

## Growth and Fruiting in High Density Apple Planting System, in Cluj-Napoca area, Romania

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**Abstract.** In the recent years high-density apple crop has gained the greatest spread. This happened because, on the one hand, this kind of orchard produces fruit from the second year recovering the investment in about three years, and on the other hand, they have high economic efficiency. In this sense, the evaluation of ten new apple cultivars ('Florina', 'Jonagold', 'Jonica', 'Top Red', 'Mutsu', 'Granny Smith', 'Golden Reinders', 'Gala', 'Topaz', 'Pinova') in conditions of Cluj-Napoca, Romania, in high density growing system in 2010-2011 was studied. The planting system chosen for the experimental plot was 3.5 m between rows and 0.9 m between trees within row, which resulted in a high density orchard with 3174 trees/ha. The trees were grafted on M9 rootstock. Differences statistically assured among cultivars regarding growth traits and yield were recorded. All cultivars have achieved high cumulative yield, most exceed 50 t/ha. Only two cultivars, 'Mutsu' and 'Top Red', failed to exceed this level of 50 t/ha. The highest yield was registered with 'Topaz' (57.16 t/ha), followed closely by 'Jonagold' (56.89 t/ha) and 'Pinova' (56.78 t/ha). The most recommended cultivars for setting up new orchards in the climatic conditions of Cluj-Napoca, are 'Pinova', 'Topaz', 'Florina', 'Granny Smith'.

**Keywords:** climate, yield, apple, growth, fruiting

### INTRODUCTION

After several decades of extensive research on new production systems, specifically on apple, it has been determined that there is no single best planting system for every grower (Hoying and Robinson, 2000).

Lauri and Lespinasse (1999) accredit the idea that the orchard system in itself does not resolve major problems such as regularity of bearing and fruit quality.

High-density apple orchards on dwarfing rootstocks offer economic advantages as a result of earlier and greater fruit yield per unit of land area (Quamme *et al.*, 1997). High tree density allows early productivity, an earlier return to capital investment and sustained high yields of good quality (Wertheim *et al.*, 2001).

Intensive orchard system became the most popular system in commercial orchards of apple culture. Orchard system is the results of combining the cultivar and the rootstock at different distances between rows and tree/row and then pruning and training to achieve maximum yield and best quality every year (Mitre *et al.*, 2011).

New apple cultivars not grown in our country so far are imported as planting material purchased by growers from nurseries in Hungary, Holland or other foreign countries. An evaluation of these cultivars in the climatic conditions of Romanian commercial orchards is obviously necessary.

The aim of this work was to determine the behaviours of ten apple cultivars under climatic conditions of Cluj-Napoca area, Romania, in order to establish the recommended ones for commercial high density orchard.

## MATERIALS AND METHODS

The research has been carried out in a high density apple orchard, set up in the autumn of 2009 at the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. The planting system chosen for the experimental plot was 3.5 m between rows and 0.9 m between trees within row, resulting in a high density orchard with 3174 trees/ha.

The response of ten apple varieties ('Florina', 'Jonagold', 'Jonica', 'Top Red', 'Mutsu', 'Granny Smith', 'Golden Reinders', 'Gala', 'Topaz', 'Pinova') was studied in a high density growing system, in conditions of climate in 2010-2011, compared to 'Golden Reinders' as control variant. The two years of experiment were normal in terms of climate. The apple trees from the experiment were grafted on M9 rootstocks. The technology of culture was a specific one to the high density orchard.

Tests were taken on comparative cultures, arranged in linear blocks, each block with 15-25 trees. There were made observations on some growth parameters (length of shoots, trunk section area, leaves area) and fructification (number of bearing branches, cumulative yield for 2010-2011). Each experimental variant had three repetitions. The results were statistically processed and interpreted by means of the ANOVA test.

## RESULTS AND DISCUSSIONS

Tab. 1 presents the experimental results referring to the vigour of the trees. The trunk diameter registered statistically assured differences between most cultivars and the control variant. 'Top Red' and 'Gala' cultivars achieved similar trunk diameter values as compare to the control variant, with no statistically differences assured. The highest values of the trunk diameter with 'Granny Smith' (25.98 mm) and 'Florina' (25.74 mm) were recorded with very significant positive differences compared to the control.

Tab. 1

Synthesis of experimental results on trees vigour, mean value (Cluj-Napoca, 2010-2011)

Cultivar	Trunk diameter (mm)	Tree height (cm)	Crown volume (m <sup>3</sup> )
'Golden Reinders' (Control)	15.38	220.83	3.09
'Florina'	25.74 <sup>***</sup>	286.50 <sup>**</sup>	10.09 <sup>***</sup>
'Jonagold'	19.31 <sup>*</sup>	228.50	2.99
'Jonica'	20.44 <sup>*</sup>	223.67	3.40
'Top Red'	16.52	212.17	3.20
'Mutsu'	21.49 <sup>**</sup>	199.50	2.89
'Granny Smith'	25.98 <sup>**</sup>	275.00 <sup>*</sup>	6.50 <sup>*</sup>
'Gala'	18.89	246.83	4.14
'Topaz'	20.58 <sup>**</sup>	201.33	1.67
'Pinova'	21.45 <sup>**</sup>	209.83	1.52
Average	20.58	230.42	3.95
LSD 5%=	3.72	46.70	2.62
LSD 1%=	5.10	64.05	3.59
LSD 0.1%=	6.94	87.17	4.88

The cultivars which registered distinct significantly differences compared to the control were 'Mutsu' (21.49 mm) 'Pinova' (21.45 mm) and 'Topaz' (20.58 mm). 'Jonagold'

and ‘Jonica’ displayed significant differences as to the control. These differences among cultivars in the vigour of the trees might be justified by genetic distinctions.

Regarding the height of the tree, the highest values in ‘Florina’ (286.5 cm) was recorded, with distinct significant positive differences compared to the control, respectively ‘Granny Smith’ with significant positive differences compared to the control (275.0 cm). Statistical differences among other varieties have not been found, hence we conclude that these species behaved similarly in terms of increased height growth of the trees.

Most varieties showed differences compared with the control in terms of crown volume. The highest values of crown volume with significant positive differences to the control were obtained with ‘Florina’ (10.09 m<sup>3</sup>). Results statistically assured with significant positive differences compared to the control presented ‘Granny Smith’ (6.5 m<sup>3</sup>).

In Tab. 2 one can see the results regarding the number of vegetative growth, the average length of shoots, and the total length of shoots.

Tab. 2

Synthesis of experimental results regarding the number of vegetative growth, the average length of shoots, and the total length of shoots (Cluj-Napoca, 2010-2011)

Cultivar	Number of vegetative growth	Average length of shoots (cm)	Total length of shoots (cm)
‘Golden Reinders’ (Control)	26.0	26.3	515.33
‘Florina’	28.5	44.6**	1269.07**
‘Jonagold’	18.0	34.1	564.04
‘Jonica’	17.7	37.1*	623.07
‘Top Red’	18.0	36.2	590.52
‘Mutsu’	21.5	32.1	550.05
‘Granny Smith’	13.6 <sup>o</sup>	39.5*	283.10
‘Gala’	15.3 <sup>o</sup>	31.1	414.13
‘Topaz’	13.7 <sup>o</sup>	33.5	152.98
‘Pinova’	14.5 <sup>o</sup>	29.4	374.33
Average	18.7	34.4	533.66
LSD 5%=	10.1	10.3	415.89
LSD 1%=	13.8	14.1	570.37
LSD 0.1%=	18.8	19.2	776.33

Data inside the table shows that most cultivars registered similarly results without differences statistically assured. Four cultivars, ‘Granny Smith’ (13.6 pcs/three), ‘Topaz’ (13.7 pcs/three), ‘Pinova’ (14.5 pcs/three) and ‘Gala’ (15.3 pcs/three) registered significant negative differences compared to the control.

Shoot growth is a key element in the relationship between growth and fructification, which depends on the balance of fruit trees that provide yield for the year and subsequent years. The average length of shoots is an indicator of tree vigour Mitre *et al.* (2009) argues that the average length of annual branches is a key element of productivity due to mixed functions of annual increases, especially on young trees in commercial plantations.

Regarding the average length of shoots, most cultivars showed similar results, ‘Florina’ (44.62 cm), displayed distinct significant positive differences compared to the control. The cultivars ‘Granny Smith’ (39.5 cm) and ‘Jonica’ (37.09 cm) also recorded significant differences compared to the control.

The total length of annual branches is a character that was influenced by physiological factors, by the total number of shoots of a cultivar and their vigour of growth and technological factors, particularly summer and winter pruning.

Mitre (2008) noted that annual branch length is strongly influenced by genotype, which is an indicator for overall vigour of the trees, data confirmed by results from the Tab. 2.

In this experiment, only ‘Florina’ performed significantly differences compared to the control. Other varieties differ to the control but the differences were not statistically assured.

Average leaf area is a character strongly influenced by phenotype component in genotype-phenotype-environment relationship. In the juvenile phase of trees life, leaf area/number of shoots is higher than in other life periods of the trees and actually fact also founded by Mitre (2008).

The results obtained reveal the differences between cultivars statistically assured (Tab. 3). Compared to the control ‘Pinova’ (35.60 cm<sup>2</sup>) and ‘Top Red’ (36.72 cm<sup>2</sup>) showed differences distinct significantly negative. Cultivar ‘Topaz’ (37.65 cm<sup>2</sup>) registered differences statistically assured compared to the control, but differences unlike cultivars described above are only significantly negative. Similar results were obtained by Mihut *et al.* (2009), making general studies on Voinești apple cultivar.

The number of leaves per tree is also a very important element. Among the varieties analyzed with significant differences compared to control stands ‘Granny Smith’ (1571.35 pcs) and ‘Florina’ (1465.67 pcs) were noted.

Tab. 3

Synthesis of experimental results regarding average foliar surface, average number of leaves/tree, leaves surface/tree

Cultivar	Average surface/leaf (cm <sup>2</sup> )	Average number of leaves/tree (pcs)	Total leaves surface/tree (cm <sup>2</sup> )
‘Golden Reinders’ (Control)	50.47	1190.69	59812.21
‘Florina’	45.43	1465.67***	66592.06
‘Jonagold’	55.92	1280.71	71759.81
‘Jonica’	53.24	1055.59	54924.01
‘Top Red’	36.72 <sup>oo</sup>	890.63 <sup>ooo</sup>	32770.26 <sup>ooo</sup>
‘Mutsu’	59.40	1321.67	78330.88*
‘Granny Smith’	44.67	1571.35***	69974.69
‘Gala’	44.83	1230.67	54901.61
‘Topaz’	37.65 <sup>o</sup>	1344.67	50421.33
‘Pinova’	35.60 <sup>oo</sup>	1366.33	48924.83
Average	46.30	1271.80	58841.17

LSD 5%= 10.00 138.92 13926.23

LSD 1%= 13.71 190.52 19098.82

LSD 0.1%= 18.66 259.32 25995.62

The cultivar ‘Top Red’ recorded a total of 890.63 leaf pieces with negative significant differences compared to the control. In order to view the trees photosynthetic potential the total leaf area of the tree were measured. The results show that there are differences in terms of total tree leaf area. Total leaf area varies between 32770.26 cm<sup>2</sup> and 78380.88 cm<sup>2</sup> from ‘Top Red’ to ‘Mutsu’; a part of cultivars recorded differences statistically assured to the control. Thus ‘Mutsu’ registered differences significantly positive compared to the control. Although this cultivar has the largest average number of leaves, it presents these results because of the average leaf area, which is the largest of the cultivars analyzed. ‘Top Red’ had the lower leaves surface and the average number of leaves, rather low leaf surface recorded at this cultivar being the lowest one, with negative significant differences compared to the control.

The cultivars studies showed specific reactions regarding branching capability.

Tab. 4

## Short and long bearing branches per tree (Cluj-Napoca, 2010-2011)

Cultivar	Short branches (number/tree)		Long branches (number/tree)			Ratio long/short
	stalks	spurs	vegetative	twigs	sprouts	
'Golden Reinders' (Control)	4	38	26	29	4	1.4
'Florina'	12*	50	29	53***	5	1.4
'Jonagold'	8	38	18	23	5	1.0
'Jonica'	9	38	18	27	4	1.0
'Top Red'	10	28	18	20	4	1.1
'Mutsu'	9	47	22	26	5	0.9
'Granny Smith'	4	27	8 <sup>000</sup>	29	5	1.4
'Gala'	5	40	15 <sup>0</sup>	26	4	1.0
'Topaz'	5	28	5 <sup>000</sup>	38	3	1.4
'Pinova'	9	66*	13 <sup>0</sup>	29	7*	0.7
Average	8	40	17	30	5	1.1
LSD 5% =	5.7	21.95	10.13	11.62	2.83	
LSD 1% =	7.81	30.10	13.89	15.93	3.88	
LSD 0.1% =	10.64	40.97	18.91	21.69	5.28	

The presence of a large number of vegetative or bearing branches in the tree crown is due to the application of a very well agro technical measure. In high-density orchards where the space of trees is used to maximum summer and winter pruning are of major importance (Gonda, 2003), which were made with two purposes. The first rule is to set yield and the second rule is to stimulate new growth in the crown of trees. Stakes and vegetative growth are in larger number in the juvenile stage and during aging period (Mitre *et al.*, 2001).

In Tab. 4 one can observe that the average number of stalks is quite low. Varieties behaved differently regarding this character differences among them ranging from 4 to 12 being statistically assured only between 'Florina' (12 pcs) and control. By analyzing the results one can observed that there are differences statistically assured among the control and the other cultivars 'Topaz' (5.2 pcs) registered the lowest number of vegetative shoots followed by 'Granny Smith' with significant differences negative compared to the control. Although 'Gala' and 'Pinova' have as a genitor the 'Golden Reinders' cultivar which in this experience used to be control variant they registered differences negative and significantly in terms of this character. Spurs as a short fruit branches is a desirable element in the crown of the trees, which is an indicator of value in selecting varieties used in high-density apple plantations. The cultivars having an average or medium to large number of spurs are much easier to maintain. Most cultivars tracked the average number of spurs with no statistically differences assured compared to the control only 'Pinova' (66.3 pcs) registered significant differences.

Twigs are the most common long bearing branches into the crown of standard type of fruiting (Mitre *et al.*, 2001). Depending on the type of bearing branches, apple cultivars are classified in one of the five types of fructification (Mitre, 2008). In this experiment the number of twigs ranges from 20.3 to variety fewest 'Red Top' and 53.3 'the variety most 'Florina'. 'Florina' presented differences very significantly, positive compared to the control confirming its natural tendency to capitalize on long fruit branches. Sprouts are long bearing branches which occurring in very good agro technical conditions. They are an indicator of the optimum balance between growth and fruiting. All varieties taken into experience show this element, their number varying from 3 ('Topaz') to 7 ('Pinova'). The differences statistically assured between 'Pinova' and the control was registered.

The main objective of any commercial plantations is getting very high yields per unit area and high quality of fruits. All tested varieties are designed to have high yields but lack the detail of how these varieties behave in different locations can make the final result not to be the expected one. The cultivars with the highest average yields were ‘Topaz’ (28.58 t/ha), ‘Jonagold’ (28.44 t/ha) and ‘Pinova’ (28.39 t/ha) with significant positive differences to the control. ‘Granny Smith’ (27.99 t/ha) is also a productive cultivar with significant differences compared to the control. The lowest yield with ‘Top Red’ was obtained (24.02 t/ha), with negative significant differences compared to the control. As shown in Fig. 1 many cultivars exceeded an average of 25 t/ha which means significant income realized from these yields.

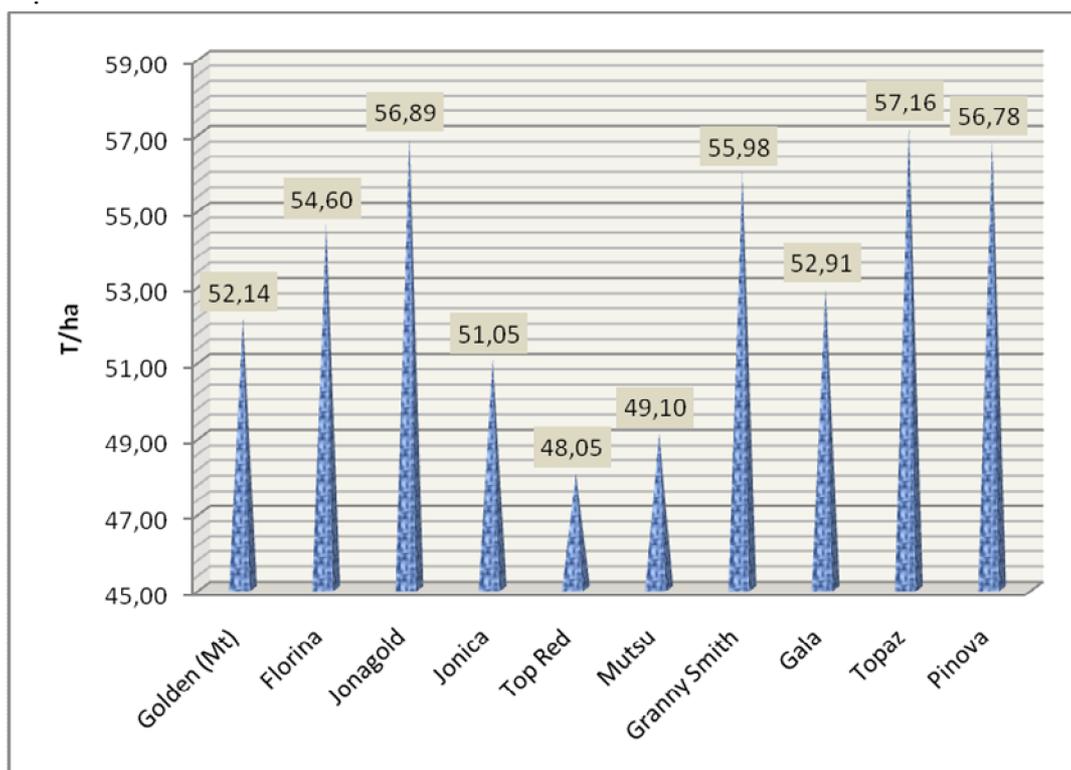


Fig.1. Cumulative fruit yield (2010-2011) of the ten apple cultivars

The cumulative yield is a striking indicator, which offers information about the total yield during the two years of experiment. This indicator is important because it shows the estimated time for the investment to be recovered. Based on the data in Figure 5 one can see that the cultivar with the highest yield was ‘Topaz’ (57.16 t/ha) followed closely by ‘Jonagold’ (56.89 t/ha) and ‘Pinova’ (56.78 t/ha). All varieties have achieved high cumulative yield, most exceed 50 t/ha. Only two cultivars ‘Mutsu’ and ‘Top Red’ failed to exceed this level of 50 t/ha. Regarding the average cumulative production environments five varieties (‘Topaz’, ‘Jonagold’, ‘Pinova’, ‘Granny Smith’ and ‘Florina’) exceeds the average.

## CONCLUSION

All apple cultivars tested in the experiment behaved normally in terms of growth and fruiting in the climatic condition of Cluj-Napoca, Romania in the high density growing system. The most vigorous cultivars proved to be ‘Florina’ and ‘Granny Smith’. These cultivars require a larger volume of pruning than the other ones to keep each tree in the

allocated space. 'Florina' registered the highest ramification capacity in terms of long bearing branches, with very significant differences, followed by 'Topaz'. Within this experience, the ten varieties registered exemplary high yields. Cultivars with the highest average yields on the first two years of yielding were 'Topaz' (28.58 t/ha), 'Jonagold' (28.44 t/ha) and 'Pinova' (28.39 t/ha), with significant positive differences to the control. Regarding the average cumulative yield, five varieties ('Topaz', 'Jonagold', 'Pinova', 'Granny Smith' and 'Florina') exceeded the average the cultivars being very productive. The highly recommended cultivars for growth in the conditions of Cluj-Napoca are 'Pinova', 'Topaz', 'Florina', and 'Granny Smith'.

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