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Effect of Roots Pruning upon the Growth and Fruiting of Apple Trees in High Density Orchards

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Abstract. The influence of roots cutting on growth and fruiting of five apple cultivars 'Gala', 'Jonica', 'Topaz', 'Florina', 'Granny Smith'), under the climatic conditions of Cluj-Napoca, Romania, in 2009-2010, was studied. The trees were grafted on M9 rootstocks, trained as slender spindle and the orchard had a density of 3174 trees/ha. Roots were cut twice annually, at 60 cm distance from the trunk and 30 cm depth, as followed: first time, to the autumn fall leaves on one side of the row and the second time, in spring, at blooming time. The treatments had a strong influence, statistically assured, upon the shoot growth, number of bearing branches, cumulative yield, trunk cross sectional area, the ratio of the yield to a trunk cross-section. Root pruning reduced the average length of shoots. The longest shoots, in mean values, gave unpruned root variant (52.07 cm). Root pruning decrease the average length of annual growth (29.47 cm). The biggest average trunks cross sectional area with the unpruned system were obtained (34.82 cm^2). Also root pruning influenced the yield of the trees. The best cumulative yield was obtained in variant of root pruning system (98.75 t/ha) followed by unpruned root system (97.8 t/ha). Finally, root pruning increased productivity. The biggest value in 'Topaz' with root pruned was registered (1.79 kg/cm^2). The lowest value of productivity index in unpruned system variant was obtained.

Keywords: root pruning, vegetative growth, yield, trunk cross-sectional area, bearing branches

INTRODUCTION

Performance of a culture system of fruit trees are largely related to creating an optimal balance between growths and fruiting. Luxuriant vegetative growth delay the shade crown for entry bearing trees and reduce yield and fruit quality.

In high-density apple orchard, otherwise as in any fruit growing culture, the vegetative growth must temperate and turn them as bearing branches or as branches support. In addition, the vegetative growth must be balanced with flowering (Hugard, 1980; Sharma *et al.*, 2009; Walker, 1980).

The maintenance of a proper equilibrium between the vegetative and reproductive processes is a major challenge in tree fruit production (Sharma *et al.*, 2009). There are many horticultural ways to maintain a permanent balance between growth and fruiting: rootstocks (that control directly vegetative growth), dormant pruning, summer pruning, root pruning, branches orientation, scoring, girdling and bark inversion, plant growth regulators, deficit irrigation, fertilisation, but, to date, none have proven to be universally successful (Sharma *et al*., 2009). Rootstocks have provided apple growers with trees of reduced stature suited to a wide range of planting densities (Faust, 1989) but are partially successful in controlling excess growth (Sharma *et al.*, 2009).

Limiting the uptake of water and nutrients can be achieved through manipulating root systems of fruit trees. Root pruning can decrease resource uptake or create a plant hormone imbalance which can adversely affect shoot growth.

Pruning of root systems has been successful in some fruits but less efficacious with others (Sharma *et al*., 2009). Pruning roots of young and mature apple trees reduced shoot growth and thus controlled tree size (Ferree, 1989; Schupp and Ferree, 1988; Sharma *et al*., 2009). Root pruning reduced the number of apple tree roots in the top 30 cm of soil (Ferree, 1994). In 15-years-old apple trees, this method of root pruning reduced trunk cross sectional area (TCSA) and shoot length without reducing fruit yield (Schupp and Ferree, 1988). A later study indicated that yield, as well as trunk cross sectional area (TCSA) of 'Golden Delicious' was reduced by root pruning that were grown on different rootstocks (Ferree and Knee, 1997; Sharma *et al*., 2009). The timing of root pruning is an important factor and root pruning in the dormant season or at full bloom was more effective in reducing shoot elongation than at June drop (Schupp and Ferree, 1987).

Because root pruning is a mechanical mean of controlling tree size which could reduces growth, pruning time, preharvest drop etc. (Ferree and Rhodus, 1993), the present paper tackles the influence of root pruning in a high-density apple orchard depending on the cultivars.

MATERIALS AND METHODS

The research has been carried out at a commercial apple orchard, set up in autumn of 2004 at Cluj-Napoca, in the centre of Transylvania, 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 root pruning system of the trees having two graduations (unpruned roots and pruned roots) and the second one the cultivar with five graduations ('Gala', 'Jonica', 'Topaz', 'Florina' and 'Granny Smith'). In order to correspond to such a bi factorial model, there were formed 30 experimental plots comprising the 10 variants (2 x 5) in three replications.

There were made observations on some growth parameters (length of shoots, trunk section area, leaves) and fructification (number of bearing branches, cumulative yield for 2010-2011 period, productivity index).

For the experiment, apple trees were grafted on M9 rootstocks. The technology of culture was a specific one to the high density orchard.

Roots were cut twice annually, at 60 cm distance from the trunk and 30 cm depth, as followed: first time, to the autumn fall leaves on one side of the row and the second time, in spring, at blooming time.

The results obtained were processed with the variant analysis of the bi factorial model of the divided plots, using analysis of variance, respectively Duncan's Test to determine the significant differences between groups.

RESULTS AND DISCUSSIONS

Analysing data from the Tab. 1, one can see that the root pruning 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 unpruned root variant (52.07 cm). Root pruning decrease strongly average length of annual growth (29.47 cm).

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 (51.17 cm) followed by 'Granny Smith' (44.50 cm), 'Jonica' (42.33 cm), 'Topaz' (35 cm) and 'Gala' (53.8 cm).

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 achieves a balance between two processes. Annual branches placed in the right position help form a strong framework of branches, allow air and light into the tree, induce flower and fruit bud formation, restrict tree size and maintain a balanced shape. In the experience, taking into account the combined action of two experimental factors, one can say that the longest shoots were obtained in combining 'Florina' in unpruned roots variant (69.33 cm) and the shortest shoots at 'Gala' in root pruned variant (27.33 cm).

Pruning roots of young and mature apple trees reduced shoot growth and thus controlled tree size (Schupp and Ferree, 1988; Ferree, 1989). Elfving *et al.* (1996) showed that root pruning reduced shoot growth and fruit load in 'Empire' and 'McIntosh' apple trees.

Tab. 1

The influence of root pruning and the cultivar on average length of shoots (cm) in high density apple orchard (Cluj-Napoca, Romania, 2010-2011)

Cultivar/ root pruning system	Unpruned root	Root pruned	Mean cultivar
'Gala'	34.33^{e}	27.33^{ef}	30.83^{C}
'Jonica'	53.00^{c}	31.67^{e}	42.33^{B}
'Topaz'	43.33^{d}	26.67^{ef}	35.00^{C}
'Florina'	69.33^{a}	33.00e	51.17^{A}
'Granny Smith'	60.33^{b}	28.67^{ef}	44.50^{B}
Mean root pruning system	52.07^{M}	29.47^{N}	-

Note: Different letters between cultivars denote significant differences (Duncan test, $p < 0.05$). LSD5% cvs 4.32-4.76; LSD5% root pruning system 2.73-2.87; LSD5% interaction cv x root pruning system 6.11-7.04.

According to the results of Ferree and Knee (1997), Sharma *et al*. (2009), this experiment proved that root pruning influenced the surface of the trunk section (Tab. 2). The biggest average trunks cross sectional area with the unpruned system were obtained 34.82 cm^2). The smallest trunk cross sectional area with the root pruned system was registered (31.23 $cm^{2)}$.

Tab. 2

The influence of root pruning and the cultivar on average trunk sectional area (cm2) in high density apple orchard (Cluj-Napoca, Romania, 2010-2011)

Cultivar / root pruning system	Unpruned root	Root pruned	Mean cultivar
'Gala'	29.93^{b}	28.00^{b}	28.97^{D}
'Jonica'	35.33^{a}	31.43^{b}	33.38^{B}
'Topaz'	32.57^{ba}	30.13^{b}	31.35^{CB}
'Florina'	39.57^{a}	34.90^{ba}	37.23^{A}
'Granny Smith'	36.70^{a}	31.67^{b}	34.18^{B}
Mean root pruning system	34.82^{M}	31.23^{N}	-

Note: Different letters between cultivars denote significant differences (Duncan test, $p < 0.05$). LSD5% cvs 2.6-2.86; LSD5% root pruning system 1.65-1.73; LSD5% interaction cv x root pruning system 3.67-4.23.

Excessive vegetative growth reduces flowering and ultimately fruiting (Forshey and Elfving, 1989; Luckwill, 1970). A certain amount of growth is necessary in order to maintain vigour and healthy bearing canopy with an adequate leaf surface (Sharma *et al*., 2009). The

desires to obtain early cropping and to reduce labour inputs have also necessitated the maintenance of dwarf trees planted in high density systems. Moreover, excessive growth in bearing orchard often leads to overcrowding and reduced light penetration into the canopy, poorer fruit quality and increased pest problems. In the present experience, there are differences statistically assured regarding the trunk cross sectional area among the cultivars. These differences could be explained only from a genetic point of view. The largest trunk section in 'Florina' was obtained (37.23 cm^2) and the smallest in 'Gala' (29.87 cm^2). Data inside the table shows the combined influence of two experimental factors. The biggest average trunk cross sectional area with 'Florina' and root pruned training system was registered and the smallest with 'Gala' with root pruned system.

Cumulative yield is by far the most important indicator that reflects the performance of orchards. Contrary to the results from the specialty literature (Ferree and Knee, 1997), root pruning increased yield per surface unit and obviously cumulative yield.

Tab. 3 introduces data referring to the influence of the root pruning system of the apple trees and the cultivar upon cumulative yield (kg/ha) in 2010 and 2011 growing seasons. Following the data of the last row of the table, one can see that the best cumulative yield was obtained in variant of root pruning system (98.75 t/ha) followed by unpruned root system (97.8 t/ha) without differences statistically assured between these two treatments.

Looking at the data from the last column one can observe that between the cultivars there are differences statistically assured. The best yield gave 'Topaz' (106.93 t/ha) and the lowest 'Granny Smith' (88.42 t/ha). Between 'Jonica' and 'Topaz', respectively 'Florina' and 'Gala' there is no differences statistically assured. Regarding the combined influence of two experimental factors, the best cumulative yield was obtained at 'Topaz' followed by 'Jonica' in root pruned system.

Tab. 3

The influence of root cutting and the cultivar on average cumulative yield (t/ha) in high density apple orchard (Cluj-Napoca, Romania, 2010-2011)

Cultivar / root pruning system	Unpruned root	Root pruned	Mean cultivar
'Gala'	95.93b	95.63b	95.78^{B}
'Jonica'	102.07a	104.07a	103.07^{A}
'Topaz'	105.93a	107.93a	106.93^{A}
'Florina'	93.20b	97.57b	95.38^{B}
'Granny Smith'	88.27c	88.57c	88.42^{C}
Mean root pruning system	97.08^{M}	98.75^{M}	-

Note: Different letters between cultivars denote significant differences (Duncan test, $p < 0.05$). LSD5% cvs 4.02-4.42; LSD5% root pruning system 2.54-2.67; LSD5% interaction cv x root pruning system 5.68-6.54.

The number of bearing branches is a very important indicator of productivity of the trees because this is related in a close dependence with the number of fruits on the tree.

Reducing growth shoots caused their transformation in bearing branches. This is the reason why the number of bearing branches increased after root pruning.

Tab. 4 introduces data regarding the influence of root cutting and the cultivar on number of bearing branches in high density apple orchard. Analyzing data in last row of the table one can observe that, there are differences statistically assured between the two variants, root pruning technical system increasing the number of bearing branches on the trees (48.0 instead of 32.13).

Certainly, there are differences between cultivar regardless the treatment, which could be explained from a genetic point of view. The biggest number of bearing branches, regardless the root pruning system, in 'Florina' cv. was registered (59.33) followed by 'Jonica', 'Gala' and 'Granny Smith'.

Regarding to the combined influence of two experimental factors, one can see that the biggest number of bearing branches in 'Florina' and 'Jonica' with pruned root variant was obtained and the lowest in 'Topaz' and 'Granny Smith' with pruned root variant.

Tab. 4

The influence of root cutting and the cultivar on number of bearing branches in high density apple orchard (Cluj-Napoca, Romania, 2010-2011)

Cultivar / root pruning system	Unpruned root	Root pruned	Mean cultivar
'Gala'	33.67^{d}	47.67^{c}	40.67^{C}
'Jonica'	35.33^{d}	54.00^{b}	44.67^{B}
'Topaz'	22.33^{e}	33.33^{d}	27.83^{E}
'Florina'	45.00^{c}	73.67^{a}	59.33^{A}
'Granny Smith'	24.33	35.33^{d}	29.83^{D}
Mean root pruning system	32.13^{N}	48.80^{M}	-

Note: Different letters between cultivars denote significant differences (Duncan test, $p < 0.05$). LSD5% cvs 2.59-2.85; LSD5% root pruning system 1.64-1.72; LSD5% interaction cv x root pruning system 3.66-4.21.

The yielding efficiency index, expressed in kg per 1 cm^2 of trunk cross section area (TCA) in Fig. 1 is presented.

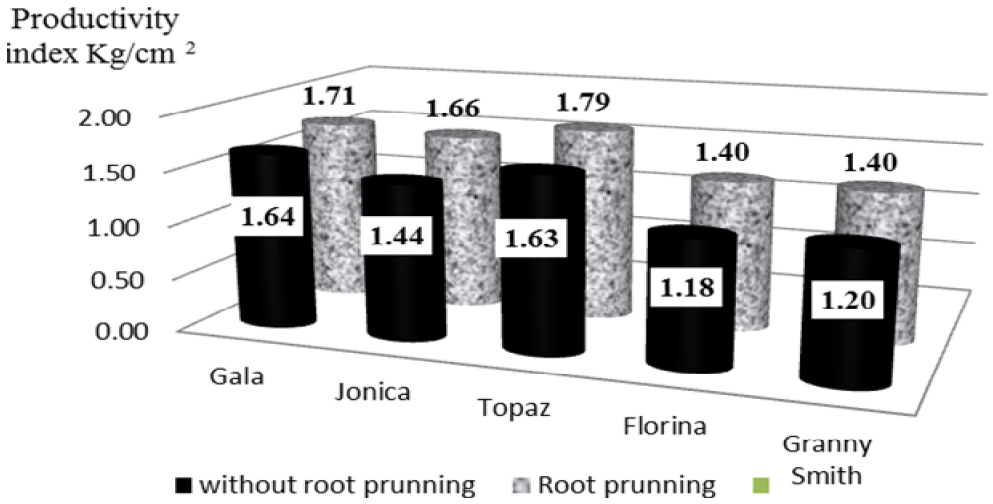

Fig. 1. Productivity index of apple cultivars in the experiment regarding the influence of root pruning on growth and fructification in apple high density orchards

Looking at the data of the figure one can observe that root pruning increase productivity index in the experiment with the five apple cultivars. The biggest value in 'Topaz' with root pruned variant was registered (1.79 kg/cm^2) followed by 'Gala' and 'Jonica' in the same system of root pruning. The lowest values of productivity index in unpruned system variant were obtained. In this variant, best results were given again by 'Topaz' (1.63 kg/cm^2) followed by 'Gala' and 'Jonica'.

One can say that root pruning is an important measure in creating the right balance between growth and fruiting in high density apple orchards.

CONCLUSION

Maintaining the right balance between growth and fruiting is the most important goal in the technology culture of the high-density apple orchards. Classical measures controls of growth fruiting ratio by pruning are often too costly and less effective. Root pruning reduced the vegetative growth of 'Gala', 'Jonica', 'Topaz', 'Florina' and 'Granny Smith' apple trees cultivars, in a high density orchard especially in the first years of yielding. Root pruning reduced obviously the length of shoots and the surface of the trunk section compared to the un-pruned roots control. Root-pruned trees yielded significantly better in comparison to the un-pruned roots control.

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