the reaction of different apple varieties to the effect of growth regulators on the regulation of fruit number, productivity and quality; to point out the economic effects of apple production depending on the variety and the method of controlling the fruit number by growing apple varieties which are very productive and effective in dense orchards.

Research hypothesis: the permanent increase of the efficiency of modern cultivation systems which are characterized by early fruiting and short operation life, can be achieved by the utilisation of highly productive varieties from the world collection, the right exploitation of the natural potential of an orchard area and cultivation technologies. As a result of the research carried out, technological processes will be developed which will permit to obtain big and high-quality crops at low cost. The new procedures will aim to maintain the balance between growth and fruiting on account of canopy tending and the regulation of the fruit number.

Synthesis of the research methodology: the study is based on complex researches organized in the experimental orchards of Ltd "Elit Fruct" and Ltd "Prodcar", as well as in the laboratory *Technology of agricultural products storage and processing* within the Department of Horticulture of SAUM. Morphological descriptions, biometric evaluations, physiological and biochemical analyses and statistical processing of the results were carried out. In order to interpret the scientific results, different methods, such as analysis, synthesis, tabulation, comparison and the graphical method, were used.

Scientific novelty and originality: the identification of especially those varieties from the world collection which are proper for high-dense orchards in the central area of the Republic of Moldova; the scientific argumentation of the new canopy forming and tending methodology of the apple tree which has the form of a slender spindle [5*; 13*]; the estimation of the parameters of the orchard structure and their maintenance in a physiological balance; the argumentation, from the agronomic and economic viewpoint, of the advantages of the number of fruit regulation in order to obtain sustainable harvests.

The obtained result which promotes solutions of the important problems of productivity enhancement of high-dense apple orchards and the economic efficiency of apple fruit production, permits to substantiate scientifically the use of highly productive varieties, as well as the methods of fruit number regulation and the maintenance of trees in physiological balance. Four new apple varieties from the world collection, and procedures of canopy tending and fruit number regulation were recommended to be utilized.

Approval of the research results. The main results of the studies were analysed in the annual reports which were approved by the Department of Horticulture and at the Council of the Faculty of Horticulture of SAUM in the years 2016 – 2019. They were also presented at the Students scientific conference of SAUM in 2012, 2013, 2014 and 2020, the International Scientific Congress "Life Science – a Challenge for the Future" (October 20th - 22nd, 2016, Iasi, Romania), the International Scientific Symposium "Horticulture, Food and Environment Priorities and Perspectives" (October 27th-28th, 2016, Craiova, Romania), the International Scientific Symposium "Modern Horticulture – achievements and perspectives", dedicated to the 85th anniversary of SAUM (2018), the International Specialized Exhibition "INFOINVENT 2019", 16th edition (November 20th-23rd, 2019, Chisinau, the Republic of Moldova) and the International Invention Exhibition "INVENTICA 2020" (July 29th-31st, 2020, Iasi, Romania).

SYNTHESIS OF CHAPTERS

1. THE ASSORTMENT, CULTIVATION SYSTEM AND TECHNOLOGY OF APPLE ORCHARDS TENDING

The present chapter gives an outline of the actual state of affairs concerning the elaboration and use of technological processes based on varieties. An analysis has been made regarding the cultivation, evolution and assortment of apple varieties worldwide, in Europe and in the Republic of Moldova. Different stages in the evolution of modern and high-dense apple orchards, and their role in the development of future orcharding were pointed out. Possible tendencies of the super-intensive cultivation system development have been also outlined in terms of reducing the action of risk factors in fruit tree and bush growing.

Particular attention has been paid to the study of materials on the maintenance of the physiological balance between the tree growth and fruiting while using growth regulators during different phases of fruit organs development. Based on the analysis of the most important and advanced researches on the tending, formation and pruning of the apple tree canopy, as well as on the methods of fruit number controlling, basic parameters that ensure the productivity of orchards and their economic efficiency have been identified.

2. THE OBJECTIVES, METHODS AND CONDITIONS OF THE RESEARCH CONDUCTING

2.1. The biological material used in the experiment

The study focuses on the apple varieties Granny Smith, Gala Buckeye Simmons, Red Velox, Golden Delicious Reinders and Fuji Kiku grafted on the rootstock M9. The Granny Smith was chosen as the control variety; it was approved in the Republic of Moldova in 2015 for the southern orchards. 2-year-old planting material of "Certificate" category was used. The level between the rows was 3.2 m, and in a row it was 0.8 m (3900 trees/ha). The trees were formed using the improved slender spindle canopy type.

2.2. The organization and the performance of the experiments

The researches into the utilisation of new apple varieties and the planting of orchards with a high level of productivity were carried out within 3 stationary experiments, using four randomized groups of 8 trees each. **Experiment 1. The study of the behaviour of new apple varieties with relation to favourable climatic conditions, intensity of physiological growth and fruiting processes in correlation with the agrobiological potential**. The researches were carried out at the Ltd „Elit Fruct” in the village of Cosernita, the district of Criuleni during the years 2015–2019. The orchard was planted in 2015.

Experiment 2. The evaluation of new apple varieties with relation to growth and fruiting capacity in correlation with climatic conditions and agrobiological potential. The researches were carried out at the Ltd "Prodcar" in the village of Negureni, the district of Telenesti, during the years 2015-2019. The apple orchard was planted in 2014. **Experiment 3. The study of the reaction of apple varieties to the effect of growth regulators on the fruit number regulation, productivity and fruit quality.** During the experiment carried out at the Ltd "Elit Fruct" the following procedures were used for the fruit number controlling: **G1** – untreated control sample; **G2** – the manual thinning of the fruit was carried out after the physiological fall in June, when the fruit reached the diameter of 16-18 mm; G**3** – the spraying with Urea 46% N, 6 kg/ha, at the temperature of 12-25^{o}C and air humidity of 65-80%, when 75% of the flowers were open until the shedding of the first flowers; **G4** – the spraying with Geramid-New, 1.5 l/ha, at the temperature of 15-20^{0}C, when the central fruit reached the diameter of 4-7 mm; **G5** – the spraying with Dira Max LG, 2 l/ha, at the temperature of 15-25^{0}C, when the central fruit reached the diameter of 10-15 mm.

2.3. The research methods

The researches included the biometric evaluations in the field, the physiological and biochemical analyses in the laboratory, the determination of the photosynthetic activity of the trees and the light intensity in the trees canopy, and the evaluation of the fruit organs formation and of the fruit productivity and quality.

Field investigations. Annually, at the end of the vegetation period, measurements were made on the diameter of the trunk 20 cm above the grafting place, on the height of the trees, the width of the canopy, the average and total length of the annual branches, the number of vegetative branches and, respectively, the fruit branches.

The leaf area on the tree was determined at the end of the vegetation period. The photosynthetic and growth potential of the trees was calculated based on the number of fruit and the fruit branches in the bud, as well as on the average and total length of the annual branches. The leaf area was measured separately on different kinds of shoots [3]. The intensity of the light received by the foliar apparatus was also studied. The dynamics of the daytime lighting of the canopy was recorded during a day using the universal pyranometer M-80 and the galvanometer GSA-1. Measurements were made in the area of the axis and in the joint of the canopy at the height of 0.5, 1.0, 1.5 and 2.0 m from the ground, in the centre of the canopy and at 0, 3 m away from centre of the canopy towards the area between the rows.

The intensity of flowering, the stages of fruit development and the time before and after the treatment provision were analysed. In the pink bud phase, the number of red dotted buds (NBR) was determined, and the number of tied inflorescences (NIL) was determined after the fall of the fruit in June. The weight of fruit in an inflorescence was specified taking samples from 12 trees of the variant.

The number of flowers and fruit and their distribution inside the canopy and on various branches were studied during the flowering period, after the fruit binding (in May), the physiological fall of the fruit and two weeks before their harvesting. These indices were determined on 3 typical trees of each variant. The number of fruiting branches was established by counting different types of branches of different ages on 3 trees in each procedure, vertically, at the height of 60-160 cm, 160-240 cm and 240-320 cm at the Ltd "Elite Fruit", and at 70-150 cm, 150-230 cm and 230-310 cm at the Ltd "Prodcar". At the end of each production year, the value of the harvest per hectare of 32 trees was determined. The average weight of the fruit was determined by the method of weighing and counting the apples on 3 trees in each group. The statistical processing of the research results was done making use of the method of randomized blocks and the method of single-factor dispersion analysis using Statgraphics and MS Excel 2013. To assess the significance of differences between varieties and the experimental variants,

the T Student test was applied, and $P<0.05$ was considered as significant. The production potential of the trees was calculated according to the volume of the canopy, the transverse surface of the trunk and the fruit harvest per tree.

Laboratory investigations. The weigh and firmness of the fruit, the dry substance, the total sugar content and the titratable acidity were determined annually. The dry matter in the fruit was determined using the refractometric method, the total sugar content – via the cyanuric method, and the titratable acidity – applying the neutralization with the 0,1 N NaOH solution in the presence of phenolphthalein, as an indicator, expressed in malic acid (%).

The calculation and interpretation of the obtained results. The main indicators of the economic efficiency of the apple orchard were calculated based on the production data and according to the method of fruit number regulation, the type of fruiting, the quality of the fruit, the ripening and consumption period, as well as the expenses incurred and the marketing price of the fruit.

2.4. The ecological basis of the research conducting

2.4.1. The thermal and pluviometric regime. The apple orchard of the Ltd "Elit Fruct" is situated at latitude 47.1458, longitude 29.0686 and altitude of 61 m, at the level of 30 km from the city of Chisinau, and the orchard of the Ltd "Prodcar" – at latitude 47.6011, longitude 28.5100 and the altitude of 57 m above the sea level, and at the level of 69 km away from Chisinau. The area is characterized by an average water supply, an uneven relief and fertile soils, predominantly north strong winds, early autumn and late spring white frosts. The average amount of the atmospheric precipitates during the last four years has constituted 489 mm, 70% of which as rainfall and has happened during the warm period of the year. The relative humidity of the air was 52.02% in August and 91.50% in January. In general, the thermal regime (15.10-22.42^{o}C), the pluviometric regime (0-16.2 mm) and the air humidity (55.03-84.98%) during the research years, in the flowering and binding phase of the fruit, have created favourable conditions for pollination and flower fertilization.

2.4.2. The soils on which the experiments were carried out. The experimental orchard at the Ltd "Elite Fruit" was situated on ordinary clay chernozem. The superficial layer (0-20 cm) contained 3.31% of humus; at the depth of 20-40 cm the humus in the soil constituted only 1.76%. Values lower than 1% of the humus content were attested at the depth of 60 cm, the lower part of the pedogenetic horizon B. At the Ltd "Prodcar", the experiments were carried out on typical weakly humiferous chernozem. At the depth of 0-20 cm, the humus content was 3.71%, followed by a decrease in the humus content up to 2.15% at a depth of 20-40 cm. At a level of 80 cm the content of humus was less than 1%. Such lands are recommended for apple

trees grafted on a vegetative rootstock which form a superficial root system given that, at a depth lower than 60-100 cm, the carbonate content is high [25].

2.4.3. The agricultural engineering. Before the orchards were planted, the tree support system was installed – a simple, monoplane one made of reinforced concrete pillars with a height of about 4 m, as well as the irrigation system. In the second year, the hail net was installed. The orchards began to bear fruit in the 2nd year after their planting. The maximum production potential (70-80 tha) was reached starting with the 3rd year after their plantation. The fertigation machinery and the software were computerized and could be easily monitored. Thus, the horticulturist knew when to irrigate or start an operation of the fertigation even not being present on the spot. After planting the trees, the soil was artificially grassed. The grassy strips between the rows, 2.2 m wide, were mowed and used as mulch. The trees were formed using the system of improved slender spindle.

3. THE VARIABILITY OF THE GROWTH, DEVELOPMENT AND PRODUCTIVITY INDICES OF NEW APPLE VARIETIES CULTIVATED IN THE CENTRAL AREA OF THE REPUBLIC OF MOLDOVA

Chapter 3 contains the results of the biometric, physiological and biochemical analyses which have been performed, the results obtained as a consequence of the development of technological procedures, as well as the presentation of ample conclusions, based on the experimental data and the studied literature.

3.1. Forming and pruning the apple tree in the shape of a slender spindle

The process of forming the central axis of the apple tree applied to the Granny Smith variety grafted on M9, is performed when in the canopy design area there are well-developed branches, in order to choose 3-4 branches to form the floor, and the extension branch of the axis is vigorously developed and does not have anticipated branches [13] *.

The method of forming the shaft proved to be an efficient technological process in driving the trees after the shape of a slender spindle canopy, favouring the increase of the harvest by 23.97-58.80 % in the first two years after the planting. During this period, the fruit harvest registered the highest values when the axis has been shaped.

3.2. The main indices of apple tree rearing

3.2.1. The structure of the vegetative ensemble in apple trees. Tree cultivation, determined genetically and quantitatively by the volume of vegetative growth accumulated annually by the trunk size, the height and parameters of the tree canopy, is the most important factor in establishing the cultivation system [2; 12]. The lateral surface of the canopy in the 3-year-old apple trees is 20975-24568 m^2/ha, and the volume of the canopy is 1.6-2.6 m^3/tree, and, respectively, 6249-10155 m^3/ha. The lateral surface of the canopy in the 4th year of its vegetation is from 22498 m^2/ha, in the Red Velox variety, up to 25779 m^2/ha, in the Granny Smith variety. In 5-year-old trees, the lateral surface of the canopy (24021-28709 m^2/ha) had increased significantly and achieved the optimal values for such orchards, and in 6-year-old trees the lateral surface of the canopy had increased up to 30662 m^2/ha.

The volume of the canopy, in the 4-year-old trees, was 7968 m^3/ha in the Red Velox variety and had increased considerably in the varieties which were more vigorous, reaching 10741-11600 m^3/ha. In 2019, the volume of the canopy of 6-year-old trees reached the optimal values, namely 9608-14881 m^3/ha. The area of soil cover by the canopy of the 4-year-old trees was 36.9 – 41.3 % and was slightly different in various varieties. The 6-year-old trees covered the the whole planting area, the coverage level reaching the level of 43.8 %.

3.2.2. The diameter and surface of the cross section of the trunk. In the 3rd year of vegetation, the diameter of the trunk varied from 22.15 mm in the Granny Smith variety, to 23.32 mm in the Gala Buckeye Simmons variety. In the 5th year after the planting, the index under the study doubled and was

37.29 – 41.42 mm. The largest trunk diameter was recorded in the Gala Buckeye Simmons variety (37.29 mm), and the smallest – in the Red Velox variety (37.29-41.42 mm). Corresponding values of the cross-sectional area of the trunk were obtained in the Gala Buckeye Simmons variety both in 2017 (366.1 mm^2) and in 2019 (650.2 mm^2).

3.2.3. Average and total length of the annual branches. In the 2nd year of vegetation, the average length of the annual branches in the studied varieties was 38.9-45.2 cm. The difference was significantly assured in the Granny Smith and Golden Delicious Reinders varieties, compared to the Red Velox variety. In the 3-rd year, the trees had a favourable development and the length of the annual branches was 37.5-42.8 cm. In the 4th year of vegetation, the varieties under the study recorded a decrease in growth (25.3-37.5 cm) compared to the previous year (35.4-42.3 cm). The Gala Buckeye Simmons and Red Velox varieties formed a total annual growth length of 880-971 cm/tree, while in the Granny Smith, Golden Delicious Reinders and Fuji Kiku varieties this index ranged from 1419 to 1564 cm/tree. The growth potential of the trees decreased as the branches aged. The increase in the average length of the annual branches in the Granny Smith and Golden Delicious Reinders varieties was significantly assured compared to the Gala Buckeye Simmons and Red Velox varieties. In the 3rd year after the planting, the total length of the annual branches was 675-952 cm/tree, with insignificant differences between varieties. In the 4th year of vegetation, the length of the annual growths in the Red Velox and Golden Delicious Reinders varieties was smaller (878-971 cm/tree) compared to the Granny Smith (1571 cm/tree) and Gala Buckeye Simmons varieties (1310 cm/tree). In the 5-th year, the total length of the annual growths was 1116-1574 cm/tree, with higher values in the Granny Smith and Gala Buckeye Simmons varieties. In both experiments, higher annual growth values were recorded in the Gala Buckeye Simmons, Granny Smith, Golden Delicious Reinders and Fuji Kiku varieties as compared to the Red Velox variety, but these were not always significantly assured.

3.3. The structure of the canopy

The canopy of 3-year-old Gala Buckeye Simmons apple trees had 45 annual branches and 19 biennial branches. Over 60% of the branches were located at a level of 60-160 cm from the ground, 26-29 % – at 160-240 cm, and only 2-5 % – at a level of 240-320 cm from the ground. In 4-year-old trees, in the basal part of the canopy, there are 41 % of annual branches, 41 % of biennial branches and 64 % of 3-year-old branches at a level of 70-150 cm from the ground. At a level of 150-230 cm from the ground, the number of one-year-old branches (36%), 2-year-old branches (34 %) and 3-year-old branches (18%) decreases in comparison with the basal part of the canopy, and in the upper part of the tree the number of branches decreases considerably (18-25%).

The rational location of the branches of different ages on the axis formed premises for a more uniform distribution of the fruit in the canopy of the trees (tab. 1).

The distribution of fruit along the axis in 2018 differed a lot from that in 2017, because the fruit harvest in 2018 was much smaller (28-54 fruit/tree) compared to 2017 (82-101 fruit/tree). Thus, in the Golden Delicious Reinders variety, at the height of 60-160 cm from the ground, there were 27 fruit, at 160-240 cm there were 16 fruit, and at the level of 240-320 cm there were only 8 fruit. Gala varieties Buckeye Simmons, Granny Smith, Red Velox and Fuji Kiku recorded the same distribution of fruit, as regarding the decrease of their number from the bottom of the canopy to its top**.**

Table 1. Number of fruit according to the biological peculiarities of the variety

Variety	**Level from the ground, cm**	**Number of fruit, piece/tree**			**Average, piece/tree**	**%**
		y. 2017	**y. 2018**	**y. 2019**		
Granny Smith (control samples)	60-160	32	21	45	32,7	35,5
	160-240	31	17	50	32,6	35,4
	240-320	21	9	49	26,3	29,1
Total	**-**	**84**	**48**	**144**	**92**	**100**
Gala Buckeye Simmons	60-160	34	26	58	39,3	38,3
	160-240	30	17	65	37,3	36,1
	240-320	28	11	39	26	25,6
Total	**-**	**92**	**54**	**162**	**102,7**	**100**

In the 5th year, the number of fruit increased significantly compared to the previous years and ranged from 129 pcs/tree in the Red Velox variety up to 170 pcs/tree in the Golden Delicious Reinders variety. In the Red Velox variety, out of 129 fruit, 52 were placed at a level of 60-160 cm, 48 fruit – at 160-240 cm and only 29 fruit grew at a level of 240-320 cm from the ground. On average, during 3 years of fruiting, 37.0-43.0% of the fruit were located at the level of 60-160 cm from the ground, 31.2-36.4 % – at 160-240 cm, and 24.4-29.2 % were in the upper part of the canopy. he distribution of fruit along the shaft was much more uniform compared to the number of first-rank branches and fruit branches.

The studied varieties were suitable for the formation of simple keeping canopy which had the ability to produce quality fruit along the entire length of the axis.

3.4. The photosynthetic activity of apple trees

3.4.1. Leaf area. In the 2-year-old trees, higher leaf area values were recorded on shoots (1.32-1.63 m^2/tree), and only 0.91-1.24 m^2/tree leaves were recorded on the fruit branches. In the 3-rd year the leaf area increased significantly (5.72-9.23 m^2/tree) both on the annual branches (3.20-4.62 m^2/tree) and on the fruit branches (2.52-4.81 m^2/tree). The highest values, by 34.39-61.30 % higher, were identified in the trees of Gala Buckeye Simmons, Granny Smith, Golden Delicious Reinders and Fuji Kiku varieties, as compared to the Red Velox variety. The leaf area of the 4-year-old trees developed mainly on the fruit branches (2.77-6.47 m^2/tree), and only 1.56-

2.91 m^2/tree – on the annual branches. The Gala Buckeye Simmons, Granny Smith and Golden Delicious Reinders varieties formed a larger leaf area compared to the Red Velox variety, which also had a more pronounced fruiting alternation. In the 4th year, the leaf area was larger in the Golden Delicious Reinders and Fuji Kiku varieties, both on shoots (4.12-4.62 m^2/tree) and on the fruit branches (4.61-4.81 m^2/tree). In the 5-th year, at the end of the vegetative stage, the leaf area on the shoots was 1.99-3.33 m^2/tree (fig. 1). A higher increase in the leaf area per shoot was recorded in the Granny Smith variety (3.33 m^2/tree), and a smaller increase – in the Gala Buckeye Simmons variety. At the same time, the leaf area on the fruit branches was the largest in the Gala Buckeye Simmons variety, and the smallest – in the Red Velox variety (1.72 m^2/tree). The number of leaves per tree (3.91-6.44 m^2/tree) differed depending on the variety, and was related to the leaf area on shoots (1.99-3.30 m^2/tree) and fruit branches (1.72-4.14 m^2/tree).

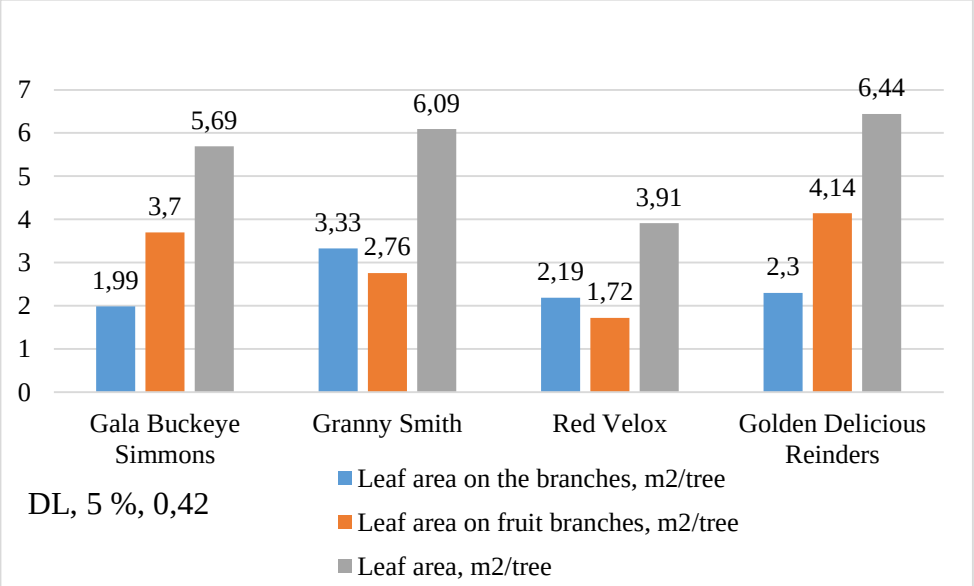

Figure 1. The leaf area of the trees depending on the biological characteristics of the variety (Ltd "Prodcar", 2018)

The Golden Delicious Reinders variety produced the largest leaf area (6.44 m^2/tree), and the Red Velox variety – the smallest one (3.91 m^2/tree) compared to the Gala Buckeye Simmons and Granny Smith varieties. The 2-year-old trees formed a leaf area of 8710-11093 m^2/ha, and the 3-year-old trees doubled or even tripled this index (22308-35997 m^2/ha) (fig. 2).

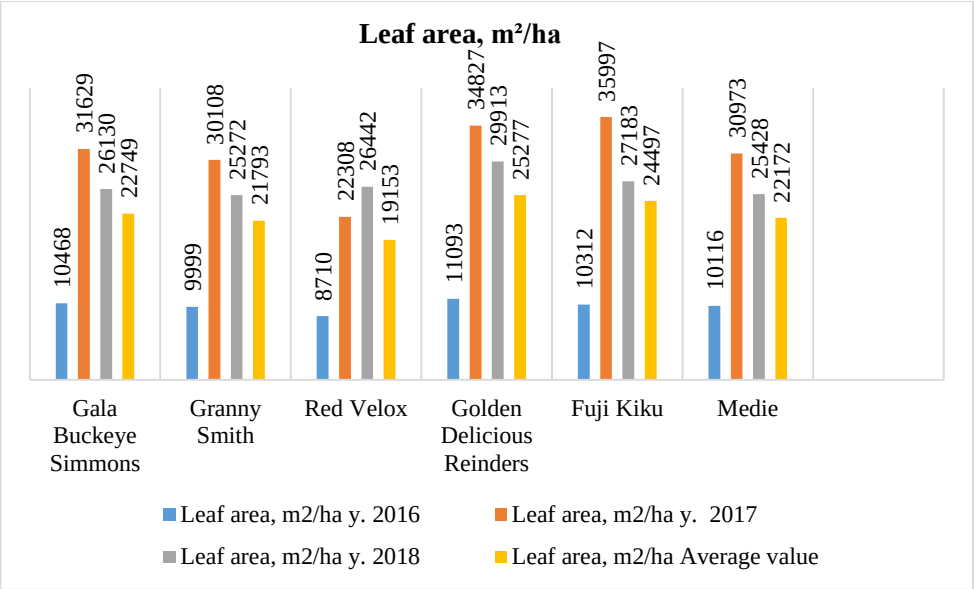

Figure 2. The leaf area of the apple trees depending on to the biological peculiarities of the variety, (Ltd "Elite Fruit")

Significantly higher values of leaf area, by 56.1-61.4 %, were recorded in the trees of Golden Delicious Reinders (34827 m^2/ha) and Fuji Kiku (35997 m^2/ha) varieties, compared to the Red Velox (22308 m^2/tree) variety. During the period of tree growth and fruiting, higher leaf surface values were recorded in the Golden Delicious Reinders and Fuji Kiku varieties.

During the growth period of the trees, 68.9-76.1 % of the leaves were formed on the shoots and only 23.9-31.1 % on other types of branches. During the growth and fruiting periods, the leaf area on the tree registered identical values on both shoots and fruit branches. The 4-year-old trees provided optimal photosynthetic conditions for intensive orchards (25272-29913 m^2/ha), which varied depending on the variety and the productivity of trees.

3.4.2. Foliar index. In the 2nd year of vegetation, in the Gala Buckeye Simmons variety, the foliar index had the value of 1.0, in the 3rd year – the value of 3.1, and in the 4th year it constituted 1.8. In the 4th vegetation year, higher values of the foliar index were obtained in the orchards of Gala Buckeye Simmons, Granny Smith and Fuji Kiku varieties. The Red Velox variety differed from the Gala Buckeye Simmons, Granny Smith and Fuji Kiku varieties by a significantly lower leaf index. The trees of Gala Buckeye Simmons, Granny Smith, Red Velox, Golden Delicious Reinders and Fuji Kiku varieties, grafted on the rootstock M9, at the age of 4-5 years, achieved an optimal level, for high-dense orchards, of nutrition surface (40.6-43.8 %) and leaf area (25272-29913 m^2/ha). At the same time, the foliar index of the whole orchard and of the trees on the rows showed that the foliage was not uniform within the orchard.

3.5. The intensity of the light in the canopy of the trees

The intensity of solar radiation in the canopy of the apple trees gradually increased from 9 o'clock till 13 or 15 o'clock, and then decreased. The penetration of solar energy into the canopy of the

tree intensified from the bottom to the top of the tree. During the day, the basal part and, especially, the centre of the canopy were dimly lit.

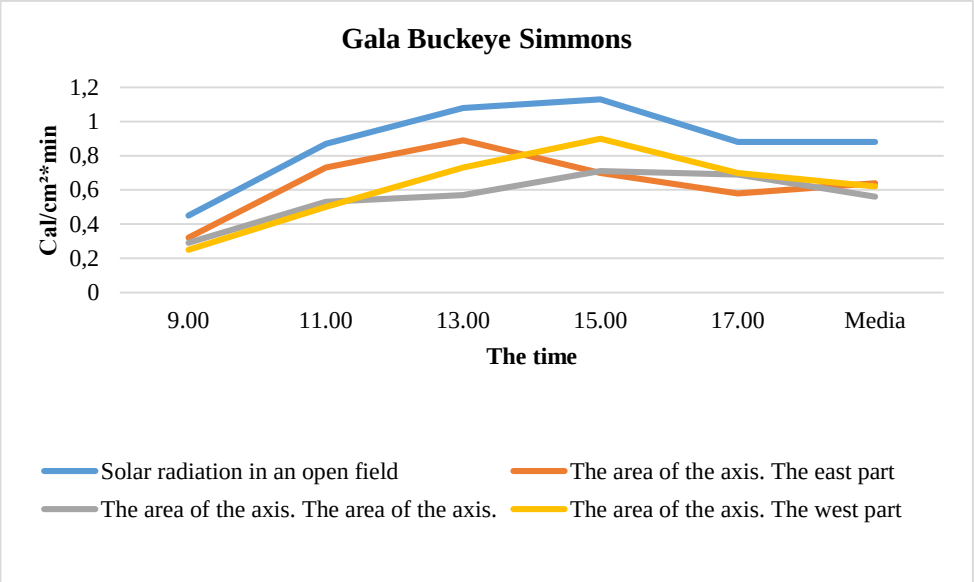

Figure 3. Light regime in the axis area in Buckeye Simmons Gala apple trees, Cal/cm^2 * min, year 2018

Analysing the values of the solar energy in the orchard of the Gala Buckeye Simmons variety, which had been grafted on low-vigorous rootstocks M9, planted at a distance of 3.2 x 0.8 m and had the canopy of an improved slender spindle shape, it could be said with certainty that the orchards in which the trees have a height of 3.5-4.0 m and the base of their canopies have a width 1.0-1.2 m, which decreases towards the top up to 0.8-1.0 m, form well-lit orchard ecosystems, which receive in all areas of the canopy more than 0.2 cal/cm^2 * min, the amount needed for the process of photosynthesis (Fig. 3). During the day a smaller amount of light penetrates the lower part of the canopy, along the row of the trees, compared to the other areas of the canopy. In the morning, in the Granny Smith variety, the leaves in the eastern part of the axis area receive 73 % of the total radiation, those which grow in the centre of the canopy receive 44 %, the leaves in the western part – 63 %, while the leaves in the upper part of the canopy receive 0.41 cal/cm^2 * min. As the angle of the incidence of the sun rays increases, the degree of illumination of the canopy also increases, reaching 0.63 cal/cm^2 * min in the eastern part, 0.40 cal/cm^2 * min in the centre of the canopy, and 0.51 cal/cm^2. * min in the western part. The penetration power of the solar radiation into the canopy is higher at 13 o'clock, when the eastern part receives 0.79 cal/cm^2 * min (73 % of the total radiation of 1.08 cal/cm^2 * min), the central part of the canopy receives 0, 47 cal/cm^2 * min (44%) and the western part – 0.51 cal/cm^2 * min (47 %). At 13 o'clock, when the sun reaches its zenith, the least illuminated area is situated in the centre of the canopy.

The light penetrates more easily the canopy of the trees of the Red Velox variety in comparison with other varieties, ensuring a more rational illumination of the row of trees. This

fact proves that the Red Velox variety of the second type of fruiting, can withstand a higher density per row of trees.

Analysing the lighting regime in the apple orchards of Gala Buckeye Simmons, Golden Delicious Reinders, Granny Smith, Fuji Kiku and Red Velox varieties, it can be said that, in the case of continuous rows, in the north-south direction, in which the base of the canopy does not exceed 120 cm, the self-shading is non-existent, even if the height of the trees reaches 3.5-4.0 m. The size of the canopy depends on the growth vigour of the variety, the size of the trees and it ensures the penetration of light to all elements of the canopy - an essential condition to maintain the growth of fruit branches in order to obtain a productive volume of fruitful microstructure.

3.6. The formation of fruit organs and the production potential related to the trunk diameter

3.6.1. Number of fruit branches. The 3-year-old trees formed 85-110 fruit branches, the 4-year-old trees formed 143-153 fruit branches, and the 5-year-old trees formed 228-284 fruit branches. During the growth and fruiting period of the trees, the number of fruit branches increased significantly owing to their aging; they reached the maximum values in the 5th year after their planting, The Gala Buckeye Simmons and Golden Delicious Reinders was notable for a higher number of fruit branches, without always being significantly assured.

3.6.2. Number of fruit per tree. The trees started to bear fruit in the 2nd year after their planting; there were 35-41 apples the tree. In the 3rd year of fruiting, the trees yielded 82-101 fruit per tree, and in the 4th year of fruiting the crop decreased significantly and constituted only 28-54 fruit per tree (fig. 4).

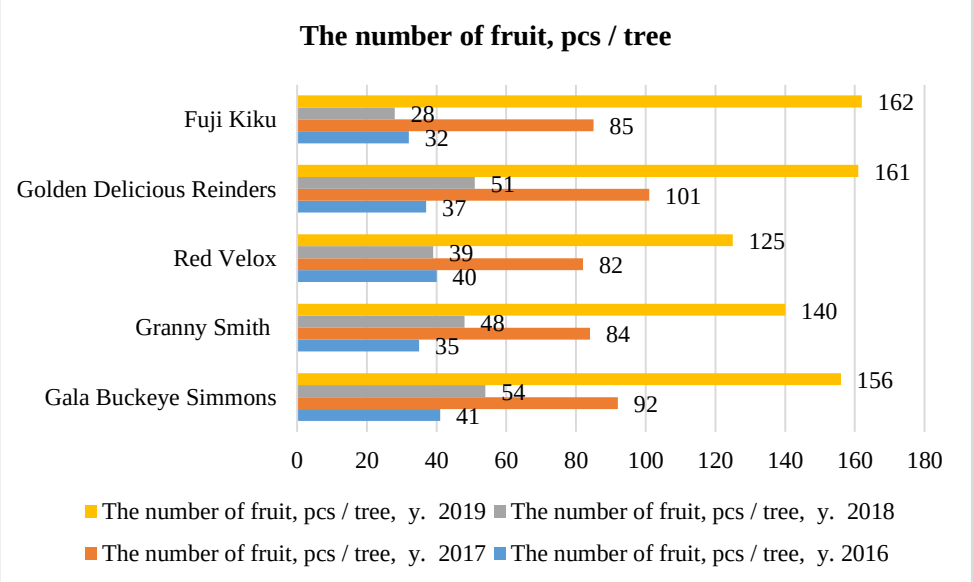

Figure 4. Number of fruit per tree depending on the biological characteristics of the variety

(Ltd "Elite Fruit")

In the 2nd and 3rd fruiting years, the Gala Buckeye Simmons and Golden Delicious Reinders varieties recorded higher number of fruit compared to the Granny Smith, Red Velox and Fuji Kiku varieties. In the 5th year after the planting, the trees yielded 125-162 pcs/tree. The Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties produced a higher quantity of fruit as compared to the Red Velox variety.

3.6.3. The production potential in relation to the trunk diameter. The production potential was calculated according to the diameter of the trunk and the number of fruit per tree (fig. 5).

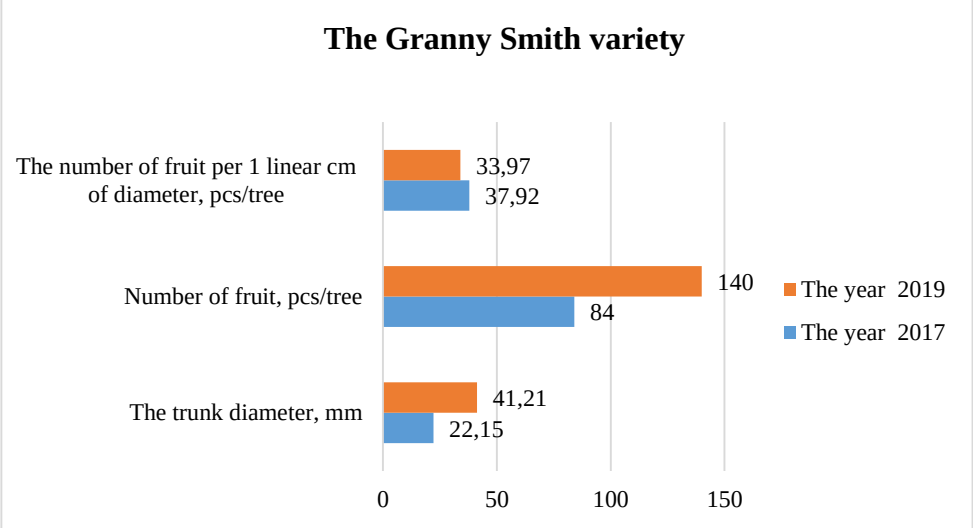

Figure 5. The production potential in Granny Smith variety in relation to the trunk diameter (Ltd "Elite Fruit")

In the 3rd year of vegetation, the number of fruit per linear centimetre of trunk diameter was from 35.95 pcs/tree in the Red Velox variety up to 43.83 pcs/tree in the Golden Delicious Reinders variety. In the 5th year, the Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties produced a larger amount of fruit per 1 linear cm of trunk diameter (37.66-39.20 pcs/tree) compared to the Granny Smith and Red Velox varieties (33.52-33.97 pcs/tree). Thus, during the growth and fruiting period, in order to obtain optimal fruit harvests, it is necessary to obtain 38.89-36.67 fruit per linear centimetre of trunk diameter.

3.7. The regulation of the reproductive organs

The thinning of the reproductive organs of a tree is essential in obtaining qualitative fruit, because it influences the fruit colour and size, the balance between the vegetative growth and fruit etc. [2. 3].

3.7.1. The number of red-spotted buds (NBR), of the tied inflorescences (NIL) and the number of fruit in an inflorescence. The trees in the untreated group and those in the group where manual thinning of the fruit had been used, registered the higher number of tied inflorescences (147-166 pcs/tree), while in the groups where the chemical thinning was applied their number decreased a lot and

constituted only 119-132 pcs/tree. In the Gala Buckeye Simmons variety, the number of fruit per tree was from 136 pcs/tree in the group where they had been sprayed with Dira Max LG, 2 l/ha, up to 164 pcs/tree in the control group of trees. Therefore, the chemical thinning of newly formed flowers and fruit substantially reduced the number of fruit per tree. The trees in G3 produced 155 apples per tree, and those in G2, G4 and G5 produced 144, 142 and 136 fruit per tree, respectively (fig. 6).

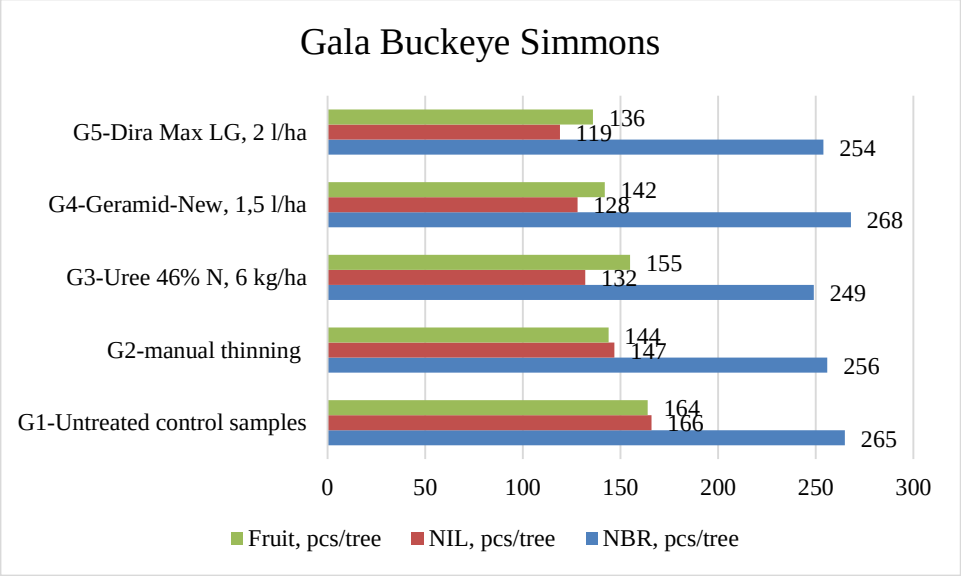

Figure 6. The number of red-spotted buds (NBR) and the number of tied inflorescences (NIL) in the canopy of the trees of Gala Buckeye Simmons variety depending on the mode of the reproductive organs thinning

In the untreated group (G1), the fruit were distributed relatively evenly on the fruit branches, 45.6 % by one, 35.0 % by two and 19.4 % by 3 fruit. In the manual thinning group (G2), most fruit (76.8 %) were placed by or two (19.6 %), and only 3.6 % of the fruit were placed by 3 in the inflorescence. The treatment of trees with Urea 46% N, 6 kg/ha significantly contributed to the increase in the number of single fruit in the inflorescence (70.5 %) and decreased the number of groups in threes (3.7%). The same tendency was registered when treating the trees with Geramid-New, 1.5 l/ha (G4) and with Dira Max LG, 2 l/ha (G5), in the sense that there was only one fruit in the inflorescence (69.4-70.8 %) and only 8.2-10 % of the fruit were grouped in threes (fig. 7).

In the Granny Smith variety, the NIL values in G1 (190 pcs/tree) and G2 (185 pcs/tree) were 57-91% higher compared to G3, G4 and G5 variants. In G1, 39.1% of apples were distributed by one, 35.0% by two and 25.4% of the fruit was by 3 per inflorescence, and in G2 the highest number of apples was registered (86.2%) which were placed by one in the inflorescence. The use of Geramid-New, 1.5 l/ha, and LG Dira Max, 2 l/ha, also increased the number of single fruit (72.1-75.6%) in the inflorescence. As for the Fuji Kiku variety, the manual thinning in June (G2) and use of Urea products

46% N, 6 kg/ha (G3), Geramid-New, 1.5 l/ha (G4) and Dira Max LG, 2 l/ha (G5) ensured an optimal number of fruit per tree (127-135 pcs/tree).

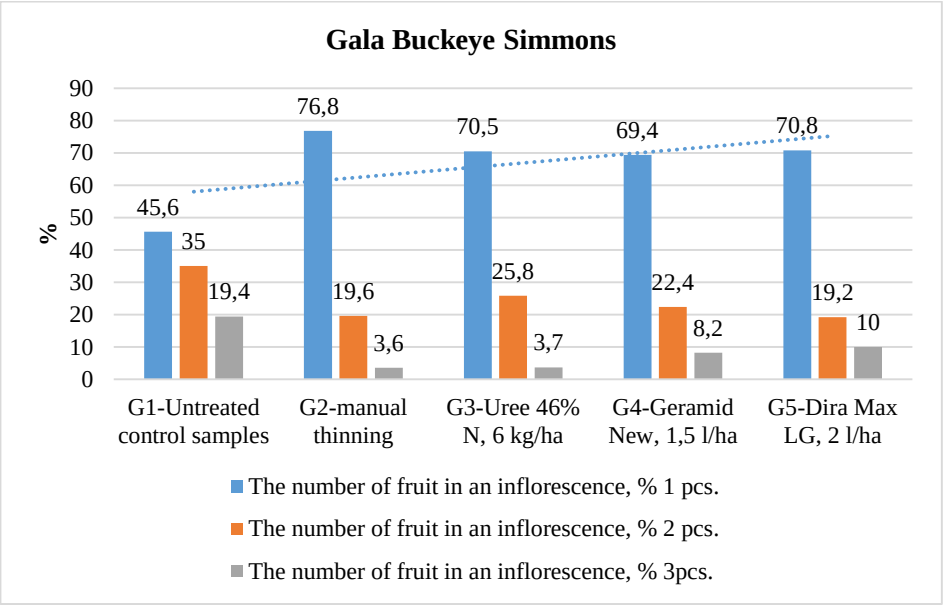

Figure 7. The number of fruit in an inflorescence in the Gala Buckeye Simmons variety depending on the mode of thinning of the reproductive organs

In the group of trees where the manual thinning was used (G2), the number of the single fruit in the inflorescence was of 88.1%; their number in the groups where growth regulators were used – G3, G4, G5 – was of 69.1-75.1%, while in the untreated group, their number was of 48.6%. The thinning of the fruit reproductive organs to only one fruit per inflorescence reduced the competition between the fruit which allowed each fruit to obtain the optimal dimensions.

3.7.2. Fruit diameter. The diameter of the fruit in the Gala Buckeye Simmons variety changed depending on the method of fruit number regulation and constituted 54.9-74.9 mm (tab. 2). In the groups G2, G3, G4 and G5, the most fruit (47.3-59.5%) had the diameter of 71-75 mm and only 3.4-7.6% of them had the diameter of 61-65 mm. An impressive part of the fruit (10.2-21.5%) had the diameter of 76-80 mm and even more than 80 mm (6.9-11.6%).

Table 2. The impact of the method of fruit reproductive organs thinning on the fruit distribution in the Gala Buckeye Simmons variety depending on their diameter

Group	Average diameter, mm	Fruit diameter, mm						
		55	56-60	61-65	66-70	71-75	76-80	80
		Number of fruit (%)						
G1– untreated control samples	54,9	3,4	41,2	20,7	4,7			
G2 – manual thinning	72,4			7,6	19,4	51,2	10,2	11,6
G3 – Urea 46% N, 6 kg/ha	72,9			5,8	12,4	59,5	12,7	9,6
G4 – Geramid New, 1,5 l/ha	74,9			3,4	19,6	55,8	14,3	6,9
G5 – Dira Max LG, 2 l/ha	69,7			6,6	15,8	47,3	21,5	8,8

In the Granny Smith and Fuji Kiku varieties, in G1 more than 75% of the fruit had the diameter of less than 60 mm, and in G2, G3, G4 and G5 the fruit with a diameter of more than 71 mm made up more than 80%. The obtained data reconfirmed the efficiency of the chemical thinning using growth regulators the active substances of which were NAA, NAD and Urea 46% N, as well as their impact on the fruit size.

3.7.3. Fruit size categories. According to IOS, the fruit quality is determined according to their commercial appearance, namely their size, shape, colour, dry matter content etc. In the Gala Buckeye Simmons variety, in G1, the most fruit (74.6%) had the II category and only 25.4% had the I category. The manual fruit thinning (G2) contributed to the production of 73% of fruit of the "Extra" category, 19.4% of the category I and 7.6% of the II category. The utilisation of Urea 46% N, 6 kg/ha (G3) increased the number of fruit of the "Extra" category (81.8%). The use of Geramid-New, 1.5 l/ha (G4) and Dira Max LG, 2 l/ha (G5) also contributed to the production of 77.0-77.6% of "Extra" category apples, and only 3.4-6.6% of the II category fruit.

3.7.4. The average fruit weight and the fruit production. In the Gala Buckeye Simmons variety, the highest fruit weight (144-172 g) was recorded in G3. The fruit weight was registered statistically, 15.5-17.8% in 2017 and 10.2-13.4% in 2019 in the groups G2, G3, G4 and G5 compared to the control group. The fruit harvest was of 49.9-57.4 t/ha in 2017 and 72.6-88.2 t/ha in 2019. In 2017, the trees in the group G1 showed the lowest indices - 12.6%, and the trees in G5 - 14.0%. In 2019, the fruit harvest in the groups G2, G4 and G5 also decreased compared to the harvest obtained from the untreated control samples.

The Fuji Kiku variety is characterized by large fruit and big crops (Table 3). In the groups where manual (G2) and chemical thinning (G3, G4, G5) had been used, the fruit weight increased significantly in relation to the control group. In 2017 the fruit harvest was 51.6-62.3 t/ha. The lowest productivity (51.6 t/ha) was registered in the group G5, and the highest – in the group G3. In 2019, the values of fruit harvest in the groups G1 and G3 were ensured statistically compared to the groups G2, G4 and G5.

Table 3. The impact of the method of fruit reproductive organs thinning in the Fuji Kiku variety on fruit weight and production

Group	Average fruit weight, g		Fruit production, t/ha		Average value, t/ha	%
	y. 2017	y. 2019	y. 2017	y. 2019		
G1- Untreated control samples	145	125	57,7	85,5	71,6	100
G2-Manual thinning	177	147	55,9	74,6	65,2	91,1
G3-Urea 46% N, 6 kg/ha	182	159	62,3	81,2	71,7	100,2
G4-Geramid New, 1,5 l/ha	174	151	54,8	75,7	65,2	91,1
G5-Dira Max LG, 2 l/ha	175	154	51,6	76,1	63,8	89,2
DL, 5 %	9,5	7,3	5,4	4,9	-	-

In the Granny Smith variety, the utilisation of manual fruit thinning (G2) and the use of growth

regulators (G3, G4, G5) significantly favoured the gain in fruit weight – 16.9-21.7 %. In 2017 the fruit harvest constituted 49.8-57.1 t/ha and in 2019 it was 68.7-76.5 t/ha. The productivity of the trees in the control group (G1) and G3 was also higher when the Urea was used 46% N, 6 kg/ha (G3). The crop of Granny Smith variety, on average in two years, was lower in the group G2 (61.5 t/ha) and in the group G4 (61.9 t/ha) compared to the group G1 (65.9 t/ha) and G3 (66.8 t/ha). As for the Red Velox variety, in 2017, the average weight of the fruit in the control group (G1) constituted 142 g, while in the other groups, this index increased significantly - by 21.1-23.2 %. The highest values were registered in the trees in the groups G4 and G5, namely 21.6%. The fruit harvest was better in 2019 (65.7-72.2 t/ha) compared to 2017 (49.6-57.4 t/ha). In 2019, the best harvests were obtained in the groups G1 (70.1 t/ha) and G3 (72.2 t/ha) as compared to the groups G2, G4 and G5. The Golden Delicious Reinders variety also reacted positively to the thinning of their fruit reproductive organs. In 2019 the fruit harvest (71.72 t/ha) significantly exceeded the 2017 harvest (60.50 t/ha). In 2017 and 2019, the best harvest was obtained in G1 (78.9 t/ha) and G3 (75.8 t/ha).

3.7.5. The influence of the method of the fruit reproductive organs thinning on the economic efficiency of fruit production. The average harvest of the Gala Buckeye Simmons variety was from 61.2 t/ha in the group G5 to 72.8 t/ha in the group G3. The income from the sale of the production constituted 212.7-436.8 thousand lei/ha. The production cost varied from 115.1 thousand lei/ha, in the control group of trees, to 168.6 thousand lei/ha in the group G4. A higher income from the sale of the production was obtained in the group G3 (272.1 thousand lei/ha), where the Urea 46% N, 6 kg/ha had been used, and the lowest - in the group G1 (97.6 thousand lei/ha). The highest values of profitability were obtained in the groups G3 (165.2%) and G4 (129.2%). The Granny Smith variety registered higher values (66.8 t/ha) in G3, and also a higher profit from the commercialization of the production (210.5 thousand lei/ha) at a profitability of 170.2 %. The expenses were higher when labour force for the manual thinning was used (163.0 thousand lei/ha). The economic values of the Red Velox, Golden Delicious Reinders and Fuji Kiku varieties were identical to the Gala Buckeye Simmons and Granny Smith varieties. The biggest profit from the selling of the obtained products was obtained in the group G3, where the Urea 46% N was used, and the smallest profit – in the group G1 (tab. 4).

The profit values varied from 97.6 and 272.1 thousand lei/ha for the Gala Buckeye Simmons variety, from 69.2 and 210.5 thousand lei/ha for Granny Smith, from 63.9 and 204.5 thousand lei/ha for Red Velox, from 99.3 and 263.1 thousand lei/ha for Golden Delicious Reinders and from 120.4 and 311.2 thousand lei/ha for the Fuji Kiku variety. It was certain that, on average in 2 years, the Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties ensured the highest profitability in the G3 in which the Urea 46% N, 6 kg/ha had been used, and in the group G2, where the manual thinning of the fruit was employed.

Table 4. The economic efficiency of the Fuji Kiku variety productivity depending on the method of fruit reproductive organs thinning

Group	Average crop, t/ha	Production sale income, thousand lei/ha	The production cost, thousand lei/ha	Production sale profit, thousand lei/ha	Production profitability, %
G1	71,6	250,6	130,2	120,4	92,4
G2	65,2	456,4	225,5	230,9	102,4
G3	71,7	501,9	199,1	302,8	152,1
G4	65,2	456,4	202,5	253,9	125,4
G5	63,8	446,6	198,6	248,0	124,9

3.8. The harvest and the fruit quality

3.8.1. Fruit production. In the second year after the trees had been planted, the harvest constituted 5.1-6.6 kg/tree. In the 3-year-old trees, the fruit harvest tripled and ranged from 14.4 kg/tree, for the Red Velox variety, to 17.0 kg/tree, for the Golden Delicious Reinders variety. In the fourth year, the fruit harvest decreased considerably and amounted to only 5.01-8.85 kg/tree. Gala Buckeye Simmons, Granny Smith and Golden Delicious Reinders varieties showed significantly higher values compared to the Red Velox and Fuji Kiku varieties. In the 5th year after the planting, the harvest increased significantly compared to previous years, the crop of the Gala Buckeye Simmons, Granny Smith, Golden Delicious Reinders and Fuji Kiku varieties increased significantly as compared to the Red Velox variety, which constituted 18,5 kg/tree. Analysing the average harvest obtained at the Ltd "Elit Fruct" in the first 4 years of fruiting it was found that the degree of fruiting alternation amounted to 53.4 % in the Gala Buckeye Simmons variety, 55.0% in the Granny Smith variety, 1% in the Red Velox variety, 61.1% in the Golden Delicious Reinders variety and 77.0% in the Fuji Kiku variety (Table 5).

Table 5. Fruit production depending on the biological peculiarities of the variety

Variety	Fruit production, kg / tree				Average value, kg/tree
	y. 2016	y. 2017	y. 2018	y. 2019	
Granny Smith (control)	5,8	14,5	8,28	20,3	12,22
Gala Buckeye Simmons	6,6	15,1	8,85	22,4	13,23
Red Velox	6,4	14,4	6,99	18,5	11,57
Golden Delicious Reinders	5,8	17,0	8,76	21,7	13,31
Fuji Kiku	5,1	14,8	5,01	21,9	11,70
DL, 5 %	1,3	2,1	2,12	1,65	-

The fruit output per hectare shows that the Gala Buckeye Simmons variety (51.7 t/ha) and the Golden Delicious Reinders variety (52.1 t/ha) had a higher productive potential compared to the Granny Smith, Red Velox and the Fuji Kiku varieties (45.2-47.8 t/ha). This is due to the fact that the

Gala Buckeye Simmons and Golden Delicious Reinders varieties have more short fruiting branches, which grow every year. In second year after the planting, the harvest varied from 19.9 t/ha in the Fuji Kiku variety, up to 25.8 t/ha in the Gala Buckeye Simmons variety. The Fuji Kiku variety had a lower yield (19.9 t/ha) which was statistically assured compared to the other varieties.

The productivity of the Golden Delicious Reinders variety amounted to 12.7-17.9% and was significantly higher compared to the Gala Buckeye Simmons, Granny Smith, Red Velox and Fuji Kiku varieties. In the fourth year, the harvest decreased compared to the third year (59.14 t/ha) and the average amount for 5 varieties constituted 29.58 t/ha. The trees of Gala Buckeye Simmons, Granny Smith and Golden Delicious Reinders varieties produced big crops (32.4 -34.5 t/ha) compared to the Fuji Kiku variety (19.5 t/ha). In the fifth year, the trees brought in a record average harvest of 81.88 t/ha. The Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties produced a bigger crop, namely by 10.3-17.2 %, which constituted 84.8-87.5 t/ha, compared to Granny Smith and Red Velox varieties (72.3-79.3 t/ha) (Fig. 8; 9).

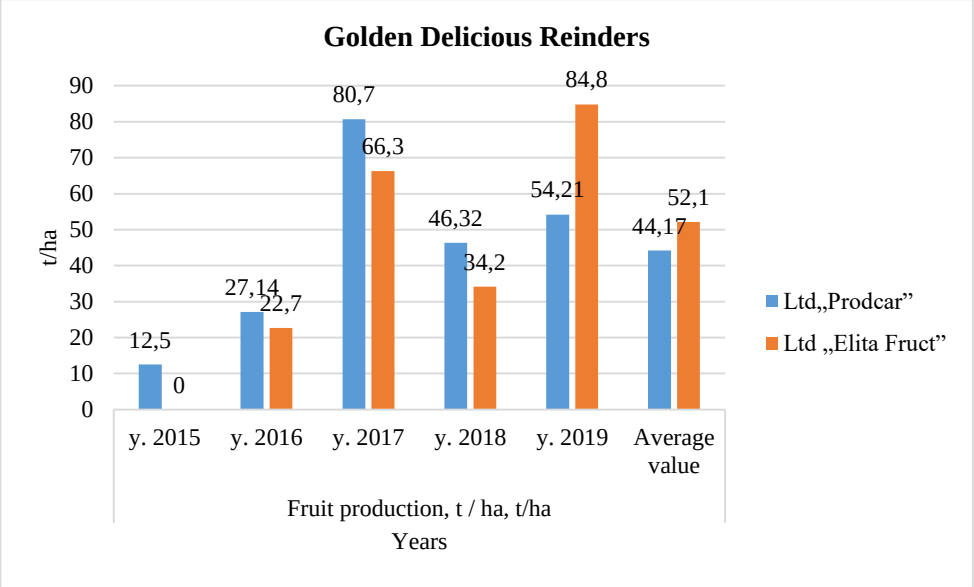

Figure 8. The Golden Delicious Reinders productivity depending on the location of the orchard and the age of the trees, t/ha

In the apple orchards at the Ltd "Prodcar", in the 4th year of vegetation, the fruit productivity was higher as compared to the second and third years; the average quantity constituted 19.32 kg/tree. In the fifth year, the Red Velox variety brought in a crop of 8 kg/tree, which was significantly lower by 37.50-48.75% compared to the Gala Buckeye Simmons, Granny Smith and Golden Delicious Reinders varieties (11.0-11.9 kg/tree). In the sixth year, the Gala Buckeye Simmons variety produced the highest fruit yield (15.38 kg/tree), by 13.0-13.6 % higher in comparison with the Granny Smith and Golden Delicious Reinders varieties (13.6-13.9 kg/tree) and by 21.1 % higher compared to the Red Velox variety (8.71 kg/tree). The fruiting alternation in the orchards of the Ltd "Prodcar" amounted to 45.7%

in the Gala Buckeye Simmons variety, 44.7% in the Granny Smith variety, 56.8% in the Red Velox variety and 50.1% in Golden Delicious Reinders variety.

In the 4th year of vegetation, the Gala Buckeye Simmons variety (77.71 t/ha) and Golden Delicious Reinders (80.70 t/ha) variety crops had significantly increased - by 9.6-13.8% versus the Granny Smith variety (70.90 t/ha) and by 7.7-11.2% versus the Red Velox variety. The Red Velox variety had a lower productivity (31.37 t/ha) – by 45% compared to the Gala Buckeye Simmons variety, by 36% compared to the Granny Smith variety and by 47% compared to the Golden Delicious Reinders variety. In the 6th year after the planting, the average Red Velox variety harvest constituted 33.97 t/ha, while the Gala Buckeye Simmons variety harvest amounted to 59.97 t/ha, and the Granny Smith and Golden Delicious Reinders varieties harvests were identical, namely 53.04-54.21 t/ha. The Gala Buckeye Simmons, Granny Smith and Golden Delicious Reinders varieties produced a bigger crop as compared to the Red Velox variety. Quite big crops were brought in by the Gala Buckeye Simmons variety compared to the Granny Smith and Golden Delicious Reinders varieties.

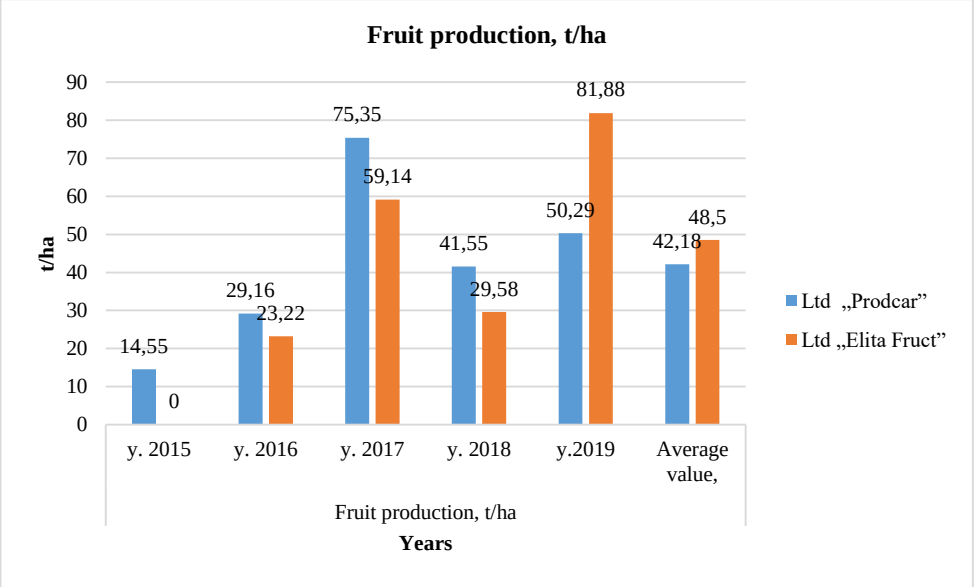

Figure 9. Integral fruit production depending on the location of the orchard and the age of the trees, t/ha

In conclusion, it could be stated that the Gala Buckeye Simmons, Granny Smith and Golden Delicious Reinders varieties are better adapted to the climatic conditions in the area, and, based on fruit yield in the first 5 years of fruiting, they can be recommended for cultivation in high-dense orchards in the central area of the Republic of Moldova.

3.8.2. The production potential related to the canopy volume and the cross-sectional area of the trunk. In the third year after the planting of the trees, the production capability of the Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties (7.05-7.72 kg/m^3) showed an essential growth compared to the Granny Smith variety (5.57 kg/m^3), but a decrease

compared to the Red Velox variety (9 kgm^3). The fruit harvest related to the transverse surface of the trunk ranged from 4.02 kg/cm^2 in the Red Velox variety, up to 4.70 kg/cm^2 in the Golden Delicious Reinders variety. In the 5th year after the planting, the canopy volume reached optimal values, and the fruit production per volume unit ranged from 5.97 kg/m^3 in the Granny Smith variety, up to 7.40 kg/m^3 in the Red Velox variety. Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties recorded 6.57-7.00 kg/m^3 each. These varieties have even greater potential (3.34-3.44 kg/cm^2) compared to the Granny Smith and Red Velox varieties (3.10-3.14 kg/cm^2).

The productive volume of the canopy of 5-year-old trees (9765 and 13280 m^3/ha), related to an area unit, has corresponding capacities to produce normal productions from the quantitative viewpoint, namely 72.3-87.5 t/ha in the Gala Buckeye Simmons, Granny Smith, Red Velox, Golden Delicious Reinders and Fuji Kiku varieties grafted on the M9 rootstock and reared in an intensive cultivation system. The productivity index values for the 5-year-old trees of Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties are higher than 3.2 kg/cm^2, and those of Granny Smith (control) and Red Velox varieties ranges between 3.10 and 3.16 kg/cm^2.

3.8.3. Fruit quality

The weight of the fruit. The experiments performed at the Ltd "Elite Fruit" showed that the average weight of the fruit differed from year to year, and constituted 140.2-172.6 g. Larger fruit were recorded in 2017 and 2018. At the Ltd "Prodcar", during the period of tree growth, the harvest amounted to 14.55-29.16 t/ha, and the average weight of the fruit was of 159.7-162.8 g. During the growth and fruiting period of the trees, not only the harvest had increased (41.55-75.35 t/ha), but also the weight of the fruit (174.4 175.9 g); during the fruiting period of the trees the harvest constituted 50.29 t/ha, and the average fruit weight constituted 144.2 g. Over the years, fruit weight was higher in Granny Smith and Red Velox varieties as compared to the Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties.

As the firmness of the fruit is a genetic index, it also changes depending on the productivity of the trees. Thus, in 2016, the fruit firmness was 7.15-7.43 kgf/cm^2 (160.6 g), in 2017 it constituted 7.45 - 7.74 kgf/cm^2 (172 g), in 2018 – 7.36-7.73 kgf/cm^2 (172.6 g) and in 2019 – 8.26-8.55 kgf/cm^2 (140.2 g). The firmness of the fruit in 2019 was much higher compared to the previous years, but their weight was lower. The low fruit weight can be explained by the fact that large fruit have a lower calcium content per 100 g of weight of a fresh product [2, pp. 208-220]. In the orchard of the Ltd "Prodcar", the lowest average weight of fruit was registered in 2019 (144.2 g), but their firmness had high values, namely 8.03-8.39 kgf/cm^2. A comparative analysis of the firmness of the fruit and its size, can indicate that the

firmness of the apples decreases when the average weight of the apple increases, which means that larger fruit, much in demand on the market, risk to become soft.

The titratable acidity of the Granny Smith variety fruit, at the Ltd “Elit Fruct”, varies between 0.39% in 2019 and 0.47% in 2016. The Gala Buckeye Simmons variety has a lower content of titratable acidity in fruit (0.29-0.30%) as compared with the Red Velox (0.27-0.34%), Golden Delicious Reinders (0.29-0.34%) and Fuji Kiku (0.28-0, 36%) varieties, but it is not always significantly insured. As for the fruit harvested at the Ltd "Prodcar", their lowest acidity was registered in 2017, when the average fruit harvest constituted 75.35 t/ha. The fruit acidity is a genetic index of a variety, but it has been identified that, when the crop increases, the titratable acidity decreases. In 2019 at the Ltd "Elit Fruct" (81.88 t/ha) and, in 2017, at the Ltd " Prodcar” (75.35 t/ha), Brix was used to assess the SUS content, as soluble sugars usually account for 75-85% of soluble dry matter. The values of this index differ insignificantly from year to year and from variety to variety. For example, at the Ltd “Elit Fruct”, the quantity of SUS in the Gala Buckeye Simmons variety constitutes 14.1-16.0 Brix%, and at the Ltd “Prodcar” it amounts to 14.9-17.5 Brix%. The Fuji Kiku variety is characterized by a higher content of SUS in the fruit (16.9-18.2 Brix%).

The colour of the fruit of Fuji Kiku variety. In the Republic of Moldova, the Fuji Kiku variety does not have in intense colour. Therefore, in order to obtain a well-coloured apple, it is essential to expose the fruit to the sun during their ripening. In order to intensify the colour of the apples, the reflective film was used, which was installed on the soil surface, between rows, 4 weeks before the fruit harvest. In the film-free group of trees, only the half of the epicarp of 75% of the fruit coloured, and only 25% of the apples reddened on an area of 60-70%. In the reflective film group, more than 80% of the surface of the epicarp of over 72% of the fruit reddened, and only less than 70% of the fruit surface of 28% of the fruit coloured. The use of reflective film also had a good impact on the harvest – it amounted to over 70% of high quality fruit in the first stage.

The commercial quality of the fruit. The first harvest of fruit at the Ltd “Elite Fruit” was of “Extra” (75,4-90,1%) and the first quality category (9,9-24,6%). In the second, third and fourth years of fruiting, the commercial quality of the fruit was also high. In 2017, the average harvest amounted to 59.14 t/ha, and the apples of the “Extra” category constituted 69.8-75.4%, those of I category - 16.8-23.6%, and those of the II category - 5.9 to 7.8%. In 2018, when the fruit harvest decreased to 29.58 t/ha, the size and number of "Extra" apples increased (78.9-83.4%). In 2019, when the largest fruit harvest was registered (81.88 t/ha), 75.3-77.4% of "Extra" category fruit were of Gala Buckeye Simmons and Golden Delicious Reinders varieties; in the Granny Smith, Red Velox and Fuji Kiku varieties, the number of "Extra" apples exceeded 80%.

At the Ltd "Prodcar", the "Extra" category of fruit predominated in all varieties. In 2016,

the fruit of the “Extra” category constituted over 60%, those of the category I - 27.1-30.0% and only 2.4-3.2% of the fruit were of the II category. In the 3rd year of fruiting, in the Gala Buckeye Simmons variety, the fruit of "Extra" quality constituted 63.5%, those of the category I - 27.7% and only 8.8% of the fruit were of category II. The same tendency was registered in the Granny Smith and Red Velox varieties, i. e. over 60% of the fruit were of the "Extra" category. In 2018, the fruit of the “Extra” category made up 55.3-71.7%, of the first category - 22.9-36.3%, and those of the second size category amounted to 5.4-8.4 %. The commercial quality of the fruit harvested in 2019 is not statistically assured depending on the variety.

3.9. The economic efficiency of the rush apple varieties in the super-intensive cultivation system in the central region of the Republic of Moldova

The variety is a means of production, and in order to develop it, it is necessary to investigate its capacity to produce sustainable fruit and the environmental conditions of the areas in which it can be cultivated in order to rear it on a large scale [7; 8]. At the Ltd “Elit Fruct”, the average harvest in the first 4 years of fruiting was relatively high and ranged from 45.2 t/ha in the Red Velox variety, up to 52.1 t/ha in the Golden Delicious Reinders variety. The Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties recorded the highest income from the sale of production (310.2-319.9 thousand lei/ha), the Granny Smith and Red Velox varieties generated a lower income. (226-239 thousand lei/ha). The cost of production increased when the crop was bigger; it ranged from 110.9 thousand lei/ha in the Fuji Kiku variety (45.7 t/ha), to 130.9 thousand lei/ha, for the Gala Buckeye Simmons variety (51.7 t/ha) (tab. 6).

Table 6. Economic efficiency of apple fruit production depending on the biological peculiarities of the variety, Ltd “Elit Fruct”

Variety	Average crop, (2016-2019), t/ha	Income from the production sale, thousand lei/ha	Cost of production, thousand lei/ha	Profit from the production sale, thousand lei/ha	Production rentability, %
Granny Smith (control)	47,8	239,0	126,2	112,8	89,4
Gala Buckeye Simmons	51,7	310,2	130,9	179,3	136,9
Red Velox	45,2	226,0	123,1	102,9	83,6
Golden Delicious Reinders	52,1	312,6	131,6	181,0	137,5
Fuji Kiku	45,7	319,9	110,9	209,0	188,4

The profit from the commercialization of the production ranges from 102.9 thousand lei / ha in the Granny Smith variety, up to 209 thousand lei/ha in the Fuji Kiku variety. The Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties generated a much higher profit compared to the Granny Smith and Red Velox varieties. At the Ltd "Prodcar", the varieties

Gala Buckeye Simmons and Golden Delicious Reinders showed a higher profit (159.4-165.0 thousand lei/ha) and profitability (146.7-150.7%) compared with the Granny Smith and Red Velox (81.0-104.1 thousand lei/ha and, respectively, 81.4-96.2%) varieties. It can be stated from the obtained data, that the Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties are profitable in the Republic of Moldova; moreover, they are among the most requested by consumers [2; 10; 11].

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The research conducted and the analysis of the obtained results refers to the study of apple varieties in a super-intensive cultivation system in the central area of the Republic of Moldova, and the development of an apple assortment with high fruiting potential by developing methods to maintain the balance between growth and fruiting. The general conclusions and recommendations are as follow:

1**.** The analysis of the literature on high-dense apple orchards highlighted the main factors which allow to increase the efficiency of solar energy use in orchards, the possible ways to optimize the structure of the orchard that determine productivity which is influenced by both climate and soil, and the vigour of growth of the variety-rootstock association; it also established the methods of apple fruit number regulation using growth regulators [1 *; 2*].

2**.** The formation of the shaft by arching is used when the shaft is strong and the branches on it are poorly developed. The method of directing the shaft proved to be an efficient technological process in forming the trees canopy in the shape of a slender spindle, which favours the increase of the fruit harvest by 23.97-58.80% in the first two years after the planting [2 *; 9 *; 13 *].

3**.** The area of the soil covered by the vegetative structure of the trees (38.8-40.6%), the surface of the canopy (24021-28709 m^2/ha) and its volume (9608-14881 m^3/ha) ensure optimal values at the end of the fruit growing and fruiting periods, being superior in the Gala Buckeye Simmons, Granny Smith, Golden Delicious Reinders and Fuji Kiku varieties compared to the Red Velox variety. Higher values of the annual branch length have been recorded in the Granny Smith, Golden Delicious Reinders and Fuji Kiku varieties (35.0–37.5 cm; 1419–1564 cm/tree) as compared to Gala Buckeye Simmons and Red Velox varieties (25.3-27.8 cm; 880-971 cm/tree).

4**.** In the bottom part of the canopy, the trees form over 41% of the annual and biennial branches and 64% of the 3-year-old ones. In the central part of the canopy, the number of one-year-old (36%), 2-year-old (34%) and 3-year-old (18%) branches decreases compared to the bottom part of the canopy; in the upper part of the tree the number of branches decreases considerably (18-25%). The varieties which have been studied formed 37-43% of their fruit at a level of 60-160 cm from the ground, 31.2-36.4% – at a level of 160-240 cm, and only 24.4-29.2% of the fruit developed in the upper part of the canopy.

5**.** During the period of the tree growth, 68.9-76.1% of the leaves are formed on shoots, and only 23.9-31.1% develop on different kinds of branches; during the period of tree growth and fruiting, the leaf area on the shoots and fruit branches has had identical values. Higher values of the leaf area, by 56.1-61.4%, have been registered with the trees of the Golden Delicious Reinders (34827 $m^{2/}$ha) and Fuji Kiku (35997 m^2/ha) varieties, compared to the Red Velox variety (22308 m^2/tree), but the foliage is not evenly placed in the orchard [1 *].

6**.** The trees have optimally formed the nutritional area (40.6-43.8%) and the leaf area (25272-29913 m^2/ha), creating well-lit plantations, which receive in all areas of the canopy more than 0, 2

cal/cm^2 * min, the amount necessary for the photosynthesis process [3 *]. Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties differ from other varieties by a larger amount of fruit per 1 linear cm of the trunk diameter (37.66-39.22 pcs/tree) compared to the Granny Smith and Red Velox varieties (33.52-33.97 pcs/tree).

7**.** The manual thinning of fruit (G2) has contributed to the formation of 73.00-86.9% of the "Extra" category fruit; the utilisation of Urea 46% N, 6 kg/ha, has increased the number of fruit of the "Extra" category by 81.8-92.4%, and the use of Geramid-New products, 1.5 l/ha, and Dira Max LG, 2 l/ha, contributed to the formation of 74.9-85.5% apples of the „Extra" category, and only of 2.1-6.6% of the II category fruit.

8**.** The values of the average weight of the fruit in the Gala Buckeye Simmons variety were statistically assured by 15.5-17.8% in 2017 (49.9-57.4 t/ha) and by 10.2-13.4% in the year 2019 (72.6-88.2 t/ha) in the groups of trees where the manual (G2) and chemical thinning of the fruit (G3, G4, G5) were applied, in relation to the untreated control group. The harvest of Granny Smith variety fruit constituted 49.8-57.1 t/ha in 2017 and 68.7-76.5 t/ha in 2019, and the manual thinning of fruit (G2) and the use of growth regulators (G3, G4, G5) favoured the fruit growth by 16.9-21.7%. The harvest of Red Velox variety fruit was higher in 2019 (65.7-72.2 t/ha) compared to 2017 (49.6-57.4 t/ha), and the average weight of the fruit in the year 2019 (144.6 g) decreased in comparison with 2017 (167 g). The crop of Golden Delicious Reinders variety fruit in 2019 (71.72 t/ha) also exceeded significantly the 2017 harvest (60.5 t/ha); the highest harvest was obtained in G1 group of trees (78.9 t/ha) and G3 (75.8 t/ha), with an average fruit weight of 142 g in the G1 group, and 168-172 g in the experimental groups. The value of the harvest of Fuji Kiku variety fruit in groups G1 and G3 were assured statistically in comparison with the groups G2, G4 and G5. In 2017 the average weight of fruit constituted 145-182 g, but it decreased significantly in 2019 (125-159 g).

9. The regulation of the fruit organs of the varieties which were studied permitted to obtain a profit of 153.1-302.8 thousand lei/ha. The Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties generated the highest profit (253.1-302.8 thousand lei/ha) and the level of profitability (150.2-165.2%) when Urea 46% N, 6 kg/ha (G3) was used as a product for thinning, but also as a foliar fertilizer.

10. At the Ltd "Elit Fruct", the varieties Gala Buckeye Simmons (51.7 t/ha) and Golden Delicious Reinders (52.1 t/ha) had a higher yield compared to the varieties Granny Smith, Red Velox and Fuji Kiku (45.2-47.8 t/ha). The alternation of fruiting manifested itself at a fairly high level, being higher than 50% in all varieties. The harvest of Red Velox fruit at the Ltd "Prodcar" (36.07 t/ha) was significantly lower, namely by 28.1% compared to the Gala Buckeye Simmons variety (46.42 t/ha), by 17.2% as compared with the Granny Smith variety (42.27 t/ha) and by 22.5% compared to the Golden Delicious Reinders variety (44.16 t/ha) [9*].

11**.** During the period of tree growth and fruiting, the productive volume of the canopy (9765 and 13280 m^3/ha) favoured the obtaining of large fruit crops, 72.3-87.5 t/ha. The fruit of the "Extra" category constituted 69.8-90.1%, those of category I - 9.9-24.6% and only 2-8.4% of fruit were of the II category. In the Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties, the productivity index values per area unit of the trunk section exceeded 3.2 kg/cm^2. The weight of the fruit over the years was higher in Granny Smith (145-185.6 g) and Red Velox (148-196.6 g) varieties as compared to Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties (135-178 g).

12. As the firmness of the fruit is a genetic index, it also changes depending on the productivity of the trees and the weight of the fruit. Thus, in 2016, the fruit firmness constituted 7.15-7.43 kg/cm^2 (160.6 g), in 2017 – 7.45-7.74 kg/cm^2 (172 g), in 2018 – 7.36-7.73 kg/cm^2 (172.6) and in 2019 – 8.26-8.55 kg/cm^2 (140.2 g). The Gala Buckeye Simmons variety is characterized by a lower content of titratable acidity of the fruit (0.29-0.30%) as compared to the Red Velox (0.27-0.34%), Golden Delicious Reinders (0.29-0.34%) and Fuji Kiku (0.28-0.36%) varieties. The Fuji Kiku variety is characterized by a higher content of SUS in the fruit (16.9-18.2 Brix%). 80 % of the surface of the epicarp of over 72% of the Fuji Kiku fruit in the group where a reflective film was used, were red-orange in colour; and 70% of the apple crop in the first stage was also due to the utilisation of the reflective film.

13. At the Ltd "Elit Fruct", the Gala Buckeye Simmons, Golden Delicious Reinders and Fuji Kiku varieties showed a profit (179.3-209.0 thousand lei/ha) and a level of profitability (136.9-188.4%) much higher compared to the Granny Smith and Red Velox varieties (102.9-112.8 thousand lei/ha). At the Ltd "Prodcar", the Gala Buckeye Simmons and Golden Delicious Reinders varieties showed a higher profit (159.4-165.0 thousand lei/ha) and profitability (146.7-150.7%) in comparison with the Granny Smith and Red Velox varieties (81.0-104.1 thousand lei/ha; 81.4-96.2%).

The result obtained, which contributes to the settlement of the important problem of improving the productivity of apple trees plantations by the identification of highly productive varieties and the development of methods to maintain the balance between growth and fruiting, consists in the scientific substantiation of the plantation structure' parameters, of the criteria of maintaining trees in physiological balance, and the argumentation, from the agronomic and economic point of view, of the effect of fruit number regulation; the application of these results has led to the recommendation to homologate some highly productive varieties in the Republic of Moldova.

Personal contribution. The structure of the research was formed by the author under the guidance of the academic supervisor and the steering committee. The author has her share in the materials that reflect the content of the patent, in accordance with the list of authors. All the other results obtained, their analysis, generalizations and conclusions belong entirely to the author.

Recommendations

In the central fruit tree-growing area of the Republic of Moldova, it is recommended to plant high-dense orchards of Gala Buckeye Simmons, Golden Delicious Reinders, Granny Smith and Fuji Kiku varieties grafted on M9.

The formation of the tree axis by arching is recommended to be used when its development is strong, and the branches at the base are poorly developed [2 *; 6 *; 13 *]. The method of tending the trees which are formed to have canopies in the shape of a slender spindle, includes the arching of the strong shaft when a vertical shoot is chosen from the shoots that appear on the curve, to replace the shaft, and the rest of the vertical shoots are suppressed at the ring [13 *].

The thinning of the fruit organs can be carried out in 3 stages when the climatic conditions are favourable for the tying of a large number of fruit and the trees blossom abundantly [2; 5*]:

1) the spraying with Urea 46% N solution, 6 kg/ha, when 75% of the flowers are open until the petals of the first flowers shed, at a temperature of 12-25ºC and the air humidity of 65-80%;

2) the administration of the Geramid-New growth regulator, 1.5 l/ha, when the central fruit reaches 4-7 mm in diameter, at a temperature of 15-20ºC;

3) the use of the solution Dira Max LG, 2 l/ha, when the central fruit reaches 10-15 mm in diameter, at a temperature of 15-25^{0}C.

Suggestions concerning future researches

These researches are important for the fruit tree growers in the Republic of Moldova, because they contribute to the development of the high-dense apple trees system by using low vigour rootstocks (M9), the cultivation of early branches trees, the formation of trees the canopies of which have the shape of a slender spindle, the rearing of at least 2750 trees/ha, and the installation of the support and drip irrigation system and the anti-hail net.

1. The expansion of the study on the estimation of ecological factors in correlation with the agrobiological potential of new apple varieties in order to mitigate fruiting alternation.

2. The establishment of the parameters of the orchard structure which determines the productivity of apple orchards in the context of climate change, the use of platforms for fruit cutting and harvesting.

3. The expansion of the theoretical and practical research on fruit number regulation by selecting sustainable varieties and by using chemical and mechanical thinning of fruit.

SELECTIVE BIBLIOGRAPHY

1. BABUC, V. *Pomicultura.* Chişinău. 2012. 662 p. ISBN 978-9975-53-067-5.
2. BABUC, V., PEŞTEANU, A., GUDUMAC, E., CUMPANICI, A. *Producerea merelor: manual tehnologic*. Chişinău, 2013. 240 p. ISBN 978-9975-80-590-2.
3. BALAN, V. Metoda de determinare a suprafeţei foliare la măr. In: *Ştiinţa agricolă*. 2009, nr. 2, pp. 35-39. ISSN 1857-0003.
4. BALAN, V. Sisteme de cultură în pomicultură. Randamentul producţiei de fructe. In: *Akademos.* 2009, nr. 4(15), pp. 82-90. ISSN 1857-0461.
5. BALAN, V. Tehnologii pentru intensificarea culturii mărului şi cireşului. In: *Akademos.* 2015, nr. 3(38), pp. 82-87. ISSN 1857-0461.
6. BALAN, V., VĂMĂŞESCU, S., PEŞTEANU, A., BALAN, P. Influenţa fertilizării foliare asupra răririi fructelor şi recoltei la soiul de măr Golden Delicious. In: *Ştiinţa agricolă.* 2019nr. 1, pp. 47-51. ISSN 1857-0003.
7. BRANIŞTE, N. Relizări în ameliorarea sortimentului de mere şi pere la I.C.D.P. Piteşti-Mărăcineni, Romania. In: *Lucrări ştiinţifice, Univ. Agrara de Stat din Moldova*. 2005, vol. 14, pp. 15-18.
8. BUCARCIUC, V. Precocitatea de rodire şi productivitatea soiurilor de măr. In: *Cercetări în pomicultură.* Institutul de Cercetări pentru Pomicultură. 2007, vol. 6, pp. 190-207.
9. BUCARCIUC, V. *Soiuri de măr de perspectivă:* [manual tehnologic]. Chişinău, 2015. 133 p. ISBN 978-9985-87-004-7.
10. BUCARCIUC, V. Răspîndirea mărului şi producţia de mere pe plan mondial. In: *Lucrări ştiinţifice, Univ. Agrara de Stat din Moldova.* 2015, vol. 42(1): Horticultură, Viticultură şi vinificaţie, Silvicultură şi grădini publice, Protecţia plantelor, pp. 3-10. ISBN978-9975-64-269-9.
11. BUDAN, C., AMZAR, Gh. Cercetări de ecologie în pomicultură. In: *ICPP Piteşti-Mărăcineni: 25 ani de activitate (1967-1992)*. Bucureşti, 1992. pp. 222-241.
12. CIMPOIEŞ, Gh. *Pomicultura specială*. Chişinău: Print Caro, 2018. 558 p. ISBN 978-9975-56-572-1.
13. CIMPOIEŞ, Gh. *Soiuri de pomi*. Chişinău: Print Caro, 2020. 332 p. ISBN 978-9975-56-727-5.
14. GREENE, D., COSTA, G. Fruit thinning in pome and stone-fruit: state of the art. In: *Acta Horticulturae*. 2013, no. 998, pp. 93-102. ISSN 0567-7572.
15. GREENE, D.W. Chemicals, timing, and environmental factors involved in thinner efficacy on apple. In: *HortScience*. 2002, vol. 37(3), pp. 477-481. ISSN 0018-5345.
16. LESPINASE, J.M., DELORT, F., CARBONEAU, A. Conduite de `Roial gala`: etude comparative de different systems. In: *L`arboriculture fruitière*. 1992, nr. 449, pp. 30-36.
17. ODIER, G. Rôle du rayonnement solaire en arboriculture fruitière. In: *L`arboriculture fruitière*. 1978, nr. 295, pp. 23-29.
18. PEŞTEANU, A. Fruit thinning by using NAA agent on the Jonagored apple variety. In: *Analele Univ. din Craiova. Seria Biologie, Horticultură, Tehnologia Prelucrării Produselor Agricole, Ingineria Mediului.* 2013, vol. XVIII (LV), pp. 299-306. ISSN 1453-1275.
19. ROBINSON, T.L. The evolution towards more competitive apple orchard systems in the USA. In: *Acta Horticulturae*. 2008, no. 772, pp. 491-500. ISSN 0567-7572138.
20. ROBINSON, T.L. HOYING, S. SAZO, M.M., DeMARREE, A., DOMINGUEZ, L. A Vision for Apple Orchard Systems of the Future. In: *NY Fruit Quarterly*. 2013, vol. 21, no. 3, pp. 11-16.
21. ROBINSON, T.L., DEMARREE, A., HOYING, S.A. An economic comparison of five high density apple planting systems. In: *Acta Horticulturae*. 2007, vol. 732, pp. 481-490. ISSN 0567-7572.
22. SHARMA, N., SINGH, K. Effect of plant growth regulators on fruit set, yield and fruit quality in pear cv. Baggugosha N. In: *Asian Journal of Horticulture.* 2008, vol. 3(2), pp. 352-355. ISSN 0973-4767.
23. SILVA, L., HERRERO, M. Effects of gibberellic acid and pollination on fruit set and fruit quality in "Rocha" pear. In: *Acta Horticulturae*. 2008, vol. 800, pp. 199-203. ISSN 0567-7572.

24. STOPAR, M. Thinning of 'Fuji' apple trees with ethephon, NAD and BA, alone and in combination. In: *Journal of Fruit and Ornamental Plant Research*. 2006, vol. 14, pp. 39-45. ISSN 1231-0948.
25. URSU, A., BARCARI, E. *Solurile Rezervaţiei „Codrii".* Chişinău, 2011. 84 p. ISBN 978-9975-62-283-7.
26. VĂMĂŞESCU, S. *Sporirea cantităţii şi calităţii producţiei de mere prin aplicarea fertilizării şi normării încărcăturii cu rod:* autoref. tz. doct. in agricultura. Chişinău, 2018. 29 p.
27. WERTHEIM, S.J. (). Developments in the chemical thinning of apple and pear. In: *Plant growth regulation*. 2000, vol. 31(1-2), pp. 85-100. ISSN 0167-6903.

THE AUTHOR'S PUBLICATIONS ON THE TOPIC OF THE DOCTORAL THESIS

Articles in international specialized journals

1. **BÎLICI, I.** Formarea suprafeţei foliare la soiurile noi de măr în condiţiile Republicii Moldova. In: Ştiinţa agricolă. 2020, nr. 1, pp. 55-62. ISSN 1857-0003.
2. **BILICI, I.,** BALAN, P., VAMAŞESCU, S., BALAN, V. Conducerea pomilor de măr în forma de fus zvelt. In: Ştiinţa agricolă. 2020, nr. 1, pp. 33-36.

Articles in national scientific works

3. **BÎLICI, I**. Regimul de lumină în plantaţia superintensivă de măr. In: Lucrări ştiinţifice, Univ. Agrară de Stat din Moldova. 2018, vol. 47: Horticultură, viticultură şi vinificaţie, Silvicultură şi grădini publice, Protecţia plantelor, pp. 54-57. ISBN 978-9975-64-296-5

Articles in international collections

4. BALAN, V., **BÎLICI, I.,** BALAN, P. Apple production in Republic of Moldova. In: Lucrări Ştiinţifice, USAMV Iaşi. Seria Horticultură. 2016, vol. 59(1), pp. 75-80. ISSN 1454-7376
5. **BÎLICI, I.,** BALAN, V., BALAN, P., VAMAŞESCU, S. The driving of apple trees in the shape of a slender spindle. In: Analele Univ. din Craiova. Seria Biolog., Horti., Tehnologia Prelucrării Produselor Agricole, Ingineria Mediului. 2019, vol. XXIV(LX), p. 272-276. ISSN 1453-1275

Theses of scientific communications

6. BOTNARIUC (**BÎLICI**), **I.,** CHETRUSCA C**.** Creşterea şi fructificarea pomilor de măr în funcţie de fertilizarea foliară. Tezele celei de-a 65-a conferinta ştiintifică a studenţilor. Chisinau 2012, p. 10
7. BOTNARIUC (**BÎLICI**), **I.,** ROŞCA A. Productivitatea plantaţiei de măr în funcţie de normarea încărcăturii cu rod. Tez. celei de-a 66-a conferinta ştiintifică a studenţilor. Chisinau 2013, p. 24
8. **BÎLICI, I**. Influenta regulatorilor de crestere la rarirea organelor reproductive şi formarea recoltei de fructe la soil de mar Fuji. In : Tez. celei de-a 73-a conferinţă a studenţilor UASM. Chişinău, 2020, p. 7.
9. **BÎLICI, I**. Creşterea şi fructificarea soiurilor de măr Gala Buckeye Simmons, Granny Smith, Golden Delicious, Red Velox, Red Delicious, Fuji, altoite pe M9, în condiţiile zonei centrale a Republicii Moldova. Idem, p. 10.
10. BALAN V., BALAN P., **BILICI I.** Procedeu de formare a coroanei pomului de măr în formă de fus zvelt. Brevet de invenţie MD 1229 Z 2018.09.30. Infoinvent 2019. Ediţia XVI-a. Catalog oficial Expoziția Internaţională specializată, 20-23 noiembrie, Chişinău, 2019, p 154-155.
11. BALAN V., BALAN P., **BÎLICI I**. Process for shaping the slender spindle canopy of the apple tree. Patent MD 1229 Z 2018.09.30. The 24th International Exhibition of Inventions. In Inventica, julay 29-31, 2020. "Gheorghe Asachi" Technical University Iasi-Romania. p. 430. ISSN:1844-7880.
12. BALAN VALERIAN, PEŞTEANU ANANIE, VĂMĂŞESCU SERGIU , IVANOV IGOR, BALAN PETRU, **BÎLICI INNA,** ŞARBAN VASILIE, LIUŢCAN VALENTINA. Improving the maintenance technology of the super-intensive sweet cherry and apple orchards, developing the techniques for increasing fruit quality at European level. Idem p. 430. Project nr. 18.817.05.29A

Patents

13. BALAN, V., BALAN, P., **BÎLICI, I.** Procedeu de formare a coroanei pomului de măr în formă de fus zvelt: brevet MD de scurtă durată nr. 1229. Nr. depoz.: s 2017 0099. Data publ.: 28.02. 2018. In: BOPI nr. 2/2018.

(Note * from the list of the author's publications)

ADNOTARE

Bîlici Inna „Evaluarea unor soiuri noi de măr în sistemul de cultură superintensiv în condiţiile Republicii Moldova”, teză de doctor în ştiinţe agricole, Chişinău, 2020.

Teza este expusă pe 120 de pagini şi include: 3 capitole, 43 de tabele, 41 de figuri, 5 anexe, concluzii și recomandări, precum şi sugestii privind cercetările de perspectivă. Sursele bibliografice cuprind 174 de titluri. Rezultatele obţinute sunt publicate în 13 lucrări ştiinţifice, inclusiv un brevet de invenție.

Cuvintele-cheie: soiuri de măr; formarea și tăierea pomilor; regulatori de creștere; normarea organelor de rod; recoltă; calitatea fructelor.

Scopul: ridicarea productivității plantațiilor de măr prin identificarea soiurilor înalt productive și elaborarea metodelor de menținere a unui echilibru între creștere și fructificare.

Obiectivele: identificarea comportării soiurilor noi de măr sub aspectul capacităţii de creştere şi fructificare în vederea promovării în sortiment a celor mai valoroase soiuri pentru obţinerea de producţii constante, mari și calitative; determinarea intensităţii proceselor fiziologice de creștere și rodire, în corelație cu potenţialul agrobiologic al soiurilor de măr Granny Smith, Gala Buckeye Simmons, Golden Delicious Reinders, Red Velox şi Fuji Kiku, altoite pe M9, în zona de centru a Republicii Moldova; elaborarea procedeelor de formare și tăiere a pomilor de măr care pun în valoare potenţialul natural de creştere şi rodire al soiului, pentru obţinerea de fructe competitive, intens colorate şi cu un conţinut biochimic superior; determinarea reacţiei soiurilor de măr la efectul regulatorilor de creștere asupra normării organelor de rod, productivității și calității fructelor; punerea în evidenţă a efectelor economice ale producţiei de mere în funcţie de soi și metoda de normare a încărcăturii de rod prin promovarea în cultură a soiurilor de măr cu productivitate înaltă și valoroase pentru livezi de mare densitate.

Noutatea şi originalitatea rezultatelor ştiinţifice: au fost identificate soiurile înalt productive, din colecția mondială, care au prioritate pentru livezile de mare densitate în condițiile climatice din centrul Republicii Moldova; a fost demonstrată științific metodologia de formare și întreținere a coroanei pomului de măr în formă de fus zvelt [21]; au fost estimaţi parametrii structurii plantației și criteriile de menținere a pomilor în echilibru fiziologic; a fost demonstrat, din punct de vedere agronomic și economic, efectul normării încărcăturii de rod în scopul obținerii recoltelor durabile.

Noutatea și originalitatea rezultatelor obținute este susținută de un brevet de invenție pentru întreținerea coroanei, precum și de 3 distincții la saloane internaționale de inventică oferite pentru aceste cercetări științifice.

Rezultatul obținut, care contribuie la soluționarea problemei importante de sporire a productivității plantațiilor de măr în sistem de mare densitate și a eficienței economice de producere a fructelor de măr, constă în fundamentarea științifică a utilizării soiurilor înalt productive, a metodelor de normare a încărcăturii de rod și de menținere a pomilor în echilibru fiziologic. Toate acestea au condus la recomandarea pentru producție a 4 soiuri noi de măr din colecția mondială, a procedeelor de întreținere a coroanei, cu stabilirea momentului și a dozei de utilizare a regulatorilor de creștere.

Semnificația teoretică: au fost acumulate date noi care contribuie la completarea cunoștințelor despre formarea și tăierea pomilor conduși după forma de coroană fus zvelt și a bazei de date științifice pentru elaborarea modelului optimal al structurării coroanei pomilor de măr în livezi de mare densitate.

Valoarea aplicativă: au fost recomandate pentru producție soiurile de măr Gala Buckeye Simmons, Golden Delicious Reinders, Granny Smith și Fuji Kiku, altoite pe M9, metoda recomandată de întreținere a pomilor fiind după forma de coroană fus zvelt [21; 24; 34; 39], cu efectuarea răririi chimice a organelor de rod [38].

Implementarea rezultatelor: recomandările privind soiurile de măr și procedeele tehnologice de întreținere a plantațiilor pomicole au fost implementate în gospodăriile APEF Moldova Fruct: SRL „Prodcar”; SRL „Elit Fruct”; SRL „Balcom”; ÎI „Petru Balan”.

ANNOTATION

Bîlici Inna „Evaluation of new apple varieties grown in the super-intensive cultivation system in the conditions of the Republic of Moldova", Doctoral Thesis in Agricultural Sciences, Chisinau, 2020.

Thesis structure includes 120 pages of the basic text, 3 chapters, 43 tables, 41 figures, general, 5 annexes conclusions and recommendations for production, as well as suggestions for future research and a bibliography of 174 sources.

Publications on the thesis theme: the obtained results were published in 13 scientific papers, including 2 patents.

Key-words: apple varieties, tree training and pruning, growth regulators, crop load management, yield, fruit quality.

Purpose: consists in enhancing the productivity of apple plantations by identifying high yielding apple varieties and developing new methods to maintain a balance between growths and fruiting.

Objectives: To study the behavior of new apple varieties in terms of growth and fruiting capacity, in order to promote the most valuable assortment for obtaining constant, high and qualitative yields; To determine the intensity of physiological growth and fruiting processes, in correlation with the agro-biological potential of the apple varieties Granny Smith, Gala Buckeye Simmons, Golden Delicious Reinders, Red Velox and Fuji Kiku, grafted on M9 and grown in the central fruit growing zone of the Republic of Moldova; To establish the processes for apple tree training and pruning that highlight the natural growth and fruiting potential of the variety, in order to obtain competitive fruits with intense colour and higher biochemical content; To study the response of apple varieties to the effect of growth regulators on the crop load management, productivity and quality of fruits; To highlight the economic effects of apple production depending on the variety and the method of crop load management, by promoting the cultivation of valuable and high yielding apple varieties in high-density orchards.

Scientific novelty and originality of the scientific results consist in: identifying high yielding apple varieties of the world collection, which have priority for high-density orchards established in the climatic conditions of the central region of the Republic of Moldova; scientific argumentation of the new methodology for the formation and maintenance of the apple tree crown shape grown under the slender spindle system [21]; determining the parameters of the plantation structure and maintaining the physiological balance of trees; demonstrating the advantages of crop load management from an agronomic and economic point of view in order to obtain sustainable yields.The novelty and originality of the obtained results is justified by 1 patent for the maintenance of the tree crown, as well as by 3 distinctions at international invention salons offered for these innovations.

The obtained results, which contribute to solving the important problem of enhancing the productivity of high-density apple plantations and increasing the economic efficiency of apple production, consist in the scientific substantiation of using high yielding varieties, methods of crop load management and maintaining the physiological balance of trees. As a result, the thesis gives recommendations on the production of 4 new apple varieties from the World collection, crown shape maintenance procedures, determining the period and dose of use of growth regulators.

The theoretical value of the research: consists in accumulating new scientific data that contribute to the completion of knowledge on the tree pruning and training according to the slender spindle crown shape and completing the scientific database in order to develop the optimal model of crown shape of apple trees in high-density orchards.

The applicative value of the research. It is recommended: to grow Gala Buckeye Simmons, Golden Delicious Reinders, Granny Smith and Fuji Kiku apple varieties, grafted on M9, using the recommended method of tree training according to the slender spindle crown shape [21; 24; 34; 39] and to perform chemical thinning of the reproductive organs [38].

Implementation of the results: the recommendations related to the apple varieties and the technological procedures for the maintenance of the fruit plantations were implemented in the the agricultural farms of APEF Moldova Fruct: „Prodcar" Ltd., „Elit Fruct" Ltd., and IE „Petru Balan".

АННОТАЦИЯ

Былич Инна, «Оценка новых сортов яблони в супер-интенсивной системе возделывания для условий Республики Молдова», диссертация на соискание ученой степени доктора сельскохозяйственных наук, Кишинёв, 2020 год.

Диссертация изложена на 120 странице и включает 3 главы, 43 таблицы, 41 рисунок, 5 приложения, выводы и рекомендации. Литература включают 174 наименования. Результаты были опубликованы в 13 научных работах, в том числе 1 патент.

Ключевые слова: сорта яблони; формирование и обрезка деревьев; регуляторы роста; нормирование репродуктивных органов; урожайность; качество плодов.

Цель: повышение продуктивности насаждений яблони за счет выявления высокопродуктивных сортов и разработки методов поддержания баланса между ростом и плодоношением.

Задачи: определение поведения новых сортов яблони, с точки зрения особенности роста и плодоношения, с целью включения в ассортимент наиболее ценных из них для обеспечения стабильных, высоких и качественных урожаев; определение интенсивности таких физиологических процессов, как рост и плодоношение, в соответствии с агробиологическим потенциалом таких сортов яблок, как «Granny Smith», «Gala Buckeye Simmons», «Golden Delicious Reinders», «Red Velox» и «Fuji Kiku», привитых на M9, в центральной зоне Республики Молдова; разработка методов формирования и обрезке деревьев с целью рационального использования естественного потенциала роста и плодоношения; определение реакции сортов яблони на использование регуляторов роста нормирующих количество репродуктивных органов, урожайность и качество плодов; определение экономической эффективности производства яблок в зависимости от сорта и способа нормирования нагрузки урожаем, посредством продвижения высокопродуктивных сортов яблони, которые представляют интерес для садов с высокой плотностью посадки.

Новизна и оригинальность научных результатов: были выявлены сорта из мировой коллекции яблони, которым отдаётся приоритет в интенсивных садах в условиях центральной зоны Республики Молдова; научно подтверждена методология формирования и ухода за кроной яблонь по типу «Стройное веретено» [21]; определены критерии поддержания физиологического равновесия деревьев; доказана эффективность нормирования нагрузки деревьев плодами. Результаты подтверждены изобретениями по уходу за кроной, а также 3 наградами на международных выставках изобретений.

Полученный результат, который способствует решению такой важной проблемы, как увеличение продуктивности интенсивных насаждений яблони и экономической эффективности производства яблок, заключается в научном обосновании использования высокопродуктивных сортов, методов нормирования нагрузки урожаем и поддержании деревьев в физиологическом равновесии. Полученные данные позволили рекомендовать производству 4 новых сорта яблони из мировой коллекции, методы по уходу за кроной, установлении сроков и доз использования регуляторов роста.

Теоретическая значимость: были получены новые данные, которые позволили дополнить знания о формировании и обрезке деревьев по типу стройное веретено, а также расширили научную базу данных для разработки оптимальной модели структуры кроны яблони в садах с высокой плотностью посадки.

Прикладная ценность: рекомендованы для производства такие сорта яблони, как «Gala Buckeye Simmons», «Golden Delicious Reinders», «Granny Smith» и «Fuji Kiku», привитые на M9; способ формирования кроны «Стройное веретено» [21; 24; 34; 39] с проведением химического прореживания репродуктивных органов [38].

Внедрение результатов: рекомендации были внедрены в хозяйствах Ассоциации «Moldova Fruct»: ООО «Prodcar»; ООО «Elit Fruct»; ООО «Balcom»; ИП «Petru Balan»

BÎLICI INNA

EVALUATION OF NEW APPLE VARIETIES GROWN IN THE SUPER-INTENSIVE CULTIVATION SYSTEM IN THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

411.06 – ORCHARDING

The abstract of the doctoral thesis on agricultural sciences

APROVED FOR Printing _____	Paper dimensions A4
Ofset paper. Digital printing	Number of the editions
Printing sheets:	Order no.14

The Publishing House of the SAUM

44, Mircesti Street,

Tel. 022-432-575