

The Productivity and Quality of New Apple Varieties Depending on The Biological Characteristics of The Variety in The Conditions of The Republic of Moldova

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Abstract

This paper deals with new apple varieties grown in the Republic of Moldova, namely in the experimental orchards of the Elite Fruit Ltd and the Spica-N Agro Farm Cooperative. A continuous increase of efficiency in modern cropping systems, i.e. early fruiting and short exploitation time, can be achieved by introducing highly productive varieties from the world collection and knowing the natural potential of a horticultural zone and the cultivation technology. The Granny Smith, Gala Delicious, Gala Buckeye Simmons, Golden Delicious, Golden Delicious Reinders, Red Velox and Fuji Kiku apple varieties, grafted on the M9 rootstock and used in high-density orchards, which are cultivated in the central region of the Republic of Moldova, were studied. High emphasis has been placed on the promotion of new varieties and sustainable cultivation systems that produce qualitative and healthy fruit in areas where the climate, soil and biocenosis correspond to the requirements of the cultivated species, and that are highly efficient economically as well.

Key words: apple variety, harvest, fruit quality.

Introduction

The apple is the priority fruit variety in the country's fruit growing which provides about 80% of the fruit production. According to the State Program for the Development of Fruit Growing until 2020, the share of the apple production will remain dominant in the future [1,2].

The production of a high, constant and qualitative apple crop is only possible via the implementation of modern technologies. It is also important to apply, in addition to the processes already in use in orchards, other suitable methods, which are able to maintain the quality of the fruit at the highest possible level, from the time of harvest to the moment it is delivered to the consumer. Under favourable conditions for the development of photosynthetic processes and depending on the technology used, high yields of fruits can be obtained, which, from an economic point of view, will satisfy the fruit producers and support their interest in growing this crop. Currently, one of the major functions of the fruit-growing system is the ability to convert the solar energy into chemical energy, which is used by fruit with maximum efficiency. That is why the performance of an orchard is determined by the conversion coefficient of solar energy by the leaf area, the time of fruiting, the volume of production depending on the age of the orchard, and the evolution of the morphological and physiological conditions of trees [4; 11; 20].

The variety is one of the basic elements of the apple growing technology, which can make the most of the weather conditions. At the same time, it can be permanently improved [3, 5, 6]. The assortment of varieties grown in a horticultural area is of particular importance, because the fruit growing is profitable only if the cultivated varieties are able to make the most of the local weather conditions, to give high yields of qualitative fruit and to be competitive on the domestic and foreign markets [23].

At present, the global assortment of apples is very rich and represents about 10-12 thousand varieties obtained by man through empirical selection of the most valuable natural varieties, as well as through research and scientific improvements [21]. Thus, the large number of varieties is also explained by the fact that all apple-producing countries have established research institutes with the aim of improving apple varieties and expanding their assortment [22]. The analysis of the evolution of apple varietal assortment in the world shows that, in the 21st century, there is a tendency towards a decrease in the number of apple varieties grown in accordance with the conditions of the environment utilization and the requirements of the international market. Today, large apple-producing countries grow a small number of varieties on huge areas, but they are of high quality and have great production potential [15; 19].

The varieties of the Red Delicious, Golden Delicious and Fuji group are the most important varieties cultivated in the world [17]. It has been observed that, while the areas under which red varieties are grown remain stable, the areas under which yellow varieties are grown are shrinking and the areas where bicolour varieties are grown are increasing.

An analysis of the global assortment of apples shows that the number of varieties remains high, but there is a tendency to reduce the varieties grown in accordance with their adaptability, the requirements of the international market and the economic capabilities of countries. Thus, three varieties, namely Golden Delicious, Red Delicious and Gala, predominates in the world apple production. Their share is over 50% [16, 18, 31].

Material and Methods

The researches into the new apple varieties and the laying out of high productivity orchards were conducted in two stationary experiments utilizing Granny Smith, Gala Delicious, Gala Buckeye Simmons, Golden Delicious, Golden Delicious Reinders, Red Velox and Fuji Kiku, grafted on the M9 rootstock.

Experiment 1. The study of the behaviour of new apple varieties in terms of favourable climatic conditions, the intensity of growth and fruiting physiological processes, in correlation with the agrobiological potential. The researches were carried out at the Elit Fruct Ltd in the village of Cosernita, the district of Criuleni, between the years 2015 and 2019. The orchard was laid out in 2015, using 2-year-old *Certificate* category planting material, with the base of the crown consisting of well-developed anticipated branches evenly distributed around the axis. The Granny Smith, Gala Buckeye Simmons, Red Velox, Golden Delicious Reinders and Fuji Kiku varieties, grafted on the M9 rootstock, were studied. The Granny Smith variety served as the control specimen; it was approved for the southern horticultural region in the Republic of Moldova in 2015. The distance between the rows was 3.2 m, and in a row – 0.8 m, i.e. there were 3900 trees/ha. The trees were grafted at a height of 15–20 cm above ground level. Before the orchard was laid out, a tree support system had been installed. It was monoplane, simple and made of reinforced concrete pillars with a height of about 4.0 m above the ground. In addition, a metal wire had been fixed at a height of 50 cm above the ground, which was also used as a support for the irrigation system. During the first vegetative year, five more metal wires were added. The first two wires were fixed at a level of 80 cm from the ground and at a distance of 80 cm from each other; the next wires – respectively at 160 cm, 240 cm and 320 cm from the ground. The experiment was carried out using four groups of eight trees each [24, 30].

Experiment 2. The assessment of new apple varieties in terms of growth and fruiting capacity in correlation with climatic conditions and agrobiological potential. The researches were carried out in the apple orchard of the Spica-N Agro Farm Cooperative in the village of Onitcani, the district of Criuleni. The orchard was laid out in 2009 for the Gala Delicious, Golden Delicious and Granny Smith apple varieties, grafted on the low vigour M9 rootstock. The trees which had an improved slender spindle shaped crown were planted at a

distance of 3.5 x 1 m (2857 trees/ha) in the north-south direction. The trees were grafted at a height of 20 cm above ground level. Each experiment involved four groups of eight trees each. In the course of research, work on tree care and phytosanitary protection work, provided by the technology of super intensive cultivation of apple trees, were carried out. The soil in the orchard was maintained by weeding and using herbicides.

The aim of the research was to study the behaviour of new apple varieties in terms of favourable climatic conditions, the intensity of growth and fruiting physiological processes in relation to agrobiological potential. The experimental groups were located in the central area of the Republic of Moldova. The area is characterized by medium water supply, uneven terrain, fertile soils, strong north winds, early autumn frost and late spring rime [29].

During the research, the temperature was high and the annual amount of precipitation was within normal limits. The average annual air temperature, according to multiannual data, is +10.9°Celsius; during the vegetative period it is +17.3°Celsius [4]. The annual amount of rainfall was 395.8-622.8 mm. The thermal, pluviometric regime and the air humidity of 41.13-97.16% during the flowering and fruit formation phase, created favourable conditions for the pollination and fertilization of the flowers.

The plot of land on which the experiments were carried out was a flat area in the Dniester meadow, which consisted of a silty-loamy deep-carbonate chernozem. Analysing the morphological and agrochemical parameters of the soil, it can be said that such lands are recommended for apple tree varieties grafted onto vegetative rootstocks that form a more superficial root system, given the fact that at a depth below 60-100 cm the content of carbonates is high [16, 28].

Results and Discussions

The productivity of apple tree varieties is a complex trait, which is genetically determined but influenced by the interaction between the variety and the climatic conditions of the growing area. Only the productive varieties, which produce qualitative fruit corresponding to the market requirements, demonstrate the advantage of the apple intensive cultivation system via a high output during the tree growth and fruiting periods.

In apple trees, as in most varieties of fruit trees, fruit production per unit area remains the main criterion for assessing the effectiveness of a cultivation system in terms of their suitability for such a system in a wide variety of environmental conditions. Under favourable conditions for the development of photosynthetic processes and depending on the technology applied, high fruit yields can be obtained, which, in economic terms, would satisfy fruit producers and keep an interest in their cultivation.

From the data on the fruit yield (Table 1), it follows that the varieties studied began to bear fruit starting with the 2nd year after their planting. It has to be mentioned that the 2-year-old trees had, when planted, a well-developed axis and 5-7 well-developed anticipated branches, placed radially around their axis. In the year when the orchard was laid out, all the varieties produced one or two fruit per tree. In the second year (2016), the harvest amounted to 5.1-6.6 kg/tree. The Gala Buckeye Simmons (6.6 kg /tree) and the Red Velox varieties (6.4 kg /tree) produced the highest yield. In 2017, the 3-year-old trees produced a harvest three times larger, which ranged from 14.4 kg/tree, for the Red Velox variety, to 17.0 kg/tree, for the Golden Delicious Reinders variety. Distinctly significant yield increases were recorded only for Golden Delicious Reinders as compared to the Gala Buckeye Simmons, Granny Smith (control group), Red Velox and Fuji Kiku.

Table 1. Fruit production depending on the biological characteristics of the variety, kg/tree (the year of laying out 2015, Elit Fruct Ltd, 2016–2020)

Variety	Year 2016	Year 2017	Year 2018	Year 2019	Year 2020	Average
Granny Smith (control group)	5,8	14,5	8,3	20,3	6,4	11,0
Gala Buckeye Simmons	6,6	15,1	8,8	22,4	4,9	11,6
Red Velox	6,4	14,4	6,7	18,5	4,3	10,1
Golden Delicious Reinders	5,8	17,0	8,8	21,7	5,6	11,8
Fuji Kiku	5,1	14,8	5,0	21,9	3,9	10,1

In 2018, the fruit harvest decreased considerably and amounted to only 5.0-8.8 kg/tree. This decline occurred because the trees were overloaded with fruit a year earlier. The Gala Buckeye Simmons, Granny Smith (control group) and Golden Delicious Reinders varieties produced much more fruit as compared to the Red Velox and Fuji Kiku varieties.

In the 5th year after the orchard had been laid out (the year 2019), the fruit harvest increased significantly as compared to the previous years. The Gala Buckeye Simmons, Granny Smith (control group), Golden Delicious Reinders and Fuji Kiku varieties, as compared to the Red Velox variety, which produced 18.5 kg /tree, showed distinctly significant harvest increases. In 2020, the harvest decreased considerably and amounted to 3.9 kg/tree for the Fuji Kiku variety and 6.4 kg/tree for the Granny Smith variety (control group). That decrease was also due to the very large harvest, which had been obtained a year before. During the growth and fruiting periods, the studied varieties brought in an average harvest of 10.9 kg/tree. The Gala Buckeye Simmons, Granny Smith (control group) and Golden Delicious Reinders tree varieties produced the highest yields, not always statistically proved.

In the fifth vegetative year, in the apple orchard of the Spica-N Agro Farm Cooperative, the Granny Smith variety produced a crop of 9966 kg/ha, and the Golden Delicious variety – 33489 kg/ha (Table 2).

Table 2. The fruit production of apple trees depending on the biological characteristics of the variety and the pruning system, kg/ha (the year of planting 2009, Spica-N Agro Farm Cooperative, 2009-2020)

Variety	Year							Average, kg/ha
	2014	2015	2016	2017	2018	2019	2020	
Gala Delicious	31256	28413	27982	43937	36483	60981	32506	37365
Golden Delicious	33489	29614	27553	41997	29398	54600	32855	35643
Granny Smith	9966	18319	23004	33436	28941	51013	19618	26328

In 2015, the Gala Delicious and Golden Delicious varieties produced less fruit, namely the Gala Delicious variety – 28413 kg/ha, the Golden Delicious variety – 29614 kg/ha. On the other hand, Granny Smith produced twice the harvest of the previous year, namely 18319 kg/ha. That increase in yield was due to a very poor harvest in the previous year. In the seventh vegetative year, the Gala Delicious and Golden Delicious varieties again produced a small crop, which amounted to 27982-27553 kg/ha; the Granny Smith, on the other hand, produced a higher harvest in comparison with the previous year, which came to 23004 kg/ha. In 2017, all the studied varieties produced a better harvest – 33436 kg/ha by the Granny Smith variety, and 43937 kg/ha by the Gala Delicious variety. That was due to the fact that the Gala Delicious and Golden Delicious varieties have more short fruit branches, especially spurs, twigs and other kinds of branches, which

grow every year. In 2018, the fruit yield was lower as compared to 2017, on average, by 20%. In the 10th year after the orchard was laid out, the trees produced a quite good harvest; the Gala Delicious variety produced the largest crop – 60981 kg/ha – in comparison with the Golden Delicious variety, the crop of which amounted to 54600 kg/ha, and Granny Smith variety which produced 51013 kg/ha. In 2020, during the fruiting period of the trees, the harvest decreased as compared to the previous year by about 40%.

The size of apples is determined by the maximum diameter of the equatorial section or by the weight. Virtually, in all the varieties, the smallest size of the apples of “Extra” Class, Class I and II is 60 mm if it is determined by diameter and 90 g if it is determined by weight [7, p. 208 -220]. The data on the influence of genotype on the average fruit weight show that, in the varieties studied, the fruit are medium to large in size.

At the Elite Fruit Ltd, the fruit average weight differed from year to year and was between 159.4 and 168.2 g (Table 3, 4). Larger fruit were obtained in 2017, 2018 and 2020. Over the years, the average fruit weight was higher for the Granny Smith (control group) and Fuji Kiku varieties as compared to the Gala Buckeye Simmons, Golden Delicious Reinders and Red Velox varieties, but the values were not always significantly insured.

Table 3. The average fruit weight depending on the biological characteristics of the variety, g (the year of laying out 2015, Elit Fruct Ltd, 2016–2019)

Variety	Year 2016	Year 2017	Year 2018	Year 2019	Year 2020	Average
Granny Smith (control group)	166	173	172	145	170	165,2
Gala Buckeye Simmons	162	164	165	138	168	159,4
Red Velox	160	176	178	148	179	168,2
Golden Delicious Reinders	157	168	170	135	172	160,4
Fuji Kiku	158	179	178	135	177	165,4

The fruit average weight is a genotypic index, but it can vary depending on the ecological conditions, the technology applied and the productivity of the trees. For example, at the Elite Fruit Ltd, during on the period of tree growth (2015-2016), the fruit harvest averaged 5.94 kg/tree, and the average weight of the fruit was 160.6 g. During the period of tree growth and fruiting (2017-2018) not only the fruit harvest increased (11.34 kg/tree), but also the average fruit weight (172.6-140.2 g). During the period of tree fruiting (2019-2020), the fruit harvest amounted to 12.99 kg/tree, and the average fruit weight was 140.2-173.2 g. The weight of the fruit of Buckeye Simmons Gala variety was lower as compared to the Granny Smith, Red Velox and Golden Delicious Reinders varieties.

At the Spica-N Agro Farm Cooperative, the average weight of the fruit also varied depending on the productivity of the trees. In 2016-2017, the fruit harvest averaged 32984 kg/ha, and the weight of the fruit was 141.8 g. In 2018, the fruit harvest amounted to 31607 kg/ha, and the weight of the fruit was 153.6 g. In 2019, the harvest increased significantly and amounted to 55531 kg/ha, but the average weight of the fruit decreased and was 136.7 g. Therefore, it may safely be said that, in those years, the weight of the fruit increased when the harvest was poor, and decreased when the harvest was good. In 2020, the harvest decreased as compared to the previous year, but the weight of the fruit also decreased and averaged 129.0 g. Thus, it can be said that, in all the research years, the Granny Smith variety produced fruit the weight of which was the greatest, on average 145.3 g. The Gala Delicious and Golden Delicious varieties produced fruit the weight of which was slightly lower – 138.2-140.2 g.

Table 4. The average weight of apples depending on the biological characteristics of the variety and the cutting system, g (the year of laying out 2009, Spica-N-Agro Farm Cooperative, 2009-2020)

Variety	Year					Average, kg/ha
	2016	2017	2018	2019	2020	
Gala Delicious	136,6	143,3	148,5	135,2	127,5	138,2
Golden Delicious	143,3	143,3	151,3	134,0	129,1	140,2
Granny Smith	145,6	148,0	161,1	140,9	131,2	145,3

Marketing standard for apples: apples are classified in “Extra” Class, Class I and II and the qualitative Class III [7, pp. 208-220]. Apples in the “Extra” Class must be of the shape, size and colouring characteristic of this class and must have an intact peduncle. The Class I apples must be qualitative and have the shape, size and colouring characteristic of this variety. The pulp of Class II apples must retain the essential characteristics regarding the quality, shelf life and marketable condition, and must be free from damage. The size is determined by the maximum diameter of the equatorial section or by weight. For all apple varieties, the minimum size of the fruit in “Extra” Class, Class I and II is 60 mm if measured by diameter and 90 g if determined by weight [7, pp. 208-220].

The commercial quality of apples is the integration of all biological and technological factors that have been involved in the formation of the final product (Table 5). The first fruit harvest at the Elite Fruit Ltd consisted of "Extra" Class (75.4-90.1%) and Class I apples (9.9-24.6%). In the second, third and fourth fruiting years, the commercial quality of the fruit was also high.

Table 5. The impact of variety on the fruit size (the year of laying out 2015, Elit Fruct Ltd, 2018–2019)

Variety	Fruit size categories (%)					
	“Extra” Class		Class I		Class II	
	2019	2020	2019	2020	2019	2020
Granny Smith (control group)	83,4	82,9	11,7	14,3	4,9	2,8
Gala Buckeye Simmons	80,5	77,4	13,8	16,8	7,7	5,8
Red Velox	78,9	80,2	12,7	16,3	8,4	2,6
Golden Delicious Reinders	82,1	75,3	12,3	17,2	5,6	7,5
Fuji Kiku	79,5	85,3	14,2	12,7	6,3	2,0

According to the data regarding the commercial quality of the fruit on the Spica-N Agro Farm Cooperative, the “Extra” Class fruit size predominates in all the varieties studied (Table 6). In 2017, the harvest of the “Extra” Class fruit was very high – over 80%, and that of Class I – 10-13%. In 2018, over 50% of the fruit were of the “Extra” Class, and 36-42% of Class I. In the 10th fruiting year (2019), when an abundant crop of apples was harvested (55531 kg/ha), the commercial quality of the fruit suffered and the number of apples of “Extra” Class came to only 26-29% ; the number of fruit of Class I, on the other hand, raised and amounted to 55-59%. In 2020, both the average fruit harvest (28326 kg/ha), as well as the commercial quality of the fruit suffered as compared to the previous year. The fruit of the "Extra" Class made up 18-24%, and those of Class I – 52-62%.

Table 6. The impact of variety on the fruit size category (the year of laying out – 2009, Spica-N Agro Farm Cooperative, 2009-2020)

Variety	Fruit size categories,%							
	„Extra” Class				Class I			
	year 2017	year 2018	year 2019	year 2020	year 2017	year 2018	year 2019	year 2020
Gala Delicious	81	53	27	24	13	37	59	57
Golden Delicious	85	55	29	23	10	36	55	52
Granny Smith	84	49	26	18	10	42	56	62

In the period of the tree growth and fruiting, the commercial quality of apples of the varieties taken under study differed insignificantly from year to year and from one variety to another. This proves once again that the technological processes used at the Elit Fruct Ltd and the Spica-N Agro Farm Cooperative were adequate for the cultivation system.

Conclusions

The works on high-density apple orchards specify the main factors of increasing the efficiency of the solar energy utilization in orchards, the possible ways to optimize the structure of the orchards that determines their productivity, which are imposed by both climate and soil, and by the growth vigour of the variety-rootstock combination.

At the Elit Fruct Ltd, the Gala Buckeye Simmons (11.6 kg/tree) and Golden Delicious Reinders varieties (11.8 kg/tree) had a higher productive potential as compared to the Granny Smith, Red Velox and Fuji Kiku varieties (10.1-11.0 kg/tree). The Gala Delicious and Golden Delicious varieties had a higher productive potential also at the Spica-N Agro Farm Cooperative (37365- 35643 kg/ha). That was due to the fact that the Gala Delicious and Golden Delicious varieties, depending on the biological peculiarities of the variety, have more short fruit branches, especially spurs and other kinds of offshoots which grow every year.

The average weight of the fruit, over the years, registered higher values in the varieties grown by the Elit Fruct Ltd (159.4-168.2 g) as compared to the varieties grown by the Spica-N Agro Farm Cooperative (138.2-145, 3 g). Therefore, in those years, the weight of the fruit increased when the yield was low, and decreased when the yield was high. It was noticed that on the Spica-N Agro Farm Cooperative, over all the research years, the Granny Smith variety produced fruit of the greatest weight, which averaged 145.3 g, and the fruit produced by the Gala Delicious and Golden Delicious varieties were slightly smaller, i.e. 138.2-140.2 g.

The commercial quality of apples is the integration of all biological and technological factors that have been involved in the formation of the final product (Table 3). The first fruit harvest at the Elite Fruct Ltd consisted of "Extra" Class (75.4-90.1%) and Class I apples (9.9-24.6%). In the second, third and fourth fruiting years, the commercial quality of the fruit was also high. In the period of the tree growth and fruiting, the commercial quality of apples of the varieties taken under study differed insignificantly from year to year and from one variety to another. This proves once again that the technological processes used at the Elit Fruct Ltd and the Spica-N Agro Farm Cooperative were adequate for the cultivation system.

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