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**THE INFLUENCE OF PLANTING DENSITY ON THE FRUIT QUALITY  
AND ECONOMIC EFFICIENCY IN THE APPLE ORCHARD**

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**ABSTRACT**

*The prospect presents a research which determines the optimum density limit for orchards. The author made an experience with planting scheme 4 x 1.5 m; 3 x 1.0 m; 3 x 0.66 m and 3 x 0.33 m. The varieties Golden Delicious and Idared grafted on rootstock M9 were studied. High density planting promoted increase in productivity by 44-51% at a young age. In the variant where it was planted 10 000 tree/ha the share of the fruit of the highest category is reduced to 16-24%, that resulting decline in profitability to 149-246% compared with a controlled scheme. According to the received information, the optimum density limit for apple grafted on rootstock M9 we believe is 3 x 0.66 m or 5000 tree/ha.*

**INTRODUCTION**

The increase of productivity and quality for the apple planting is determined by the development of the sector. One of the most efficient elements in this process is the increase of trees per unit area. The plantation of small rootstocks, new varieties, formation and location of tree systems in the orchard during the last 20 years, permitted to increase the planting density of apple trees in the Republic of Moldova from 500-1000 trees per 1 ha, till 2-3,5 thousands (Balan et al. 2001; Cimpoiș 2012). The issue of optimization of the perimeter is very important in horticulture. Numerous researches were made in different soil-climatic zones (Агафонов 1983; Gonta 2003; Mica 2010; Babuc 2012; Babuc et al. 2013). When designing the actual orchard it was established that more than 60% of the existing orchards do not provide a rational use of ecological resources.

The main direction of current research in this field is to determine the optimal level of density for the existing variety-rootstock combinations and for the technologies used for cultivation. The purpose of our research was to establish the productivity, and the effect of super-dense planting systems on the economic efficiency of apple tree growth.

**MATERIALS AND METHODS**

The orchard described in the research was planted in 2008 in the farm "M. Pachiu", Orhei region, Republic of Moldova. Two varieties of apple trees had been taken as objects of the research: Golden Delicious and Idared, grafted on rootstock

M9. We studied several schemes of planting:

1. 4 x 1.5 m or 1666 trees per 1 ha (control). This scheme is recommended in Moldova for the middle varieties of apple trees grafted on rootstock M9.

2. 3 x 1.0 m or 3 333 trees per 1 ha.

3. 3 x 0.66 m or 5 000 trees per 1 ha

4. 3 x 0.33 m or 10 000 trees per 1 ha.

## RESULTS AND DISCUSSIONS

The results of the described research show that the density of planting trees has a big influence on the productivity of planting (tab. 1). In 2012 a doubling of the number of trees in the scheme 3 x 1.0 m in comparison with the controlled scheme, gave an increase of 38% of productivity for the Golden Delicious variety, reaching 60.3 t/ha. However, the subsequent two-fold increase of number of trees per 1 ha gave a lower increase of yield: 4.2% and 12.2% in comparison with the previous year.

Table 1  
Productivity of apple trees depending on variety and planting distance, t/ha

Variety	Planting distance,m	2012	2013	2014	2015	Average 2012-2015
Golden Delicious	4 x 1.5	37.6	30.6	33.1	28.7	32.5
	3 x 1.0	60.3	33.0	48,7	40.4	45.6
	3 x 0.66	62.9	26.1	47.0	41.5	44.3
	3 x 0.33	71.6	29.1	48.5	34.2	45.9
Idared	4 x 1.5	33.8	30.2	39.7	34.1	34.5
	3 x 1.0	58.4	35.3	47.8	42.3	45.9
	3 x 0.66	66.6	37.7	53.7	47.0	51.3
	3 x 0.33	68.7	41.6	70.4	29.8	52.6

In 2013 a sharp decline in productivity of plantations was noted, especially at the Golden Delicious variety, due primarily to the overload of trees in the previous year. In the controlled scheme the overload represented only 18.7%, but after the increase of planting density till 3 x 1.0m, and specially till 3 x 0.33m, the reduction was respectively 45.3 и 59.4%, which was even lower than in the controlled scheme. In 2014 the productivity increased in comparison with 2013 in all variants of the research. The difference between variants in Golden Delicious variety (0.2 -1.5 t/ha) wasn't as big as in the Idared variety (6.7-22.6 t/ha).

In 2015, a similar pattern is stored in the productivity of plantations, against the background of no significant decrease compared to the previous year.

In general, analyzing the average yield for the last 4 years it is clear that for both varieties is typical the increase of productivity as a result of density growth. However, if in the controlled scheme we can observe an uniformity data in fruiting during the period, the high-density versions, due to high yields in some years has been a sharp drop in its next year and a manifestation of the periodicity of fruiting. Most clearly this phenomenon is observed in Golden Delicious variety.

An important indicator of the effectiveness of various schemes of planting is also the product quality of fruits. The technical regulations "Requirements to the

quality and sales for fresh vegetables and fruits” approved by the decision of the Government of Republic of Moldova Nr. 229 from 21.12.2009, standard, shows that the index of quality is determined by the commercial aspect of the product and its physical properties (size, form, color etc.). The size determined by the maximum cross-sectional diameter or by the weight.

Table 2

Commercial aspects of apple fruits in dependence with the density of tree planting distance, year 2014

Variety	Planting density, tree/ha	Weight kg/ tree	Diameter, mm	Average weight, g	Proportion, kg		Extra+I category, %
					Extra +I category	II category	
Golden Delicious	1666	19.87	74	163	18.68	1.19	94
	3333	14.61	73	161	13.44	1.17	92
	5000	9.39	66	144	8.17	1.22	87
	10000	4,85	62	112	0.53	4.32	16
Idared	1666	23.83	78	172	22.88	0.95	96
	3333	14.34	75	166	13.34	1.00	93
	5000	10.73	71	145	9.65	1.08	90
	10000	7.04	63	118	1.69	5.35	24

Analyzing the values of average fruit weight (tab. 2) it should be noted that an increase in planting density decreases it. So, if in the controlled scheme the average weight of the Golden Delicious fruit totaled 163 g, then with increasing density to 5000 trees / ha, it decreased by 12%, and at a density of 10 000 trees / ha was only 112 g. With the average weight correlates the diameter of fruit, which decreases from 74 mm in the controlled scheme to 62 mm in the option with the highest thickening. And although for all varieties and quality categories the minimum size is 60 mm in diameter, or 90 g in weight, market demand for apples is at a minimum diameter of 70 mm for the category „ Extra” and 65 mm for category I of quality. In this connection, the quality of the fruit in the option with a maximum diameter of fruit thickening was below market requirements.

Analyzing the market index of fruits, it can be observed that with the increase of planting density the fruit share of „Extra” and I category of quality decreased in both studied varieties (with 94-96% in the control, to 87-90% at density of 5000 trees/ha). In the option with the highest proportion of thickening the proportion of commodity fruits accounted for Idared - 24%, and for Golden Delicious only 16%.

The purchase prices strongly influenced the economic efficiency of apple trees growth, which in 2014 due to a number of factors were the lowest during the years of research, amounting to 3.8 lei / kg for Idared variety, to 4.5 for Golden Delicious, and just 0.48 lei / kg for industrial processing.

Analyzing the data in table 3 we made a conclusion that not always indicators of economic efficiency rise with increasing yields. The poor quality of fruits in a variant with 10 000 trees per hectare density of planting and their realization in the industrial processing at a very low price has led to a decrease in the value of gross production by varieties on 49-61% compared with the controlled scheme, despite the fact that the yields in these variant were almost twice as high.

Table 3

Economic efficiency of apple tree growth, depending on the planting trees density

Variety	Plantation distance, m	Productivity, t/ha	Profit from sales, k lei/ha	Production cost, k lei/ha	Profit, k lei/ha	Profitability level, %
Golden Delicious	4 x 1.5 m	33.1	140.91	40.1	100.8	251
	3 x 1.0	48.7	202.80	48.9	153.9	315
	3 x 0.66	47.0	186.9	46.8	140.1	299
	3 x 0.33	48.5	54.5	51.7	2.8	5.0
Idared	4 x 1.5 m	39.7	145.6	48.0	97.6	203
	3 x 1.0	47.8	170.7	51.8	118.9	230
	3 x 0.66	53.7	186.1	54.9	131.2	239
	3 x 0.33	70.4	89.9	58.3	31.6	54

The increase in production costs in the variant with high thickening is mainly associated with a large number of cutting trees and high yield. All these factors led to net income in the variant with the 3 x 0.33 m scheme of planting made by species just 31.6 and 2.8 thousand lei / ha, and the level of profitability did not exceed 54% and 5%. At the same time, the profitability of Idared reached the largest value in the experiment - 239% in the variant with the landing 3 x 66 m circuit, and for a variety Golden Delicious -315% in the variant 3 x 1.0 m.

### CONCLUSION

The data obtained allow us to conclude that the increase in density of apple trees planting from 1666 to 10 000 trees/ha increases the yield by 44-51%. However, a high planting density and limiting both air and soil space leads to tension in the struggle for life factors, and, as a result, reduce fruit quality. In a variant with a density of planting trees reaching 10.000 trees/ha the proportion of fruits of higher quality and of those of first category is reduced to 16-24%, resulting in a drop in profitability level 149-246% compared with the controlled scheme. Based on the results of the research the optimal limit for thickening of apple varieties Golden Delicious and Idared grafted on M9 rootstock is 5000 trees per 1 hectare at planting scheme 3 x 0.66 m.

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