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Influence of Training System on Growth and Yield of the Apple Cultivars (*Malus domestica* Borkh.)

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Abstract. Optimizing relationships between growth and fructification processes in apple, in order to obtain high and quality yields every year, is a permanent concern of the fruit research. The relationship between apple trees training systems in 'Gala', Pinova', 'Topaz' and 'Florina' apple cultivars, grafted on M9 rootstocks, in the first 5 years of cropping under the climatic conditions of Cluj-Napoca, Romania, was studied. In the experimental field some growth parameters (trunk cross-sectional area, tree height, length of annual shoots) and fructification (yield in the end of first year of vegetation, cumulative yield for the first 5 years of fructification) were observed. The studied cultivars had a different behaviour, on hand, due to the genetic characteristic of each one and on the other hand, due to the training system of the trees. The results showed that Slender spindle and Vertical axis transmit much strongly growth than Solaxe and Tall spindle training systems. The biggest average trunk cross sectional area with the Tall spindle training system was obtained (33.4 cm^2) and also the highest trees (361.8 cm). Tall spindle gave precocity and the best yield potential compared to the all others cultivars, followed by Solaxe. Tall spindle training system proved to be, besides the other technological works, the best ones regarding the all performances of high density apple orchards.

Keywords: Training system, Solaxe, Tall spindle, apple, yield

INTRODUCTION

Intensive orchard system became the most used 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.

Certain systems may initially have a high productivity but may not be able to maintain that level of production as trees mature (Baugher *et al*., 1994). Kurahashi and Takahashi (1995), remark that at 'Fuji' cv. the angled canopy may be more efficient. In a British Columbia study the higher early yields for both 'Mc Intosh' and 'Delicious' were obtained in slender spindle and vertical axe systems on (Kappel and Quamme, 1993).

Fruiting way of apple trees have been investigated in several past studies (Bernhard, 1961; Lespinasse, 1977, 1980; Looney and Lane, 1984). Lespinasse and Delort (1986) classified apple trees according to their fruiting types and position of branches along the trunk. It has also been used to describe tree architecture in progeny, leading to the proposal of four ideotypes (Stephen *et al*., 2007).

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. Regardless of the planting system, the various components of the "Orchard System

Puzzle" (Barritt, 1992) initially designed for a specific system are always adapted to integrate not only new economic constraints but also improvements in tree growth and fruiting knowledge (e.g. Vertical Axis to Solaxe system in France; Lauri and Lespinasse, 2000).

The aim of this study was to determine the relationship between apple trees training systems in 'Gala', 'Pinova', 'Topaz' and 'Florina' apple cultivars in the first 5 years of cropping under the climatic conditions of Cluj-Napoca, Romania.

MATERIALS AND METHODS

The research has been carried out in a commercial apple orchard, set up in autumn of 2004 at Cluj-Napoca, Romania. The planting system chosen for the experimental plot was 3.5 m between rows and 0.9 m between trees within row, resulting a high density orchard with 3174 trees/ha in 2005-2010. The experience was a bi factorial one: first experimental factor was the training system of the trees having four graduations (Vertical axis, Solaxe, Slender spindle and Tall spindle) and the second one the cultivar with four graduations ('Gala', 'Pinova', 'Topaz' and 'Florina'). In order to correspond to such a bi factorial model, there were formed 48 experimental plots comprising the 16 variants (4 x 4) in three repeats. There were made observations on some growth parameters (trunk section area, height of the trees, length of shoots) and fructification (yield in the first season of vegetation, cumulative yield for 2005-2010 period). The trees were planted with more than 5 feathers and trained each ones after the rules of each training system. The technology of culture was a specific one to the high density orchard.

The results obtained were processed by means of the variant analysis the bi factorial model of the divided plots. To interpret, the Duncan Test was used.

RESULTS AND DISCUSSION

Analyzing data from the Tab. 1, one can see that the training system influenced obviously the surface of the trunk section. The biggest average trunk cross sectional area with the Tall spindle training system were obtained (33.4 cm^2), followed by Solaxe (31.6 cm^2) and Vertical axis (31.4 cm^2) training systems. The smallest trunk cross sectional area with the Slender spindle training system was registered. Data from the last column of the table show that between the cultivars there are differences statistically assured regarding the trunk cross sectional area.

Tab. 1

Influence of the training system and the cultivar upon trunk cross sectional area (cm^2) at end of 5^{th} growing season

Cultivar/Training system	Vertical axis	Solaxe	Slender spindle	Tall spindle	Mean cultivar
'Gala'	30.5^{d}	30.1^{d}	29.1^{d}	31.9^{c}	30.4^{C}
'Pinova'	29.4^{d}	28.0^{e}	28.0^{e}	30.0^{d}	28.9^{D}
'Topaz'	32.4^{c}	32.0^{c}	31.8^{c}	34.8^{b}	32.7^{B}
'Florina'	33.2^{c}	36.1^{a}	32.9^{c}	37.0^{a}	34.8^{A}
Mean training system	31.4^{N}	31.6^{N}	30.4^{O}	33.4^{M}	
LSD5% cvs 6.8- 7.2		LSD5% tree training system 6.8- 7.2		LSD5% interaction cultivar x training system 13.7-16.4	

Note * = the difference between any two values followed by at least one common letter is not significant

These differences could be explains only from genetically point of view. The largest trunk section in 'Florina' was obtained (34.8 cm^2) and the smallest in 'Gala' (30.4 cm^2). Data inside the table shows the combined influence of two experimental factors. The biggest average trunk cross sectional area with 'Florina' and Tall spindle training system was registered and the smallest with 'Pinova' trained like Solaxe and Slender spindle.

Training system also had a strong influence on trees height in the experimental plots (Tab. 2). The differences between the four training systems are statistically assured. The highest trees at end of 5^{th} growing season in the Tall spindle training system were obtained (361.8 cm) followed by Vertical axis and Solaxe with similarly behaviour. The smallest value Slender spindle training system showed. Data within last column of the table showed that 'Florina' and 'Topaz' had similarly comportment without differences statistically assured with the highest trees. The smaller ones in 'Gala' and 'Pinova' were observed. Regarding the combined influence of the two experimental factors one can say that the highest trees with 'Florina' and 'Pinova' in the Tall spindle training system were obtained.

Tab. 2

Influence of the training system and the cultivar upon mean tree height (cm) at end of 5^{th} apple growing season

Cultivar/Training system	Vertical axis	Solaxe	Slender spindle	Tall spindle	Mean cultivar
'Gala'	318.0^{d}	296.7e	305.3^{e}	356.0^{b}	319.0^{B}
'Pinova'	325.0^{d}	293.3^{ef}	307.3^{d}	367.3^{a}	323.3^{B}
'Topaz'	358.0^{b}	302.3^{e}	312.0^{d}	353.7^{b}	331.5^{A}
'Florina'	337.3^{c}	303.7^{e}	324.0^{d}	370.3^{a}	333.8^{A}
Mean training system	334.6^{N}	299.0^{P}	312.2^{O}	361.8^{M}	
LSD5% cvs 6.8-7.2		LSD5% tree training system 6.8-7.2		LSD5% interaction cultivar x training system 13.7-16,4	

Note * = the difference between any two values followed by at least one common letter is not significant

The average length of shoots, especially in the early stages of the trees, is an important indicator of growth and fruition potential of the future plantation but also achieve a balance between two processes. Annual branches placed in the right position helps form a strong framework of branches, allows air and light into the tree, induces flower and fruit bud formation, restricts tree size and maintains a balanced shape. The training system had an important influence upon average length of annual growth in the experimental field with differences statistically assured. The longest shoots, in mean values, gave Slender spindle (77 cm) and Vertical axis (68 cm) training system.

Tab. 3

Influence of the training system and the cultivar upon average length of annual shoots (cm) at end of first growing season

Cultivar/Training system	Vertical axis	Solaxe	Slender spindle	Tall spindle	Mean cultivar
'Gala'	60.3^{f}	45.7^{i}	66.3^{e}	42.7^{j}	53.8^{D}
'Pinova'	62.7^{f}	50.7^{h}	78.3^{b}	43.7^{j}	58.8^{C}
'Topaz'	72.3^{d}	51.7^{h}	80.3^{b}	48.0^{h}	63.1^{B}
'Florina'	77.3^{bc}	54.3^{g}	83.0^{a}	49.7^{h}	66.1^{A}
Mean trainig system	68.2^{N}	50.6^{O}	77.0^{M}	46.0^{P}	
LSD5% cvs 1.3-1.4		LSD5% tree training system 1.3-1.4		LSD5% interaction cultivar x training system 2.6-3.2	

Note * = the difference between any two values followed by at least one common letter is not significant

All cultivars behaved differently regarding the average length of shoots having differences statistically assured between them. The highest value of shoots average in 'Florina' was registered followed by 'Topaz' (63.1 cm), 'Pinova' (58.8 cm) and 'Gala' (53.8 cm). Taking into account the combined action of two experimental factors one can say that the longest shoots was obtained in combination 'Florina' trained like Slender spindle (83.0 cm) and the shortest shoots at 'Gala' trained like Solaxe (45.7 cm).

Fruiting in the first growing season is essential to keep a low tree vigour level and provide income from early fruit sales. Crops in the early years must also be carefully managed to prevent biennial bearing. In all training systems there were productions of fruits from first growing season. The differences of yield between different training systems were statistically assured. Regarding the precocity and highest yield in the first season of growing, one can say that Solaxe and Tall spindle taining systems gave the best results. In the Solaxe training system the average yield was 6132 kg/ha and in Tall spindle 6111.8 kg/ha. Between cultivars were also differences statistically assured. The biggest average yield in 'Pinova' was registered and the lowest in 'Gala'. Data within the table show that the biggest yield in combination 'Pinova' and Tall spindle was registered.

Tab. 4

Influence of the training system and the cultivar upon average yield (kg/ha) at end of first growing season

Cultivar/Training system	Vertical axis	Solaxe	Slender spindle	Tall spindle	Mean cv.
'Gala'	3181.3^{d}	5963.3^{a}	4305.3^{c}	6022.7^{a}	4868.2^{C}
'Pinova'	5308.0^{b}	6960.0^{a}	5307.3^{b}	6700.7^{a}	6069.0^{A}
'Topaz'	3580.0^{d}	5969.0^{a}	5312.0^{b}	6353.7^{a}	5303.7^{B}
'Florina'	2706.7^{e}	5637.0^{b}	3324.0^{d}	5370.3^{ab}	4259.5^{D}
Mean training system	3694.0^{O}	6132.3^{M}	4562.2^{N}	6111.8^{M}	
LSD5% cvs 381-401		LSD5% tree training system 381-401		LSD5% interaction cultivar x training system 63-911	

Note * = the difference between any two values followed by at least one common letter is not significant

Cumulative production is by far the most important indicator that reflects the performance of orchards. Tab. 5 introduce data referring to the influence of the training system of the apple trees and the cultivar upon cumulative yield (kg/ha) at end of 5th growing season. Following the data of last row of the table one can see that the best cumulative yield was obtained in variant of Tall spindle training system (166139.9 kg/ha) followed by Solaxe training system (139144.3 kg/ha) with differences statistically assured between these two cultivars.

Tab. 5

Influence of the training system and the cultivar upon cumulative yield (kg/ha) at end of 5th growing season

Cultivar/Training system	Vertical axis	Solaxe	Slender spindle	Tall spindle	Mean cv.
'Gala'	113060.3b	141987.7b	87633.3c	171073.0a	128438.6^{B}
'Pinova'	140596.3b	151256.0b	136160.0b	185226.0a	153309.6^{A}
'Topaz'	133630.0b	147203.0b	131843.7b	172898.7a	146393.8^{A}
'Florina'	107519.7bc	116130.3b	108743.7bc	135362.0b	116938.9^{B}
Mean training system	123701.6^{O}	139144.3^{N}	116095.2^{O}	166139.9^{M}	
LSD5% cvs 15464-16267		LSD5% tree training system 15464-16267		LSD5% interaction cultivar x training system 30928-36922	

Note * = the difference between any two values followed by at least one common letter is not significant

The lowest yields gave Vertical axis (123701.6 kg/ha) and Slender spindle (116095.2 kg/ha). Looking to the data of the last column one can observe that between the cultivars there are differences statistically assured. The best yield gave 'Pinova' (153309.6 kg/ha) and the lowest 'Florina' (116938.9 kg/ha). Between 'Pinova' and 'Topaz' respectively 'Gala' and 'Florina' there is no differences statistically assured. Regarding to the combined influence of two experimental factors the best cumulative yield was obtained at 'Pinova' followed by 'Topaz' and 'Gala' trained like Tall spindle system.

CONCLUSIONS

In the high density apple orchards besides the other technological works training system have a strong influence upon growth and fruiting processes.

Tall Spindle, Vertical axis Solaxe training systems gave the best results in increasing the surface section of the trunk. The higher mean trees height with Tall spindle training system was obtained situation due to the formation way of the trees in this system. Slender spindle training system gave the longest annual growth and Solaxe the shortest due to the bending of shoots.

All training system proved to be useful in inducing precocity of fructification of the apple trees. The best one was Tall spindle. The best yield in the first season of vegetation was assured by Solaxe and Tall spindle training systems.

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