

## The Influence of Rootstock on the Growth and Fructification of Cherry Cultivars in a High Density Cultivation System

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### Abstract

The influence of rootstock on the growth and fruiting of three sweet cherry cultivars ('Bigarreau Burlat', 'Kordia', 'Regina') was studied under the pedoclimatic conditions of Cluj-Napoca, Romania, in 2014-2016. The trees were grafted on Gisela 5 rootstock, trained as Zahn Spindle and the orchard had a density of 1666 trees/ha. Root were cut twice, at 50 cm distance from the trunk, in an angle of 45° and 30 cm depth, as followed: first time, to the autumn, in fall leaves time, on one side of the row and the second time, in spring, at blooming time, at the other side of the row. The rootstocks influenced height of the trees, the shoot growth, the number of long and fruiting branches, trunk cross sectional area yield and precocity, with differences statistically assured. The longest shoots, in mean values, gave the variant with cultivars grafted on Mahaleb rootstock (111.7 cm). 'Gisela 5' rootstock decreases the average length of annual growth (93.3 cm). Trees grafted on Mahaleb formed more long fruiting branches and fewer short fruiting branches than those grafted on 'Gisela 5'. The biggest average trunks cross sectional area were obtained for the cultivars grafted on Mahaleb (62.1 cm<sup>2</sup>). Also rootstocks influenced the height of the trees. The cumulative yield was almost double in variants where the trees were grafted on 'Gisela 5' (23.2kg/tree), compared to the variants where the trees were grafted on Mahaleb (13.1 kg/tree).

**Keywords:** rootstock, vegetative growth, fruiting, yield, trunk cross-sectional area

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### Introduction

In the last years, there has been an interest of cultivating new varieties of sweet cherries grafted on dwarf cherry rootstock (Lang, 2001). This has allowed developing high-density orchards with smaller vigour trees that are more productive and more precocious (Andersen *et al.*, 1999).

Mahaleb (*Prunus mahaleb* L.) seedling is one of a traditional rootstock used for sweet cherry production. Cherry trees grafted on these rootstocks are vigorous and difficult to maintain, especially during harvesting (Gyeviki *et al.*, 2008). In the last few years, farmers have shown an increased interest for new high density cherry orchards established on dwarfing rootstock. The Gisela 5 cherry rootstock is among the best dwarfing, precocious, and productive rootstocks for modern intensive sweet cherry growing (Zimmermann, 1994).

Maintaining an optimal balance between growth and fruiting is an ongoing concern of research in fruit growing.

Besides the classical methods of reducing the vigor (low vigor rootstocks and cultivars, compact types, pruning in green, balanced fertilization etc.) cutting root in order to reduce growth vigor and increase the number of fruit formation is increasingly more used. 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 (Mitre *et al.*, 2012).

In high-density cherry 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 properly 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 keep a permanent balance between growth and fruiting; rootstocks (who control directly

vegetative growth), dormant pruning, summer pruning, root pruning, branches orientation, scoring, girdling and bark inversion, plant growth regulators, deficit irrigation, fertilization, 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.

The aim of this research was to provide information about the growth parameters (height of trees, length of shoots, trunk sectional area), capacity of forming fruiting branches and fructification yield and cumulative yield, for 2014-2016 period, of the three cherry cultivars, grafted on two different rootstocks (Mahaleb and 'Gisela 5').

## Materials and Methods

### *Location and orchard density*

The research has been carried out at a sweet cherry orchard, set up in spring of 2012 at Cluj-Napoca, in the centre of Transylvania (Romania). The planting system chosen for the experimental plot was 4 m between rows and 1.5 m between trees within row, resulting a high density orchard with 1666 trees/ha.

### *Sampling design and cultivars*

The experience was a bifactorial one: first experimental factor was the rootstock (Mahaleb and 'Gisela 5') and the second one the cultivar ('Bigarreau Burlat', 'Kordia' and 'Regina'). In order to correspond to such a bifactorial model, there were formed 18 experimental plots comprising the 6 variants (2 × 3) in three replicates. For the experiment, sweet cherry trees were grafted on 'Gisela 5' rootstock. Vegetative and reproductive growth parameters (length of shoots, trunk sectional area, height of trees, the number of long fruiting branches, the number of short fruiting branches) were determined in the autumn of each experimental year, after the leaves fall down.

### *Cultural management of the plantation*

The technology of culture was a specific one to the sweet cherry high density orchard. The orchard was assisted by fertigation and antihail systems. Roots were cut mechanically twice, at 50 cm distance from the trunk, in an angle of 45 grade and 30 cm depth, as followed: first time, in the autumn fall leaves on one side of the row and the second time, inspring, before blooming time on the other side of the row.

### *Statistical procedures*

Processed data are presented in mean values on the three years of research. The results obtained were processed using analysis of variance and Duncan's multiple range test (DMRT, or Duncan's test) was used in order to provides significance levels for the difference between pair of means, regardless of whether a significant F resulted from an initial analysis of variance. The differences among treatments means were compared at 5% probability.

## Results and Discussion

In the high density cherry growing, keeping trees in an optimum balance between grow and fruiting is the most important challenge. Therefore, the comparative study of the response of some cultivars of cherry grafted on two rootstocks of different groups of vigour in a high density cherry cultivation system is justified.

### *Vigor of the cherry trees*

Data of the Table 1 presents the influence of the rootstocks and the cultivars on the vigor of cherry trees expressed by tree height, shoots length and trunk sectional area.

Regarding the tree height one can say that the highest value of the height of the trees was registered in 'Bigarreau Burlat' cultivar (403.0 cm). It has to be underlined that 'Kordia' and 'Regina' behaved similarly from the statistically point of view. As expected, the biggest value of trees height was obtained in the variant with trees grafted on mahaleb (389.7 cm) even if rootstock roots were cut mechanically and the lowest in the variant with trees grafted on 'Gisela 5' (364.3 cm), phenomenon explained due to the difference in vigor between the two rootstocks. A similar opinion was expressed by Santos *et al.* (2006), and Cmelik *et al.* (2002), studying the influence of the 'Gisela 5' rootstock on the average height of cherry varieties. Aglar and Yildiz (2014), indicated that '0900 Ziraat' variety grafted on 'SL 64' had bigger height of trees and crown volume than those grafted on 'Gisela 5'. Also in the experiment conducted by the same author, Aglar *et al.* (2016), mentioned that the tall of trees on 'MaxMa 14' were higher than these on 'Gisela 5' and 'Gisela 6' rootstocks.

Data of the second column of the table show an important influence of the rootstock and the cultivar on the average length of annual growth. The longest shoots, in mean value was registered for the cultivars grafted on Mahaleb rootstock (111.7 cm), while 'Gisela 5' decrease the average length of annual shoots (93.3 cm). The highest value of shoots average was registered in 'Bigarreau Burlat' (115.0 cm), followed by 'Kordia' (98.0 cm) and the shortest value of this parameter was registered in 'Regina' (94.5 cm). Asănică *et al.* (2011a) reported different number of long fruiting branches that formed 'Kordia'.

The shoots having optimal length, especially in the early stages of the trees, are an important indicator of growth and fruit production of the future plantation but also achieve a balance between two processes; also 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 (Mitre *et al.*, 2012).

It can be observed that the longest shoots were obtained on 'Bigarreau Burlat' grafted on Mahaleb (128.0 cm) and the shortest shoots at 'Regina' grafted on 'Gisela 5' (88.3 cm).

Excessive vegetative growth reduces flowering and ultimately fruiting (Forshey and Elfving, 1989; Luckwill, 1970). A certain amount of growth is necessary to maintain vigor and healthy bearing canopy with an adequate leaf surface (Sharma *et al.*, 2009). Musacchi *et al.* (2015)

obtained less vegetative growth of 'Kordia' and 'Regina' grafted on 'Gisela 5'.

In the third column of the table are presented data regarding to the influence of the rootstocks and the cultivars on average trunk sectional area. It can be seen that 'Bigarreau Burlat' registered the biggest value of this character (69.7 cm<sup>2</sup>). Data of the table shows that the biggest average trunks cross sectional area were obtained in the variant with the cultivars grafted on Mahaleb (62.1 cm<sup>2</sup>). The smallest trunk cross sectional area was registered in the variant where the trees were grafted on 'Gisela 5' (50.9 cm<sup>2</sup>). The biggest average trunk cross sectional area was registered with 'Bigarreau Burlat' grafted on Mahaleb (69.7 cm<sup>2</sup>) and the smallest one with 'Regina' grafted on 'Gisela 5' (46.3 cm<sup>2</sup>) looking to the combined interaction of the two experimental factor.

Similar results were obtained by other authors concerning the influence of 'Gisela 5' on the trunk section area. Musacchi *et al.* (2015) reported that the smaller values for 'Kordia' and 'Regina', but Gjamovski *et al.* (2016) recorded similar values for the same cultivars. The results of the trunk section area of 'Gisela 5' rootstock were similar with the values recorded by Drkenda *et al.* (2012) for 'Bigarreau Burlat' and Milinović *et al.* (2016) for 'Kordia' and 'Regina'. These results are in accordance with the data obtained earlier by Tomaszewska and Nychnerewicz (2006) regarding the influence of 'Gisela 5' rootstock on trunk section area of 'Bigarreau Burlat', 'Kordia', 'Regina' and 'Van' cultivars in a high density orchard. Also, these results are in agreement with Bielicki and Rozpara (2010), who reported similar results about the influence of 'Gisela 5' rootstock on the trunk cross-sectional area of the 'Kordia' sweet cherry cultivar in the 5<sup>th</sup> year after planting.

#### Reproductive growth potential

In the Table 2 are presented data regarding the influence of rootstock and the cultivar on the number of long and short fruiting branches. During the formation and

maintenance of the tree crowns, a very important aspect is on the one hand to maintain the optimal balance between growing and fruit production and on the other hand, to create as many branches of fruit as possible. Regarding the influence of the cultivar on the number of long fruiting branches, data of Table 2 show that, regardless the influence of rootstocks, there are differences statistically assured only between all three cultivars. Regardless the cultivar, the lowest number of long fruiting branches was registered in cherry trees grafted on Mahaleb (42.1) and the biggest number was obtained for cherry cultivars grafted on 'Gisela 5' (64.0). Taking into account of the combined interaction of the two experimental factor, the biggest number of long fruiting branches were obtained in 'Kordia' grafted on 'Gisela 5' (72.9), and the lowest value was registered in the same cultivar, 'Bigarreau Burlat', grafted on Mahaleb (36.7).

Asănică *et al.* (2011a), studding 'Skeena', 'Kordia' and 'Ferrovia' sweet cherry cultivars grafted on 'Gisela 5' rootstock in the first year after planting, reported that 'Kordia' has formed the largest number of long branches on the tree (18.7).

Regarding the influence of the cultivar on the average number of short fruiting branches, the cultivars behaved differently from statistically point of view. The biggest number of short fruiting branches was obtained at 'Kordia' (132.5) followed by 'Regina' (124.5) and 'Bigarreau Burlat' (111.6). Concerning the influence of the rootstock, the biggest value of this parameter was registered for the cherry cultivars grafted on 'Gisela 5' (148.6), and the lowest value was obtained in trees grafted on Mahaleb (91.7). A similar opinion was expressed by Asănică *et al.* (2011b) who found a significantly difference regarding the number of long and short fruit branches depending of cultivar and rootstock, starting from the second year after planting.

The smallest number of short fruiting branches was obtained by 'Bigarreau Burlat' grafted on 'Gisela 5' (86.7) and the biggest number was registered for 'Kordia' grafted on Mahaleb (164.9).

Table 1. Influence of the rootstock and the cultivar on the vigor of cherry tree expressed by tree height, shoots length and trunk sectional area

Rootstock	Cultivar	Tree height (cm)	Shoots length (cm)	Trunk sectional area (cm <sup>2</sup> )
Mahaleb	'Bigarreau Burlat'	403.0 <sup>a</sup>	128.0 <sup>a</sup>	69.7 <sup>a</sup>
	'Kordia'	385.7 <sup>b</sup>	106.3 <sup>b</sup>	59.2 <sup>b</sup>
	'Regina'	380.3 <sup>b</sup>	100.7 <sup>b</sup>	57.3 <sup>b</sup>
'Gisela 5'	'Bigarreau Burlat'	378.3 <sup>b</sup>	102.0 <sup>b</sup>	59.4 <sup>b</sup>
	'Kordia'	355.7 <sup>c</sup>	89.7 <sup>c</sup>	46.9 <sup>c</sup>
	'Regina'	359.0 <sup>c</sup>	88.3 <sup>c</sup>	46.3 <sup>c</sup>
Mean Rootstock				
	Mahaleb	389.7 <sup>M</sup>	111.7 <sup>M</sup>	62.1 <sup>M</sup>
	'Gisela 5'	364.3 <sup>N</sup>	93.3 <sup>N</sup>	50.9 <sup>N</sup>
Mean cultivar				
	'Bigarreau Burlat'	390.7 <sup>A</sup>	115.0 <sup>A</sup>	64.6 <sup>A</sup>
	'Kordia'	370.7 <sup>B</sup>	98.0 <sup>B</sup>	53.0 <sup>B</sup>
	'Regina'	369.7 <sup>B</sup>	94.5 <sup>B</sup>	51.8 <sup>B</sup>
	DS 5 % Cultivar	5.5-5.8		1.8-1.9
	DS 5 % Rootstock	4.5		1.5
	SD 5% Interaction cv. × rootstock	7.8-8.6		2.6-2.9

\* Note: Different letters between cultivars denote significant differences

Table 2. Influence of the rootstock and the cultivar on the number long and short fruiting branches

Rootstock	Cultivar	Number of long fruiting branches	Number of short fruiting branches
Mahaleb	'Bigarreau Burlat'	36.7 <sup>c</sup>	86.7 <sup>c</sup>
	'Kordia'	45.5 <sup>d</sup>	100.2 <sup>d</sup>
	'Regina'	44.1 <sup>d</sup>	104.5 <sup>d</sup>
'Gisela 5'	'Bigarreau Burlat'	56.4 <sup>c</sup>	136.4 <sup>c</sup>
	'Kordia'	72.9 <sup>a</sup>	164.9 <sup>a</sup>
	'Regina'	62.6 <sup>b</sup>	144.4 <sup>b</sup>
Mean rootstock			
Mahaleb		42.1 <sup>N</sup>	91.7 <sup>N</sup>
'Gisela 5'		64.0 <sup>M</sup>	148.6 <sup>M</sup>
Mean cultivar			
'Bigarreau Burlat'		46.6 <sup>C</sup>	111.6 <sup>C</sup>
'Kordia'		59.2 <sup>A</sup>	132.5 <sup>A</sup>
'Regina'		53.4 <sup>B</sup>	124.5 <sup>B</sup>
DS 5% Cultivar		3.6-3.8	5.3-5.5
DS 5% Rootstock		3.0	4.3
SD 5% Interaction cv. × rootstock		5.1-5.7	7.4-8.2

\* Note: Different letters between cultivars denote significant differences

### Precocity and fruit yield evaluation

Data of the Table 3 presents the influence of rootstock and cultivar on the yield of the cherry tree for each year of the analysed period. The results are all the more interesting as we analyze both the precocity of fruiting induced by the two rootstocks and the yield registered for each combination in the first three years of fruiting.

The data of Table 3 show a strong influence of the rootstock on the yielding precocity but also on the fruit production obtained during the first three years of fructification. Our results confirm those of Stehr (2005) that 'Gisela 5' enhances precocity. The yield for each analyzed year of experiment was almost double in variants where the trees were grafted on 'Gisela 5'.

The cherry trees grafted on mahaleb reached the production performance of the grafted on 'Gisela 5' barely a year later. The biggest productions have been recorded in 'Regina' and 'Kordia' during all three experimental years.

The fruit size is an important characteristic for commercial market value (Vittrup Christensen, 1995). Pérez-Sánchez *et al.* (2010) indicated that fruit weight is the most important physical of the fruit, upon which the fruit value (price) depends. Fruit size from the trees on 'Gisela 5' rootstock depends on crop load and soil moisture (Vercammen 2002; Vercammen *et al.*, 2006). Dry periods during some growth seasons and climate conditions might also affect fruit size. But a strong influence on the size of the fruit is given by variety and rootstock.

Data of the Table 4 show that fruits diameter and weight was strongly influenced by rootstock in the sense that the biggest fruits diameter on 'Gisela 5' rootstock was registered and the smallest on Mahaleb. Regardless the rootstock, between the three cultivars there were differences statistically assured, the biggest fruit diameter was registered at 'Regina' (27.5 mm), followed by 'Kordia' (26.4 mm) and 'Bigarreau Burlat' (25.1 mm). Regarding the fruits weight the results were quite similar that in case of those of fruits diameter.

Data concerning the influence of the rootstock and the cherry cultivar upon cumulative yield of 2014-2016

growing seasons are presented in Fig. 1. It can be seen that the best cumulative yield in mean value was obtained in variants of cultivars grafted on 'Gisela 5' (23.2 kg/tree) followed by the system where cherry trees are grafted on Mahaleb (13.1 kg/trees) with differences statistically assured between these two variants.

Regardless the treatment only between 'Regina', 'Kordia' and 'Bigarreau Burlat' there is differences statistically assured. The best cumulative yield gave 'Regina' (7.6 kg/tree) and the lowest 'Bigarreau Burlat' (5.6 kg/tree).

Regarding the combined influence of two experimental factors, the best cumulative yield was obtained at 'Regina' grafted on 'Gisela 5' (20.2 kg/tree) followed by 'Kordia' grafted on 'Gisela 5' (19.4 kg/tree) and the lowest cumulated yield was obtained in the variant on 'Bigarreau Burlat' grafted on Mahaleb (10.2 kg/tree).

Cumulative yield is by far the most important indicator that reflects the performance of orchards (Mitre *et al.*, 2012). Similar results were obtained by Musacchi *et al.* (2015), regarding the influence of 'Gisela 5' on the cumulative yield of 'Kordia' and 'Regina'. The results of average yield of 'Gisela 5' rootstock are slightly bigger than the results reported by Usenik *et al.* (2010). The same results was reported by Tomaszewska and Nychnerewicz (2006), studying the influence of 'Gisela 5' on the cumulative yield of 'Bigarreau Burlat', 'Kordia' and 'Regina'. It is important to note that other authors (Sitarek *et al.*, 2005; Rozpara and Grzyb, 2006; Gyeviski *et al.*, 2008) reported negative effects of dwarfing rootstocks on cumulative yield. Less cumulative yield of 'Gisela' rootstock towards to Mahaleb stocks selected at Department of Fruit Growing of Corvinus University of Budapest ('Bogdány', 'Egervár', 'Magyar', 'SM 11/4', 'Korponay') was already described by Bujdosó and Hrotkó, (2012). Our results confirm those of Stehr (2005) that 'Gisela 5' enhances precocity. According to Bielicki and Rozpara (2010), the yield of 'Kordia' grafted on 'Gisela 5' in the 5<sup>th</sup> year after planting, was 19.6 kg/ tree. In order to have a more complete picture of the influence of the two rootstocks on the growth and fructification of the trees, research should be continued in the next years of yielding.

Table 3. Influence of the rootstock and the cultivar on the yield of the cherry tree (kg/tree) in 2014-2016

Rootstock	Cultivar	2014	2015	2016
Mahaleb	'Bigarreau Burlat'	1.6 <sup>c</sup>	3.6 <sup>c</sup>	5.0 <sup>d</sup>
	'Kordia'	2.2 <sup>d</sup>	5.2 <sup>d</sup>	6.8 <sup>c</sup>
	'Regina'	2.4 <sup>d</sup>	5.4 <sup>d</sup>	7.0 <sup>c</sup>
'Gisela 5'	'Bigarreau Burlat'	3.7 <sup>c</sup>	7.7 <sup>c</sup>	8.2 <sup>b</sup>
	'Kordia'	4.6 <sup>b</sup>	9.3 <sup>b</sup>	10.7 <sup>a</sup>
	'Regina'	5.5 <sup>a</sup>	9.8 <sup>a</sup>	10.3 <sup>a</sup>
Mean rootstock				
Mahaleb		2.1 <sup>N</sup>	4.7 <sup>N</sup>	6.2 <sup>N</sup>
'Gisela 5'		4.6 <sup>M</sup>	8.9 <sup>M</sup>	9.7 <sup>M</sup>
Mean cultivar				
	'Bigarreau Burlat'	2.6 <sup>C</sup>	5.6 <sup>C</sup>	6.6 <sup>B</sup>
	'Kordia'	3.4 <sup>B</sup>	7.2 <sup>B</sup>	8.8 <sup>A</sup>
	'Regina'	4.0 <sup>A</sup>	7.6 <sup>A</sup>	8.7 <sup>A</sup>
	DS 5% Cultivar	0.5	0.4-0.5	0.6
	DS 5% Rootstock	0.4	0.4	0.5
	SD 5% Interaction cv. × rootstock	0.7-0.8	0.6-0.7	0.8-0.9

\* Note: Different letters between cultivars denote significant differences

Table 4. Influence of the rootstock and the cultivar on diameter (mm) and weight (g) of the fruits

Rootstock	Cultivar	Fruit diameter (mm)	Fruit weight (g)
Mahaleb	'Bigarreau Burlat'	23.4 <sup>c</sup>	7.0
	'Kordia'	24.7 <sup>c</sup>	8.3
	'Regina'	25.7 <sup>b</sup>	9.2
'Gisela 5'	'Bigarreau Burlat'	26.7 <sup>b</sup>	8.9
	'Kordia'	28.1 <sup>a</sup>	10.9
	'Regina'	29.3 <sup>a</sup>	11.1
Mean Rootstock			
Mahaleb		24.6 <sup>N</sup>	8.2
'Gisela 5'		28.1 <sup>M</sup>	10.3
Mean cultivar			
	'Bigarreau Burlat'	25.1 <sup>C</sup>	8.0
	'Kordia'	26.4 <sup>B</sup>	9.6
	'Regina'	27.5 <sup>A</sup>	10.2
	DS 5% Cultivar	1.3	0.4
	DS 5% Rootstock	1.0	0.3
	SD 5% Interaction cv. × rootstock	1.8-2.0	0.5-0.6

\* Note: Different letters between cultivars denote significant differences

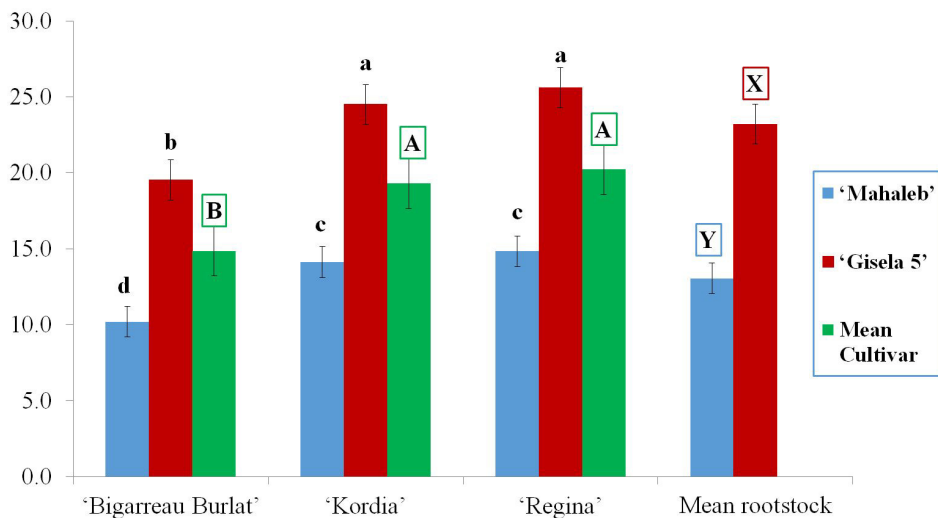


Fig. 1. Influence of the rootstock and the cultivar on cumulated yield in 2014-2016 (kg ha<sup>-1</sup>). Different letters between variants denote significant differences: DS 5% cultivar=1.1-1.2; DS 5% rootstock=0.9; DS 5% interaction cultivar × rootstock=1.6-1.7

## Conclusions

Rootstock had a strong influence on growth and fructification of studied cherry cultivars in high density culture system. Mahaleb due to its vigour has induced more vigorous growth of the cherry trees expressed by tree height, length of annual branches, the section of the trunk, even if they proceeded to cut roots. Trees grafted on Mahaleb formed more less fruiting branches and fewer short fruiting branches than those grafted on 'Gisela 5'. Fruit yield, in the first three years of fruiting, was almost double in variants where the trees were grafted on 'Gisela 5', compared to the variants where the trees were grafted on mahaleb. Mahaleb as cherry rootstock in high density plantations delay the entry of trees into bearing fruit and induce smaller yields.

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