The Influence of Cultivar, Rootstock and Culture System on Growth and Yield in Apple

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ABSTRACT

The influence of two apple rootstocks (M9 and MM106) on growth and yielding of four apple cultivars („Pinova”, „Topaz”, „Florina” and „Golden Reinders”) in two culture system was studied. The experiment was placed in a commercial orchard at SC Agroindustrială Cluj-Napoca Romania, planted in 2007, during 2012-2014. In the experimental field some growth parameters (length of annual shoots, trunk cross-sectional area, tree height) and fructification (average yield and productivity index) were observed. The studied cultivars had a different response due to the genetic characteristic of each one and on the other hand, due to the rootstock. The results showed that MM 106 transmit much strongly growth than M9. The longest shoots, in terms of mean values, gave the variants where the cultivars were grafted on MM106 (53 cm) and the shortest (34.4 cm) on M9. The biggest average height of trees were obtained on MM 106 rootstock (290 cm). The smallest average trees height were registered by the variants where the trees were grafted on M9 (239 cm). The biggest average trunk cross sectional area were obtained with the MM106 (102.1 cm²). The best yield was obtained in variant where the cultivars were grafted on M9 (47.03 t/ha). M9 rootstock has controlled the tree size of all cultivars more than MM106 resulting in the lowest TCSA (58.8 cm²) and the highest yield per hectare (47.03 tone/ha) and yield efficiency (925 kg/cm²).

Keywords: *rootstock, yield, M 9, MM 106*

INTRODUCTION

Achieving maximum biological potential of growth and fructification of a cultivar is strongly influenced by the combination of cultivar/rootstock. This combination determines the culture system (intensive or superintensive) and the complex of technological measures that influence directly production and fruit quality.

Each system has own advantages and disadvantages. High density plantations are characterized by earlier production, aiming for commercially acceptable yields from the third year, higher yield potential per hectare, higher and more uniform fruit quality, earlier return of investment, easyness of picking, as fruit is easy to see, and easyness of the access to the canopy.

However, it is very important to know all these aspects for each combination before establish a plantation.

The use of intensive orchards has been proposed to improve profitability and yield, notably of early cropping, in apple orchards (Lauri *et al.*, 2004)

Trees must be trained and pruned in order to achieve a manageable uniform size, a balance between growth and regular yield, and to allow good penetration of light and spray to the tree center (Malavolta and Cross, 2009).

In addition, fruit color is often poor in the center of the canopy of large trees (Mohammad *etal.*, 2012). This aspect is often observed in apple orchards grafted on MM106.

Small trees of uniform sizes represents the goal for the future so that safer, more efficient spraying practices can be adopted. Trees must be trained and pruned accordingly to achieve a manageable uniform size, a balance between growth and regular yields, and to allow good penetration of light and spray to the tree centre (Malavolta and Cross, 2009).

Research on apple trees using dwarf rootstocks in intensive planting systems has been carried out in different countries (Barritt *et al.*, 1995).

The switch to smaller trees and higher tree planting densities has allowed significant improvements in fruit quality (Robinson, 2007).

In modern orchards, planting systems are based on higher tree densities with 1000-6000 trees/ha and some up to 10000 trees/ha (Robinson, 2003).

Modern orchards planting systems are based on higher tree densities with a range from 1000 to 6000 trees per hectare and some up to 10000 trees per hectare (Robinson, 2003).

However, increasing only planting density does not increase yield, as planting density and yield are not linearly related and a threshold can be found beyond which a further increase in density may not result in greater yield (Webster, 2001; Hampson *et al.*, 2002).

Clonal dwarfing rootstocks for apple control scion growth by the reduction of canopy spread, branches compression and tree height. M9 has been introduced as a dwarf rootstock that induces excellent yield, precocity, efficiency and large fruit size.

The manner in which plant management systems are applied has direct implications over the planting density, the degree of fruit exposure and quality (Caprariu and Gradinariu, 2009).

Small sized crowns allow the fruit grower to perform the main manual works from the ground, with greater yield and lower percentage of the manual works in the production costs (Hoza *et al.*, 2012).

The successful balance of vegetative vigor and fruiting results in 'calm' trees that produce heavy annual crops and require only a light annual pruning.

The goal of modern high-density orchard systems is to achieve high yield at early tree age (Cody *et al.*, 1985; Jaumien *et al.*, 1993; Theron *et al.*, 2000).

The aim of this investigation were to study the influence of two apple rootstocks having different vigour (vegetative M9 and MM106 rootstocks), recommended for different culture systems on the performance of growth and fruiting of four apple cultivars with great spread in production, in order to determine which of them give higher performance.

MATERIALS AND METHODS

The experimental field was placed in a commercial orchard at SC Agroindustrială Cluj-Napoca Romania, planted in 2007 with four apple cultivars „Pinova”, „Florina”, „Topaz” and „Golden Reinders” grafted on clonal rootstocks MM106 and M9.

The trees were planted in two different culture systems: first one at distance of 4 m between rows and 2 m between trees in the row, with a density of 1250 trees/ha where trees were grafted on MM106 and the second one at distance of 3.5 m between the rows and 0.9 m between trees in the row with a density of 3175 trees/ha where the trees were grafted on M9.

The area has a temperate continental climate with an average annual rainfall of 530 mm. The orchard was established in spring of 2007, with high-quality 1-year-old nursery trees that presented 6 or more lateral branches.

The experiment was done on 12 representative trees within each replication. The plot design was used for statistical analysis on a randomized complete block (RCBD) with four replications.

In order to register the shoots growth, the average current season growth of six branches in each tree at the end of the seasonal growth was measured (cm).

Also, in order to measure the tree height, distance between graft unions to end of highest branch in main trunk was recorded in cm. In addition, yield per tree was recorded at harvest time in each tree.

For calculating the Trunk Cross Sectional Area (TCSA), trunk diameter (20 cm above the graft union) was measured twice at the beginning of March at 30 cm above the grafting union. Yield per tree was calculated on the amount of fruit in each tree at harvest time. Yield efficiency was measured as yield per tree divided to TCSA.

Analysis of variance (ANOVA) and mean separations by Duncan's multiple range test were performed.

RESULTS AND DISCUSSION

The successful management of apple trees depends on maintaining a balance between vegetative growth and fruiting. If vigor is low, excessive fruiting results, fruit size increase, biennial bearing increase too. If vegetative vigor is excessive then flowering and fruiting are reduced and also the yield.

The growing system and the rootstock had an important influence upon average length of annual growth in the experimental field with statistically assured differences. Regardless the cultivar, the longest shoots, in mean values, gave the variants where the cultivars were grafted on MM106 (53 cm) and the shortest (34.4 cm) on M9 rootstock (Tab.1.).

All cultivars behaved similarly regarding the average length of shoots without differences statistically assured between them. The highest value of shoots average in „Florina” (54.5 cm), followed by „Pinova” (42.6 cm) and „Golden Reinders” (39.5 cm) was registered. Taking into account the combined action of two experimental factors, one can say that the longest shoots was obtained in combination „Florina” grafted on MM106 (69.3 cm) and the shortest shoots at „Pinova” grafted on M 9 (30.5 cm). The influence of cultivar and rootstock on average height of trees is presented in Table 2. Analyzing data from this table, one can see that the rootstock influenced obviously the average height of trees.

The biggest average height of trees with the MM106 rootstock were obtained (290 cm). The smallest average height of trees with the variants where the trees were grafted on M9 (239 cm) was registered too. Data from the last column of the

Tab.1. The influence of cultivar and rootstock on average length of shoots (cm)

Cultivar \ Rootstock	Rootstock		Mean Cultivar
	MM 106	M 9	
„Pinova”	54.8 ^a	30.5 ^{ab}	42.6 ^a
„Florina”	69.3 ^a	39.8 ^{ab}	54.5 ^a
„Topaz”	43.0 ^a	33.5 ^{ab}	38.3 ^a
„Golden Reinders”	45.0 ^a	34.0 ^{ab}	39.5 ^a
Mean rootstock	53.0 ^M	34.4 ^N	
LSD 5% Cultivar = 13.7-14.8 LSD5 % Rootstock = 9.7 LSD5% interaction Cv. x Rootstock = 19.4-22.8			

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

Tab.2. The influence of cultivar and rootstock on average height of trees (cm)

Cultivar \ Rootstock	Rootstock		Mean Cultivar
	MM 106	M 9	
„Pinova”	271 ^b	226 ^c	248 ^A
„Florina”	339 ^a	277 ^b	308 ^C
„Topaz”	266 ^b	220 ^c	243 ^{AB}
„Golden Reinders”	284 ^b	232 ^c	258 ^A
Mean rootstock	290 ^M	239 ^N	
LSD5% cultivar 12.2-13.2 LSD5% rootstock = 8.6 LSD5% interaction cv. x rootstock = 17.2-20.3			

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

table show that for the average height of trees, there are statistically assured differences between the cultivars.

These differences could be explained only from genetically point of view. The biggest average height of trees was obtained by „Florina” (308 cm) and the smallest by „Topaz” (243 cm).

Data inside the table shows the combined influence of two experimental factors. The biggest average height of trees with „Florina” and MM 106 rootstock was registered and the smallest with „Topaz” and M9.

Analyzing data from the Figure 2, one can see that the rootstock influenced the surface of the trunk section. The biggest average trunk cross sectional area with the MM106 were obtained (102.1 cm²).

The smallest TCSA was registered with M9 rootstock. Data from the top part of the figure show that between the cultivars there are differences statistically assured regarding the TCSA.

These differences could be explained also from genetically point of view. Data from the bottom part of the figure shows the combined influence

of two experimental factors. The biggest average TCSA has been noticed with „Florina” grafted on MM 106 and the smallest with „Pinova” grafted on M9.

The yield is by far the most important indicator that reflects the performance of orchards. Tabel 3 introduce data referring to the influence of cultivars and rootstocks on average yield of the apple tree.

Following the data of next table, it could be observed that the best yield was obtained in variant where the cultivars were grafted on M9 (47.03 t/ha) with statistically differences assured. Regardless the cultivar, the smallest yield gave the variants grafted on MM106.

Looking to the data of mean cultivar in the table 3, it can be seen that there were no differences statistically assured between cultivars. The biggest yield gave „Florina”(38951kg/ha) and the lowest „Topaz” (35303 kg/ha). Regarding to the combined influence of two experimental factors the best yield was obtained at „Pinova”/M9 followed by „Florina” and „Golden Reinders” also on M9.

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

LSD 5% cultivar = 33.6-36.4

LSD5 % rootstock = 23.8

LSD5% interaction cv. x rootstock = 47.6-55.9

Fig. 1. The influence of rootstock and cultivar on TSCA (cm²)

The beneficial effects of dwarfing rootstock on the precocity and efficiency of tree yields have often been attributed to a change in the partitioning of the dwarfed trees assimilate from shoot growth to fruit production (Mohammad *et al.*, 2012)

Results presented in Fig.2. showed that cultivars grafted on M9 had a more yield efficiency (925 kg cm²) than MM106 (356 kg cm²)

Increased photosynthesis and yield efficiency in grafted cultivars on dwarfing rootstock deriving

from reduction of shoot growth vegetative, competition between vegetative and productive growth, more light penetration in canopy and intensity in area unit (Avery, 1970; Webster, 2001 McAfee & Rom, 2003) is demonstrated.

Differences in TCSA indicate that rootstock controls the tree size (Dolp & Proebsting, 1989). In fact, the results of the present study confirm that the M9 rootstock has controlled the tree size of all cultivars more than MM106, resulting in the

Tab.3. The influence of cultivar and rootstock on average yield, (t/ha),

Rootstock Cultivar	MM 106	M 9	Mean Cultivar
„Pinova”	23.598 ^c	51.563 ^a	37.580 ^A
„Florina”	27.742 ^c	50.161 ^a	38.951 ^A
„Topaz”	28.255 ^c	42.352 ^{ab}	35.303 ^A
„Golden Reinders”	28.737 ^c	44.080 ^a	36.409 ^A
Mean rootstock	27.083 ^N	47.03 ^M	

DS 5 % cultivar = 5.5 – 6.0

DS 5 % rootstock = 3.9

DS 5 % cultivar x rootstock = 7.8-9.2

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

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LSD 5% cultivar = 237-256

LSD 5% rootstock = 168

LSD 5% interaction cv. x rootstock = 335-394

Fig. 2. The influence of rootstock and cultivar on productivity index (kg/cm²)

lowest TCSA (58.8 cm²) and the highest yield per hectare (47.03 tone/ha) and yield efficiency (925 kg/cm²).

CONCLUSION

The obtained results indicated that each cultivar has specific response strongly influenced by rootstock.

MM106 rootstock caused much greater vegetative growth disturbing balance between growth and fruiting in the first years of fruit.

M9 rootstock gave lower vegetative growth, which evolved into fruits, favoring the balance between growth and fruiting in the first years of fruiting.

Lower vegetative growths led to a lower volume of crowns and a lower height of trees, which makes trees to be easier to maintain.

For all this reasons, cultivation of apple grafted on M9 in high density culture has proven superiority both in terms of management but also through the trees fruits production and productivity index obtained.

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